Understanding the Teaching and Learning Experience in Fundamental Engineering Courses

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Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Engineering Education

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May 13, 2019
Blacksburg, VA

Keywords: fundamental engineering courses, academic plan model, expectancy-value theory, student evaluations of teaching

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ABSTRACT

Fundamental engineering courses are important to the undergraduate engineering student experience but have been associated with challenging educational environments. Several factors influence the educational environment, although learning experiences are primarily the outcome of interactions between instructors and students. To initiate change, it is important to understand teaching and learning experiences in fundamental engineering courses from the perspectives of the key players in these environments: instructors and students.

To accomplish the goal of understanding teaching and learning experiences, I conducted studies that examined instructors' and students' perspectives on their experiences and the educational environments, using qualitative research methodology. Through these studies, this dissertation: 1) examined instructors' beliefs and self-described behaviors, guided by motivation theory and focusing on the role of instructors as socializers in the learning process; 2) considered interacting fundamental engineering courses as a foundational curriculum within engineering curricula to describe the educational environment in these courses from instructors' perspectives; and 3) examined student perceptions of their learning experiences and the educational environments in fundamental engineering courses using responses to open-ended items in end-of-semester student evaluations of teaching surveys.

Data indicate that participants strive to integrate strategies that promote effective learning despite challenges posed by course environments, although expected gains from these behaviors may not always be maximized. Students and instructors may benefit from a student-focused, collaborative and holistic course planning process that considers interacting fundamental courses as a

foundational curriculum within engineering curricula, and that engages instructors as equal partners in the planning process. Student feedback may be infused into the course planning process by productively and meaningfully utilizing students' responses to end-of-semester student evaluations of teaching surveys. Overall, the results of this dissertation highlight the importance of institutional support, collaboration, and integrating student feedback in the quest for facilitating effective educational environments and positive learning experiences in engineering.

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GENERAL AUDIENCE ABSTRACT

Introductory engineering courses are important to engineering students' college experience but have been associated challenging learning environments. Several factors influence the learning environment, although learning experiences are primarily the outcome of interactions between instructors and students. To initiate change, it is important to understand teaching and learning experiences in introductory engineering courses from the points of view of the key players in these environments: instructors and students.

To accomplish the goal of understanding teaching and learning experiences, I conducted qualitative studies that examined instructors' and students' points of view on their experiences and the learning environments. Through these studies, this dissertation: 1) examined instructors' beliefs and self-described behaviors, guided by motivation theory and focusing on the role of instructors as socializers in the learning process; 2) considered interacting introductory engineering courses as a foundational curriculum within engineering curricula to describe the learning environment in these courses from instructors' points of view; and 3) examined student perceptions of their learning experiences and environments in introductory engineering courses using responses to open-ended items in end-of-semester student evaluations of teaching surveys. Results show that participants strive to integrate strategies that promote effective learning despite challenges posed by learning environments, although the expected benefits from these strategies may not always be realized. Students and instructors may benefit from a student-focused, collaborative and holistic course planning process that considers interacting introductory engineering courses as a foundational curriculum within engineering curricula, and that involves instructors as equal partners in the planning process. Student feedback may be included in the course planning process by productively and meaningfully using students' responses to end-of-semester student evaluations of teaching surveys. Overall, the results of this dissertation highlight the importance of institutional support, collaboration, and integrating student feedback in the quest for facilitating effective learning environments and positive learning experiences in engineering.

Dedication

To my students at the Ateneo de Davao University School of Engineering & Architecture –

This all began with you.

I am privileged to have been part of your academic journeys,

and grateful that our interactions forged a path in mine that led me here.

Pardon me for the things I could and should have done, but didn't…

and thank you for teaching me to become the educator I am today.

Lahat ng ito ay para sa inyo – this is all for you.

Acknowledgments

To my advisor, Dr. Jacob Grohs: I am infinitely grateful for your mentorship and support throughout my PhD journey. Your advice provided me with a positive, enriching, and unique PhD experience that far exceeded my visions and expectations. Thank you for advocating not just for my academic success, but my holistic professional development as well. And thank you for the constant reminder that family and personal well-being are just as important as progress to degree. You are a source of inspiration, and your encouragement led to valuable learning experiences and unforgettable graduate school memories. Words cannot express the extent of my appreciation, but for now, thank you.

To the members of my dissertation committee, Drs. Cynthia Finelli, David Knight, Holly Matusovich, and Homero Murzi: It has been a great privilege to receive guidance and mentorship from researchers and educators who I admire and respect. I am grateful that you chose to share in my PhD journey. Your support and feedback significantly shaped my research work, and what I learned from you will stay with me as I embark on the next phase of my career.

To Drs. Jacob Grohs & Holly Matusovich, and the Department of Engineering Education; Dean Karen DePauw and the Graduate School; Dr. Gary Kirk and VT Engage; and Fr. Joel Tabora, S.J., Dean Randell Espina, and the Ateneo de Davao University: Thank you for your generosity and support as I pursued my degree. This experience would not have been possible without you.

To the Investing in Instructors Project–Drs. Jacob Grohs, David Knight, Scott Case & Homero Murzi, Natasha Smith & Darren Maczka, data stewards, and participating instructors; and the Motivation and Conceptual Change Project–Drs. Holly Matusovich, Cheryl Carrico, and Sreyoshi Bhaduri, Sarah Blackowski & William Anderson, and participating instructors: thank you for sharing your knowledge, time, expertise and resources, and supporting my dissertation through the work we generated together from these projects.

To Dr. Cheryl Carrico, Dr. Homero Murzi, and Kirsten Davis: Thank you for sharing your time and expertise as I worked with my data, helping me work through my findings, validating my interpretations and assertions, and providing valuable feedback.

To Drs. Homero Murzi, Sreyoshi Bhaduri, Debarati Basu, Lilianny Virgüez, Cassandra McCall, and Glenda Young: Thank you for the support, encouragement, and advice. I am fortunate to have you as role models, sharing your academic journeys to help me shape mine.

To my fellow Graduate Students–In you I have gained lifelong friends and colleagues I will forever cherish:

> EC^3–Darren Maczka, Andrew Gillen, Tawni Paradise, and Stacey Kelly, my academic siblings: Through the successes and tribulations, you were there to celebrate, encourage, console. I will always have fond memories of group lunches, feedback sessions, and insightful conversations about teaching, research – and life. Thank you.

> Racheida Lewis, Andrew Katz, and the Fall 2015 VTENGE cohort: Thank you for the friendship and warm welcome to PhD student life from day one. Thank you for the camaraderie, encouragement, and inspiration as we navigated the intricacies of graduate school and worked towards each milestone in our shared journey.

> Kirsten Davis, Mayra Artiles, Darren Maczka, Andrew Gillen, Katherine Ayers, and Jyotsana Sharma: Thank you for accompanying me on my dissertation journey, and allowing me to join you in yours. Parts of this dissertation are fruits of our writing get-togethers in McBryde, Goodwin, Newman library, the GLC, Mill Mountain, Idego, Tea

& Jam, Zoom, GroupMe, and Gmail, accompanied by copious amounts of tea and coffee. I am grateful for your encouragement, friendship, and the motivation to organize my thoughts, focus on my goals, and accomplish just a little bit more each day.

To Andrew Espera, Aileen Holloway, and Eric & Che Vejerano: You made being halfway across the world from everything comfortable and familiar bearable, by sharing the tastes and sounds of home. *Daghang salamat* – many thanks.

To Homero Murzi and Natali Huggins: Thank you for welcoming me and being my Blacksburg family. Homero, thank you for giving me a glimpse into the culture and community of VTENGE, a crucial turning point that brought me here.

To Jenith Banluta, Jennalyn Roque and my AdDU-SEA family: This path was possible because of the work we did together. I will always hold our friendship close to my heart. Thank you for the opportunities and experiences that inspired me to take this road.

To Dr. Lourdesita Sobrevega-Chan and the AdDU University Research Council: Thank you for the inspiration, encouragement, and opportunity to actively engage in research. Your mentorship sparked an interest and passion for research, and it has been a great privilege to learn from and serve AdDU with you.

To Diana Despabiladeras and the *Dyosas* of PSHS-MC '94: Friendship, indeed, transcends both time and space. Thank you for the love, support, and prayers all these years.

And most importantly, my deepest gratitude to my family –

My daughter, Patricia: for giving me a reason to wake up each day and strive to be the best version of me I can be.

My sister, Cheryl: for inspiring me to aim higher, supporting me in achieving my goals, believing in me, and encouraging me to believe in myself again.

My brother, Michael: for caring for everyone I hold dear so that I can move halfway across the world to pursue my dreams.

And my parents, Mike and Olive, for the unconditional love and unwavering support at every turn and crossroad, through the crests and troughs, for more than four decades… all that I am and have accomplished is because of you, ours to share, and in your honor.

Ad majorem Dei gloriam.

This dissertation is based on research supported by the National Science Foundation under Grant Nos. EEC-1153084 and DUE-1712089. Any opinions, findings, conclusions, or recommendations expressed in this dissertation are those of the author and do not necessarily reflect the views of the National Science Foundation.

Attributions

The three manuscripts that comprise this dissertation are the products of original work where I had primary authorship and research responsibilities. I acknowledge, however, that they include intellectual contributions from other researchers in the Department of Engineering Education, who will receive due credit as co-authors when the manuscripts are submitted for publication. Manuscript 1 builds upon prior work conducted with Dr. Holly Matusovich and Dr. Cheryl Carrico, who were instrumental in framing the study and refining the approach to analyzing and interpreting data. I conceptualized Manuscript 2 with input from Dr. Homero Murzi, who also served as secondary coder during analysis and contributed insights during data interpretation and the crafting of results and discussion. I also acknowledge the intellectual contributions of Dr. Jacob Grohs, who serves as the principal investigator of the project that supported work on Manuscripts 2 and 3.

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Chapter 1: Overview

1.1 Introduction

The second year curriculum in engineering programs is considered academically challenging because it consists of "individual, mostly disconnected courses" (Lord & Chen, 2014, p. 182) characterized by conceptually-challenging, discipline-specific content (Lord & Chen, 2014; Seymour & Hewitt, 1997). Examples of these courses are mathematics (e.g., multivariable calculus, differential equations) and the triumvirate of mechanics courses required of multiple engineering programs: Statics, Dynamics, and Strength of Materials. Collectively called fundamental engineering courses, these courses introduce foundational concepts and develop critical skills needed in succeeding discipline-specific engineering courses (Streveler, Litzinger, Miller, & Steif, 2008). Students generally self-report dissatisfaction with their performance in these courses (Grohs, Soledad, Knight, & Case, 2016; Peng, Kessissoglou, & Lei, 2014; Suresh, 2006). The higher rate of failures and attrition in these courses have earned them the monikers "weed-out," "barrier," or "gatekeeper" courses (Gahagan & Hunter, 2006; Suresh, 2006; Van Valkenburg, 1990; Vasquez, Fuentes, Kypuros, & Azarbayejani, 2015), characterized by "a culture of highly competitive classrooms that do not promote active participation" (National Academies of Sciences, Engineering, and Medicine, 2016, p.63). The challenges posed by fundamental engineering courses to sophomore engineers is compounded further by the reality that in many institutions, especially large, public, research-intensive universities, these courses are likely taught in large classes – environments that have sometimes been considered as detrimental to student learning (e.g., Astin, 1993; Mulryan-Kyne, 2010; Seymour, 2008).

1.1.1 Need for the research

The educational environment that students find themselves in as they take a fundamental engineering class (FEC) is often in conflict with the learning experience that students value and expect (Marra, Rodgers, Shen, & Bogue, 2012). Educational environments in engineering courses should facilitate opportunities for students to take a deep and meaningful approach to learning (Litzinger, Lattuca, Hadgraft, & Newstetter, 2011). Instructors should ideally be aware of and build upon students' prior knowledge; work to facilitate deep knowledge building and scaffold students' knowledge organization in a useful way; and promote self-regulated learning (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010). Gainen (1995) states further: "many students learn best in a context that invites personal connection to professors, peers, and subject matter" (p. 11).

A number of factors, however, influence decisions that ultimately affect the academic environment. For example, the availability of and access to resources for fostering positive learning environments are influenced by factors that are not entirely in the control of individual instructors (Lattuca & Stark, 2009). In order to develop ways to foster success, positive learning experiences, and effective learning environments for students, it is thus important to understand the educational environment from the perspective of its primary stakeholders: *instructors*, who are responsible for designing the learning environment that fosters learning experiences, and the *students* who will engage in the learning process. It is equally important to understand the educational environment from a specific context, such as the large fundamental engineering classroom, in order to critically evaluate prevailing conditions and make informed decisions for continuous improvement. Context-specific understanding of teaching and learning environments is an important component in curriculum planning (Case, Fraser, Kumar, & Itika, 2016; Menges, 2000), and its absence may become a barrier to fostering effective learning environments and positive student learning experiences in engineering. This dissertation ensures the inclusion of context in curriculum planning by examining the context-specific factors that affect the fundamental engineering course environment from instructors' and students' perspectives.

1.1.2 Guiding framework: The Academic Plan Model

The Academic Plan Model (Lattuca & Stark, 2009) provides a visual representation of the various influences, interactions, and processes that shape the educational environment. Lattuca and Stark (2009) developed the Academic Plan Model as a means of thinking about and defining academic curricula, in response to "a lack of a comprehensive definition of curriculum" (p. 4). Considering the curriculum as an academic plan allows for a holistic and comprehensive overview of the learning environment, the elements that comprise it, and the factors that influence curricular decision-making processes. The development of an academic plan may consider various organizational levels of an institution (e.g., course, degree program, college).

The Academic Plan Model provides context for the educational environment in fundamental engineering courses. Decisions regarding the educational environment should ideally consider each of the following elements: *purposes, content, sequence, instructional resources, instructional processes, assessment & evaluation, adjustment,* and *learners. Learners* in the course-level educational environment in a higher education institution refer to the students enrolled in the course, and Lattuca & Stark (2009) emphasize that they serve as the focal point for designing an academic plan. An academic plan should consider the "characteristics, goals, and abilities" (Lattuca & Stark, 2009, p. 14) of the students it is designed for.

While the model acknowledges various key players, instructors in particular play pivotal roles as both decision-makers in the educational environment and stakeholders for institutional decisions made outside of their purview. I adapted The Academic Plan Model (Figure 1.1) to illustrate that students' characteristics, goals & values, and institutional constraints may influence instructors' curricular decision-making processes; that instructors' characteristics, beliefs and values influence the educational environment; and that consequently, instructors' decisions impact students' educational outcomes. However, the instructors of engineering courses may not have access to the appropriate support and resources that will allow them to include non-academic and non-engineering considerations (Borrego & Henderson, 2014; Schreiner, 2010) when creating educational environments that foster positive learning experiences.

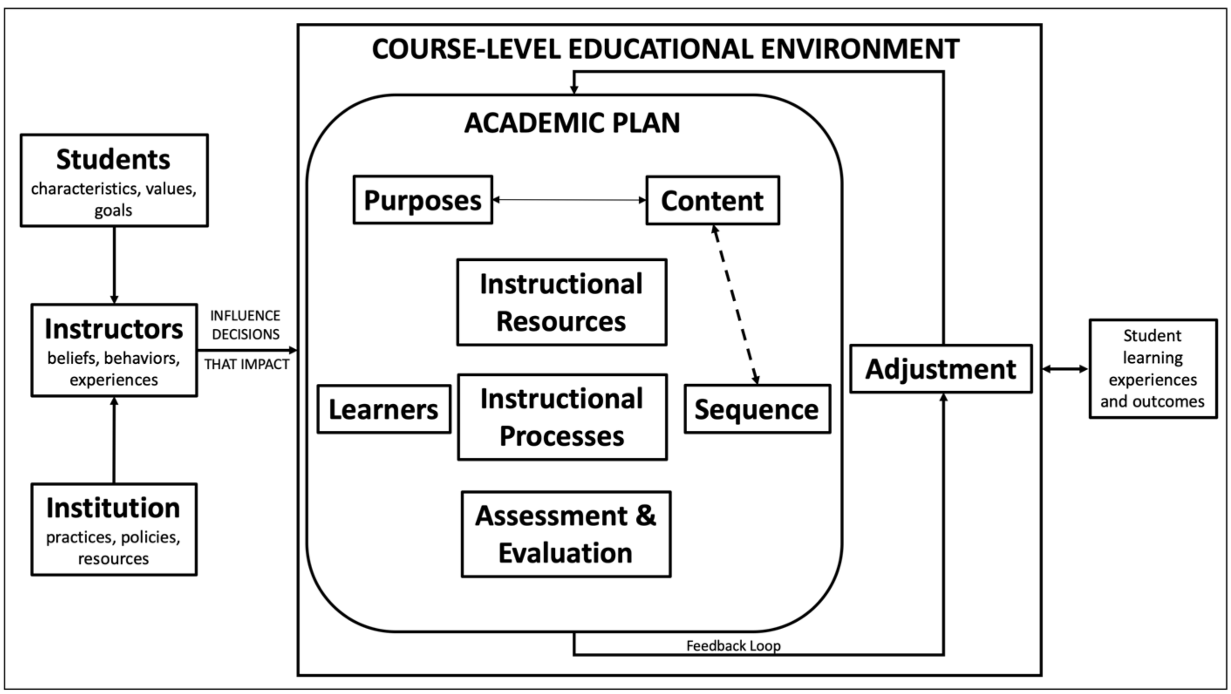

Figure 1.1. Academic plan for course-level educational environments, adapted from The Academic Plan Model (Lattuca & Stark, 2009)

Thinking about the fundamental engineering class through the Academic Plan Model is a way to visualize the interacting factors that influence decisions regarding environment, the elements that need to be considered in making curricular decisions, and how these factors and elements may be explored in order to identify opportunities for improvement. This notion is in keeping with why Lattuca & Stark presented the curriculum as an academic plan: "to identify the critical decision points that, if effectively addressed, will enhance the academic experience of students" (Lattuca & Stark, 2009, p. 4). Indeed, this is the focus of this dissertation: to systematically examine the educational environment and identify opportunities for improvement and what resources are needed towards the ultimate goal of providing positive learning experiences for engineering students.

1.2 Overview of the Dissertation

This dissertation is composed of three manuscripts, each documenting a distinct study. The overarching objective across the three studies is to provide context for the educational environment in fundamental engineering courses through teaching and learning experiences, in order to provide instructors with the appropriate support and resources that will enable them to foster positive learning experiences for their students. Two studies focus on instructors' experiences, and the third examines students' experiences, conducted in an effort to describe the educational environment from instructors' and students' perspectives (Figure 1.2).

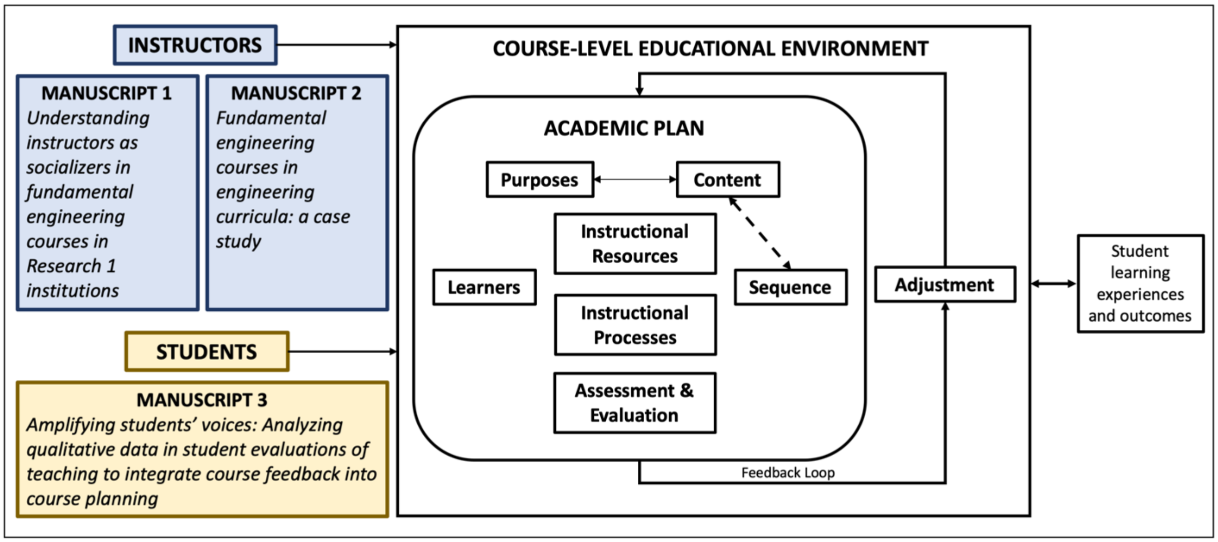

Figure 1.2 Dissertation Manuscripts

Table 1.1 shows the research questions (RQs), data collection, and analysis methods for each manuscript included in this dissertation.

Table 1.1. Research questions, data collection and analysis

Manuscript	Research Questions	Data Collection and Analysis
Understanding instructors as socializers in fundamental engineering courses in Research 1 institutions *Target Journal: Journal of Engineering Education*	***(RQ1.1)*** What *beliefs* do instructors of fundamental engineering courses in Research 1 institutions have about teaching, learning, and students? ***(RQ1.2)*** How do instructors of fundamental engineering courses in Research 1 institutions describe their *behaviors* as socializers in the learning process?	Semi-structured interviews with faculty of fundamental engineering courses (multi-institution, supra-analysis of existing data; 16 participants from R1 universities, secondary analysis of existing data, NSF EEC-1153084)
Fundamental engineering courses in engineering curricula: a case study *Target Journal: International Journal of Engineering Education*	***(RQ2.1)*** How do instructors describe the *educational environment* enacted through the foundational engineering curriculum? ***(RQ2.2)*** How do instructors describe the *factors that influence their curricular decision-making process*?	Semi-structured interviews with instructors participating in the *Investing in Instructors* project; instructor-provided documents; project-provided documentation and artifacts (case study, 7 participants teaching Math, Physics, and Mechanics at a large public research university, NSF DUE-1712089)
Amplifying students' voices: Analyzing qualitative data in student evaluations of teaching to integrate student feedback into course planning *Target Journal: Assessment & Evaluation in Higher Education*	***(RQ3.1)*** How is the fundamental undergraduate engineering *student learning experience and educational environment* described in *institutionally-collected data on student evaluations of teaching* at a large Research 1 institution? ***(RQ3.2)*** What *opportunities for continuous improvement* arise from descriptions of student learning experiences and environments in institutionally-collected SET data at a large R1 institution?	Content analysis of responses to open-ended questions in student perceptions of teaching surveys (focus on the Mechanics sequence of courses: Statics, Dynamics, and Strength of Materials, secondary analysis of existing data, NSF DUE-1712089)

Manuscript 1 explores instructors' beliefs, behaviors, and teaching experiences in fundamental engineering courses in large research-intensive institutions in the United States, guided by the role of instructors as socializers as embedded in the expectancy value model of achievement motivation (Eccles, 2007; Eccles et al., 1983). The Academic Plan Model (Figure

1.1) acknowledges instructors as an internal influence on the educational environment. Their role as significant socializer means that they play a critical role in developing the academic plan and shaping the educational environment. I thus consider instructors' perceptions as important to describing and providing context for the educational environment in fundamental engineering courses. Providing context for the prevailing learning experience in fundamental engineering courses acknowledged "critical decision points" (Lattuca, & Stark, 2009, p. 4) towards overcoming challenges specific to this educational environment.

Manuscript 2 considers the suite of fundamental engineering mechanics courses (math, physics, statics, dynamics, and strength of materials) as a common foundational engineering curriculum that enacts elements of an academic plan. It presents prevailing educational environments in fundamental engineering courses using participants' perceptions and descriptions of elements of the Academic Plan Model (Lattuca & Stark, 2009).

Manuscript 3 involves directed content analysis of responses to the open-ended responses to student evaluations of teaching surveys (SETs) of the mechanics sequence of courses (statics, dynamics, and strength of materials) in a large, public, research university. Responses were classified according to elements of the Academic Plan Model, and inferences derived from the data were used to describe students' perceptions of their learning experiences in the mechanics sequence of fundamental engineering courses in a Research 1 university.

1.4 Contributions of the dissertation

Findings from the three manuscripts contribute towards understanding the teaching and learning experience in fundamental engineering courses by providing context for this educational environment and describing how the phenomenon is experienced by the key stakeholders in the environment – instructors and students. An overview of the dissertation and the key findings for each study is shown in Figure 1.3.

The dissertation specifically makes the following contributions:

Manuscript 1. This research provides context for the educational environment in various fundamental engineering courses across multiple institutions, from the perspectives of the instructors who teach them, based on rich, personal descriptions gleaned from qualitative data. It provides context-specific information on the beliefs and behaviors of participating instructors that help shape the educational environment in the fundamental engineering courses that they taught. The study shows that participants describe behaviors that align with evidence-based recommendations for teaching, but express beliefs that indicate challenges with enacting desired behaviors and realizing the expected impacts of recommended behaviors. This information may then be used as impetus for further research of a larger scope.

Manuscript 2. This research provides context for the educational environment in a specific set of fundamental courses at a particular institution, from the perspective of the instructors who teach them. Research findings indicate that regardless of the department that manages a course, instructors of courses addressing concepts that are fundamental to engineering have shared purposes and aspirations for teaching. The study also highlights that for these courses, instructors are often critical decision-makers in course planning, but are constrained by department course-management processes. I offer the idea of a student-focused, collaborative, and holistic academic plan that encompasses multiple interacting fundamental courses at this institution, in an effort to facilitate effective learning environments and positive student learning experiences.

Manuscript 3. This research provides a method for analyzing and interpreting institutionally-collected data on student perceptions of teaching, so that instructors may use them productively and meaningfully in decision-making processes that impact the educational environment. Analysis indicates that students often describe their learning experiences in terms of instructional processes implemented in their classes, their perceptions of instructors' characteristics and behaviors, and how their interactions with their instructors impact their learning experiences. The study highlights the need for a structured way for instructors to understand and interpret students' perceptions of their learning experiences. It also emphasizes the need for institutional support to effectively leverage institutional qualitative data. It provides a baseline dataset of analyzed qualitative data that may be used to train computer algorithms, opening an opportunity to develop an automated qualitative content analysis tool to facilitate analysis and interpretation of qualitative institutional data.

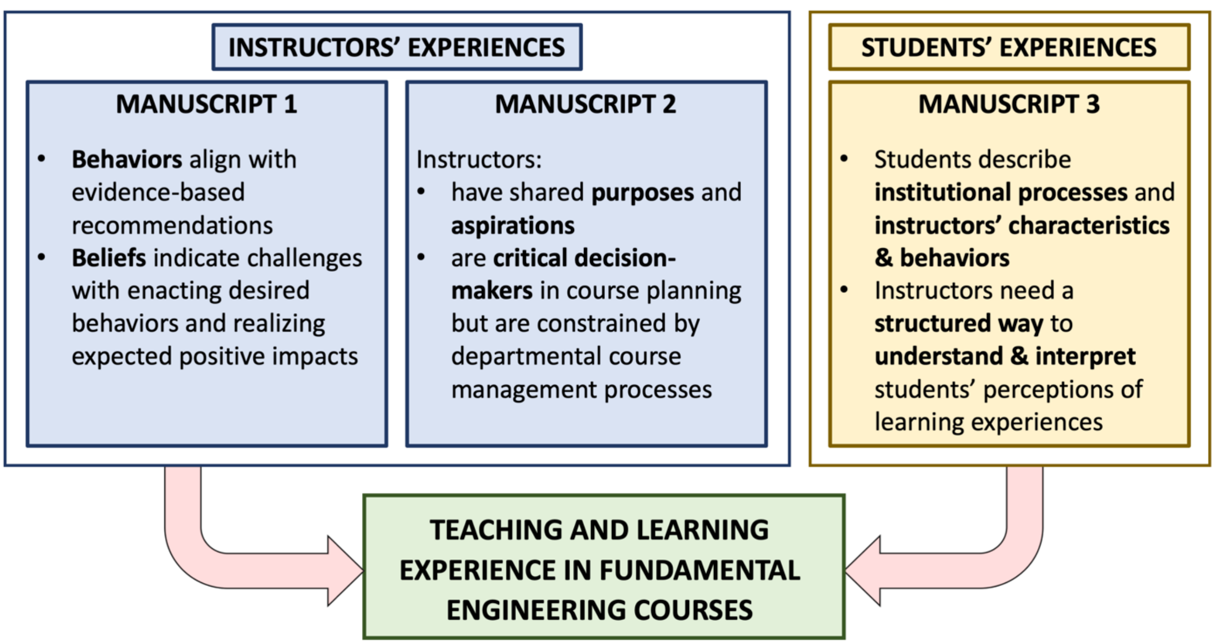

Figure 1.3. Overview of the Dissertation and Key Findings

Chapter 2: Manuscript 1

Understanding instructors as socializers in fundamental engineering courses in Research 1 institutions
Target Journal: Journal of Engineering Education
This manuscript includes intellectual contributions from Holly Matusovich, Cheryl Carrico and Jacob Grohs (see Attributions) who will be credited accordingly as co-authors in this work

2.1 Structured Abstract

Background

Fundamental engineering courses (FECs) in Research 1 (R1) institutions are important to the undergraduate engineering student experience but taught in challenging educational environments. Instructors play a crucial role in shaping student experiences; thus, efforts to ensure positive student experiences require understanding instructors' perspectives and experiences.

Purpose (Hypothesis)

We characterize FECs in R1 institutions from the lens of instructors as socializers in these educational environments. Guided by motivation theory, we examined participants' beliefs and self-described behaviors as significant socializers in the learning process.

Design/Method

This study qualitatively examined interview transcripts of sixteen participants teaching FECs in R1 institutions across the US. It specifically focused on the role of instructors as socializers as presented in Eccles' expectancy-value theory of achievement motivation, which illustrates that instructors' beliefs and behaviors affect students' self-concepts, values, goals, engagement, and performance.

Results

Participants espoused beliefs that value conceptual understanding over rote learning, and the expectation that students take more responsibility for their learning process. Participants have sufficient knowledge about, and take conscious efforts to integrate, teaching behaviors that promote effective learning, within the limitations of institutional course structures (e.g., class size, resources).

Conclusions

Findings indicated that participants strive to integrate strategies that promote effective learning despite challenges posed by course environments. Future work may corroborate this finding by investigating a larger, more representative sample and primary sources of data, and explore integrating strategies to develop metacognitive and self-regulated learning behaviors in students to increase the effectiveness of productive teaching behaviors.

Keywords

expectancy value theory, instructors, fundamental engineering courses, learning environment

2.2 Introduction

Instructors play an important role in shaping the undergraduate student experience (Pascarella & Terenzini, 2005). Student learning is sociocultural in nature, and the interpersonal interactions that students have in the educational environment contribute significantly to the learning process and the quality of their learning experience (Ormrod, 2016).

In undergraduate engineering programs at some institutions, students spend at least the first three semesters of their academic journey in educational environments fostered in fundamental engineering courses (FECs) (Sheppard, Macatangay, Colby, & Sullivan, 2009). FECs provide the foundation for advanced discipline-specific courses, are usually required of several engineering disciplines, and comprise the bulk of credit hours required to earn an engineering degree (Lord & Chen, 2014; Sheppard et al., 2009). As preparatory, concept-heavy courses, they have been characterized as disjointed, but together they contribute to the development of skills that are critical to overall student success and persistence in engineering (Chen, Whittinghill, & Kadlowec, 2010; Lord & Chen, 2014). FECs, therefore, are important to the engineering academic journey. Learning experiences in these courses can significantly affect student learning in subsequent courses, student persistence in engineering, and the quality of students' undergraduate experience in general (Felten, Gardner, Schroeder, Lambert, & Barefoot, 2016; Kim & Sax, 2009; Kuh, Kinzie, Schuh, & Whitt, 2005; Pascarella & Terenzini, 2005).

The educational environment in FECs has unfortunately been associated with low levels of student satisfaction (Pascarella & Terenzini, 2005; PCAST, 2012). Students lament that they are unable to get the learning experience that they value and expect while taking fundamental courses (Matz et al., 2017; National Academies of Sciences, Engineering, and Medicine, 2016). The concerns raised by students include poor teaching, feeling overwhelmed by the academic pace and workload, and conceptual difficulties (Marra et al., 2012; Seymour & Hewitt, 1997). A number of student narratives articulated beliefs about instructors based on instructor behavior and student-faculty interactions (Danielak, Gupta, & Elby, 2014; Foor, Walden, & Trytten, 2007), followed by how these beliefs shaped their learning experiences and affected persistence-related decisions. These narratives align with how students' perceptions of the socializers–the people that students interact with (e.g., instructors, peers)–in the educational environment affect "achievement behaviors, persistence choice, and performance" (Eccles et al., 1983, p. 80). This is especially troubling if these negative experiences are the first, powerful messages that undergraduate engineering students receive about engineering.

Research on the engineering learning experience focuses mostly on students' perspectives and recommendations for specific teaching strategies. Studies have explored the undergraduate student experience, including work focused on science, mathematics, and engineering student experiences in fundamental courses (e.g., Astin, 1993; Pascarella & Terenzini, 2005; Seymour & Hewitt, 1997; Vasquez, Fuentes, Kypuros, & Azarbayejani, 2015). In contrast, there is considerably less research focused on the instructors' experience and how they understand the context in which they are expected to facilitate effective learning environments and foster positive student experiences (e.g., Matusovich, Paretti, McNair, & Hixson, 2014). The sharing of effective teaching practices is valuable, and there is extensive literature on teaching strategies (e.g., Christiansen, Benzley, Guthrie, & Paudel, 2009; Goff, Terpenny, & Wildman, 2007). However, understanding context promotes systemic change and is key to ensuring that effective practices are adopted, as it supports the ability to discern which strategies and tools are appropriate for ever-changing classroom situations (Borrego & Henderson, 2014; Finelli, Daly, & Richardson, 2014a).

The study seeks to characterize the educational environment in FECs in Research 1 (R1) institutions in the United States (US). It examines instructors' beliefs and experiences in teaching and learning in this environment, their self-described teaching behaviors, and how the relationship between instructors' beliefs and behaviors shaped in the educational environment using supra analysis of secondary data (Heaton, 2004). We investigate instructors teaching fundamental engineering courses and focus on R1 institutions because 1) interactions with instructors as significant socializers in the educational environment shape student learning experiences, 2) learning experiences in FECs significantly impact the overall student learning experience in engineering, and 3) conditions in large R1 institutions, described as doctoral research universities with highest research activity and full-time equivalent enrolment numbers of at least 10,000 students (Indiana Center for Postsecondary Research, 2016b), lead to challenging educational environments for both instructors and students (Pike, Smart, Kuh, & Hayek, 2006). It is further crucial to focus on instructors' experiences in FEC learning environments at R1 institutions because they have a significant impact on the quality of the undergraduate learning experiences of a large number of engineering students in the US; 80% of the 50 top producers of engineering graduates are classified as R1 institutions (Indiana Center for Postsecondary Research, 2016c).

The following questions guided this research:

1. What *beliefs* do instructors of FECs in R1 institutions have about teaching, learning, and students?
2. How do instructors of FECs in R1 institutions describe their *behaviors* as socializers in the learning process?

We conducted supra analysis of existing data (Heaton, 2004) to examine interviews conducted with instructors of FECs from several R1 institutions. The study is guided by the expectancy-value theory of achievement motivation, focusing on the role of instructors as socializers in the learning process (Eccles, 2007; Soledad, Matusovich, & Carrico, 2018).

2.3 Perspectives from Literature

Prior work has associated instructors' behaviors and perceived attitudes with the quality of student learning experiences (e.g., Canning, Muenks, Levy, & Murphy, 2018; Pascarella et al., 2011) and highlighted the critical role that socializers play in the educational environment (e.g. Eccles, 2007; Pascarella & Terenzini, 2005). For example, as a "grading authority," (Matusovich, Jones, Paretti, Moore, & Hunter, 2011, p. 10) instructors are socializers who influence students' interpretation of achievement outcomes, which in turn influences ability self-concepts and expectancies for success (Eccles et al., 1983). Faculty behaviors and educational practices also affect student learning, engagement, self-image and identity. Thus, understanding student learning requires an understanding of faculty norms and beliefs (Blackburn & Lawrence, 1995; Pascarella et al., 2011). The perception that instructors are significant socializers in the educational environment (Eccles et al., 1983; Martin & Dowson, 2009; Wigfield & Tonks, 2002) indicates that they contribute more heavily to shaping the quality of the learning environment and student experience when compared with other socializers (e.g., peers).

2.3.1 Instructors as socializers and the expectancy-value model of achievement motivation

The expectancy-value theory (EVT) is rooted in the expectancy-value model of academic performance and choice (Atkinson, 1964; Eccles-Parsons et al., 1983). The theory argues that "individuals' choice, persistence and performance" (Eccles & Wigfield, 2002; Wigfield &

Eccles, 2000) in an activity may be explained by expectancy for success in a task (Am I able to perform this task?) and the value ascribed to the task (Why should I perform this task?). Several interrelated factors influence student outcomes and choices; relevant to this study are behaviors and beliefs of socializers with whom students interact.

Socializers interact with students in a social context. They usually consist of parents, teachers, and peers and are of particular interest because the quality of interactions with socializers can significantly impact students' ability beliefs and expectancies for success (Eccles, 2007; Eccles & Wigfield, 2002). When the EVT model is used as a framework in higher education research to understand student motivation, socializers consist mainly of teachers and peers (Eccles, 2007). Eccles (1983) provided an expanded model of the socializer construct in EVT showing that socializers' behaviors, self-concepts and expressed task-specific attitudes & expectations (beliefs about students' abilities and interests) impact students' expectancies for success, achievement-related choices, and subjective task values. Soledad, Matusovich, & Carrico (2018) presented a modified EVT model highlighting the role of instructors as socializers, shown in Figure 2.1.

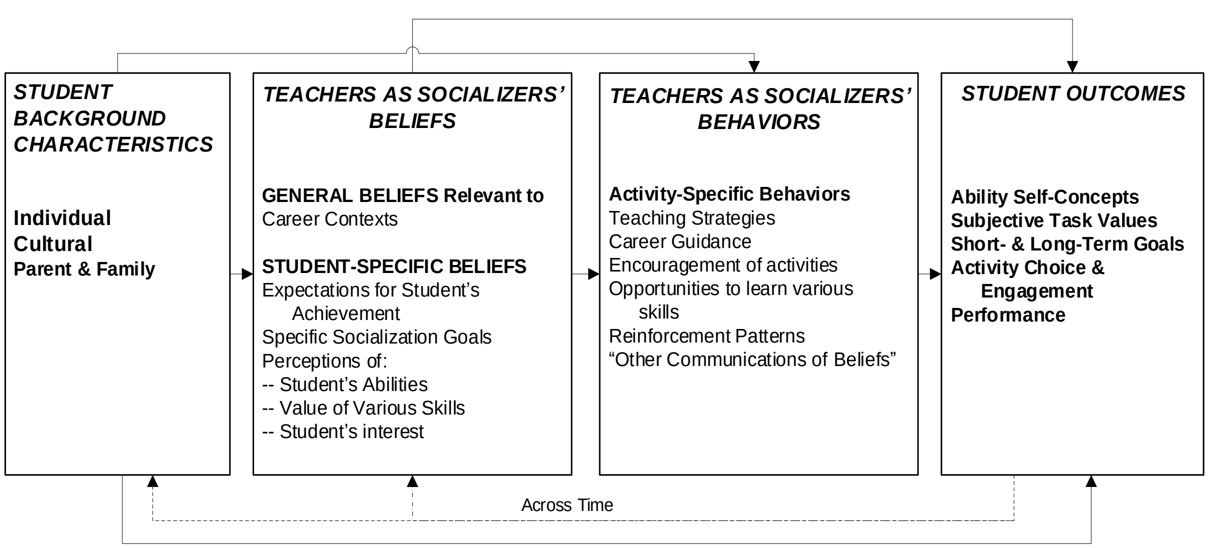

Figure 2.1 Modified Expectancy Value Theory of Achievement Motivation: Focus on Teachers as Socializers (Soledad, Matusovich, & Carrico, 2018)

Despite several studies focused on how students' expectancies and values impact performance and choice (Wigfield, Gladstone, & Turci, 2016), there are underexplored topics included in the EVT model that Eccles herself is encouraging researchers to examine further (Eccles, 2017). For example, socializers' beliefs and behaviors are factors that influence and provide context for how and why students develop their ability beliefs and expectancies for success. Although EVT is more commonly used to examine student motivation, it provides an equally useful lens for analyzing data from instructors (e.g., Anderson & Finelli, 2014), particularly in the context of instructors' roles as socializers. Adapting a socialization-focused model (Figure 2.1) acknowledges the sociocultural nature of the learning experience and facilitates an investigation of constructs that influence educational outcomes and academic performance (Soledad et al., 2018).

2.4 Methods

This study analyzed existing qualitative data to examine participants' beliefs and perspectives on the teaching and learning experience in FECs taught in R1 institutions. The data consisted of transcripts of semi-structured interviews conducted with instructors of concept-heavy engineering courses, as defined by Streveler, Litzinger, Miller, & Steif (2008), from multiple institutions across the US, collected as part of a study that explored links between student motivation and conceptual change.

2.4.1 Research Design

This study is a supra analysis of existing data. Supra analysis is a type of secondary data analysis that takes existing data and uses it for purposes that transcend those of the original study, pursuing questions that are different from those asked in the primary study (Heaton, 2004).

A project investigating the role of motivation in conceptual change conducted 41 semi-structured interviews. For this study, we examined 16 purposefully-selected interview transcripts from the project dataset for participants' beliefs and behaviors as socializers in the learning process (Figure 2.2). We share the selection process for the sample analyzed in this study in the sections below.

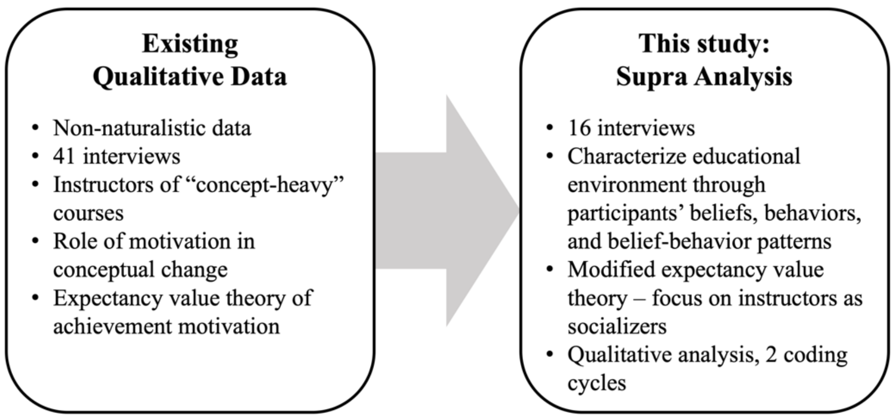

Figure 2.2 Supra analysis of existing data for this study

2.4.2 Participants

Sampling Frame for Existing Data. The sampling frame, determined in the original study, consisted of instructors teaching courses that introduce fundamental and challenging engineering concepts as described by Streveler et al (2008): *Statics, Dynamics, Strength of Materials, Fluid Mechanics, Thermodynamics, Heat Transfer, Programming* and *Circuits*. The purposefully-selected sampling frame ensured representation of instructors from a variety of institutions, and consequently, teaching and learning experiences in the dataset. Instructors teaching the identified courses at a large, public, R1 institution (Institution A), and members of ten divisions of the American Society for Engineering Education (ASEE), received invitations to participate. The project team chose Institution A because it is a R1 institution offering multiple engineering disciplines and thus had accessible instructors who met inclusion criteria for the sampling frame. They identified ASEE divisions based on the likelihood that its members taught the courses that the project was interested in, and to get multiple perspectives from a variety of participants.

Participants self-selected into the study and received $25 gift cards as a token of appreciation for their participation. Forty-one instructors participated in interviews conducted from March to August 2017. All recruitment and data collection protocols underwent review by, and received approval from, an Institutional Review Board that governs Human Subjects Research.

The project used the Carnegie Classification of Institutions of Higher Education framework, which classifies institutions by size, setting, types of degrees awarded, and level of research activity (Indiana Center for Postsecondary Research, 2016a), among others, to categorize institutions where participants taught. Following prior work that similarly used Carnegie Classifications as clustering schemes to investigate the undergraduate student learning experience (e.g., Astin, 1993; Seymour & Hewitt, 1997), we found that a significant number of participants (42%) taught in R1 institutions.

Sample included in this study. The sampling process considered participants' responses to a pre-interview survey that included items seeking demographic information (e.g. gender and race); attribute coding performed on the interview transcripts; and perspectives from existing literature. Preliminary examination revealed that of the 16 participants who taught in R1 universities, a significant majority (81.25%) taught FECs in the large class setting. Informed by literature on the challenges and barriers presented by the fundamental engineering and large class learning environment (Cuseo, 2007; Mulryan-Kyne, 2010), this finding led us to focus this investigation on instructors of FECs in R1 institutions.

Table 2.1 shows demographic information of the 16 participants included in this study. The majority of participants in the sample (N=9) taught Mechanical Engineering (ME) courses. Other disciplines represented in the sample are Aerospace Engineering (Aero, N=1), Chemical Engineering (ChemE, N=4), Electrical Engineering (EE, N=1) and Mechanics (N=1). A significant number of participants (N=13) taught courses structured as classes with 50 students or more. The class sizes corroborate observations from prior work which show that FECs taught in large class environments are more likely to occur in large research institutions (e.g., Astin, 1993). Female participants comprise 31.25% if the sample (N=5), while there were no participants who identified as belonging to underrepresented minorities; this deviates from the current demographic profile for gender and race of faculty members in engineering (17% female, 9% underrepresented minorities respectively) (National Science Board, 2018). We acknowledge this difference in the demographic profile as a limitation of the study. We assigned pseudonyms prior to analysis and omitted attributes that may lead to identification (e.g., name of institution) to ensure confidentiality.

Faculty from eleven institutions located across all four regional divisions of the United States (United States Census Bureau, 2010) are represented in the sample: Northeast (e.g., Cornell University), Midwest (e.g., Kansas State University), South (e.g., Virginia Tech) and West (e.g., University of Arizona), although more than half of the participants (56%) taught at institutions located in the South.

Pseudonym	Gender	Race/ Ethnicity	Discipline	Course Taught	Class Size	Region
Daphne	Female	White	ME	Thermodynamics	70-100	South
Erwin	Male	White	ME	Thermodynamics	>100	Midwest
Finn	Male	White	ME	Heat Transfer	<50	South
Karen	Female	White	Aero	Strength of Materials	>100	Northeast
Noah	Male	White	ME	Statics	70-100	South
Odette	Female	White	Chem E	Thermodynamics	<50	Northeast
Paul	Male	White	Chem E	Thermodynamics	70-100	Northeast
Peter	Prefer not to say	Did not indicate	ME	Thermodynamics	50-70	South
Steve	Male	White	Chem E	Fluid Mechanics	70-100	West
Tamara	Female	White	EE	Circuits	>100	South
Ulysses	Male	Asian	ME	Fluid Mechanics	50-70	South
Val	Male	White	Chem E	Fluid Mechanics	<50	Northeast
Vanessa	Female	Asian	Mechanics	Statics	70-100	South
Victor	Male	White	ME	Thermodynamics	50-70	South
Vincent	Male	White	ME	Heat Transfer	70-100	Northeast
Walter	Male	White	ME	Heat Transfer	70-100	South

Table 2.1. Participants' demographic information

2.4.3 Data Collection

The semi-structured interview protocol included prompts that allowed participants to share beliefs and experiences in teaching FECs related to the following constructs: a) *Instructors as socializers' beliefs* (e.g., What are the things that you care about the most when you are teaching a class?)*;* and b) *Instructors as socializers' behaviors* (e.g., What happens in a typical class period?). Appendix A maps interview prompts from the original project to modified EVT constructs (Soledad et al., 2018).

We analyzed 8 in-person and 8 phone interviews, ranging from 30-minutes to one-hour each, accommodating participant preferences. Interviewers kept audio recordings and field notes during each interview, and a professional transcription service transcribed the audio recordings. Flexibility in scheduling interviews, cost-related and interviewer bias-related concerns are inherent in both in-person and phone interviews. However, accommodating preferences and geographical limitations allowed us to engage with participants from various backgrounds, locations, and institutions without sacrificing data quality (Drabble, Trocki, Salcedo, Walker, & Korcha, 2016).

Research Quality – Making the data. Guided by the process-oriented model for ensuring research quality offered by Walther, Sochacka, & Kellam (2013), the project employed quality strategies for "making the data" (p. 638) during data collection. Quality in making the data included interview protocol and interview quality. We ensured data quality by training multiple interviewers regarding alignment of the type of data collected with the project's research objectives and having two interviewers jointly conduct some of the interviews. Interviewers conducted debriefing meetings immediately following interviews where two interviewers were present; they discussed the effectiveness of interview prompts and responses, and noted changes to the interview protocol when necessary. Having a second interviewer also facilitated consistency of interview approaches, particularly when either interviewer conducted solo interviews, as the secondary interviewer was able to observe and debrief with the primary interviewer (Soledad et al., 2018).

2.4.4 Data Analysis

We used EVT, specifically the role of instructors as socializers who contribute to the student learning experience, to guide data analysis. We used Dedoose™, a cross-platform online qualitative research analysis tool, to qualitatively analyze transcribed interview data. The use of Dedoose™ facilitated collaboration between multiple researchers for peer examination, served as a data repository, and helped ensure the integrity of data analysis.

Analysis of interview transcripts involved two coding cycles. The first coding cycle consisted of the following:

1) Initial reading of interview transcripts.
2) Assigning labels to meaningful statements using open-coding strategies (Saldana, 2016) but paying particular attention to excerpts that align with the following constructs embedded in EVT (Eccles et al., 1983):
    a. Instructors as socializers' beliefs
    b. Instructors as socializers' behaviors

    Since we were inductively developing codes and labels, we also assigned labels to excerpts outside of the EVT constructs to allow us to track other context-specific observations and experiences shared by the participants.
3) Writing memos and reflective notes during the coding process.

The first author had primary responsibility for analysis, but engaged in analysis meetings with other members of the research team within both coding cycles (Miles, Huberman, & Saldaña, 2013). An analysis of a sample of three transcripts from the complete dataset of the broader research project (Soledad et al., 2018) provided a start list of codes in Dedoose™ for the first coding cycle. The start list evolved into a codebook consisting of applicable labels from the start list of codes, additional codes from experiences and beliefs found in the sample analyzed for this study, and their associated descriptions.

The second coding cycle examined patterns observed in the data using pattern coding techniques (Saldana, 2016). We identified patterns across participants by organizing labelled excerpts from the first coding cycle into clusters of related codes, based on the theoretical framework and natural similarities noted from the data. The data clustered around four themes, shown enclosed in bolded boxes in Figure 2.2. Going back to the modified EVT model guiding this research (Figure 2.1), instructors as socializers' *beliefs* and *behaviors* as articulated by participants serve as signposts for presenting results. We found two other salient themes in the rest of the labelled excerpts: *instructional resources* and *course structure & processes.* These clusters provided context for the environment where the *beliefs* and *behaviors* occurred.

In order to visually examine patterns from the data, we created tabular displays, re-evaluating and merging codes with similar excerpts where applicable. In consolidating and summarizing labels, we documented all decisions and captured each iteration until we reached the final summary, so we can still trace all consolidated codes to their original form. This allowed us to view patterns across participants, and between participants' articulated beliefs and behaviors. Table 2.2 shows the salient themes and codes identified during the second coding cycle.

Research quality – Handling the data. Still guided by Walther, et al (2013), we maintained quality in "handling the data" (p. 638) by running two coding cycles, where the primary coder conducted at least two iterations of detailed analysis of the interview transcripts and documented analysis decisions through memos embedded within Dedoose™. The research team conducted analysis meetings that reviewed coding decisions, discussed codes and their corresponding descriptions during the first coding cycle, and examined themes and patterns from the analyzed data using tabular displays, as suggested by Miles et al (2013), during the second coding cycle until they reached agreement (Creswell, 2012).

2.4.5 Limitations

We acknowledge that this study has several limitations. First, participants self-selected into the broader project and come from a sampling frame composed of faculty who are part of an engineering education community. This may account for the high rates of knowledge and utilization of productive teaching strategies found in the data. Second, participants described the behaviors found in the study from memory, and because we are using secondary data, there was no opportunity to corroborate self-described behaviors through follow-up research activities like in-person classroom observations. Finally, we do not have student data to substantiate beliefs expressed by the instructors, and how instructors' behaviors impacted students from students' perspectives. We thus present results confined within the contexts where our participants' beliefs and behaviors occurred, and offer insights for further investigation of a larger scope.

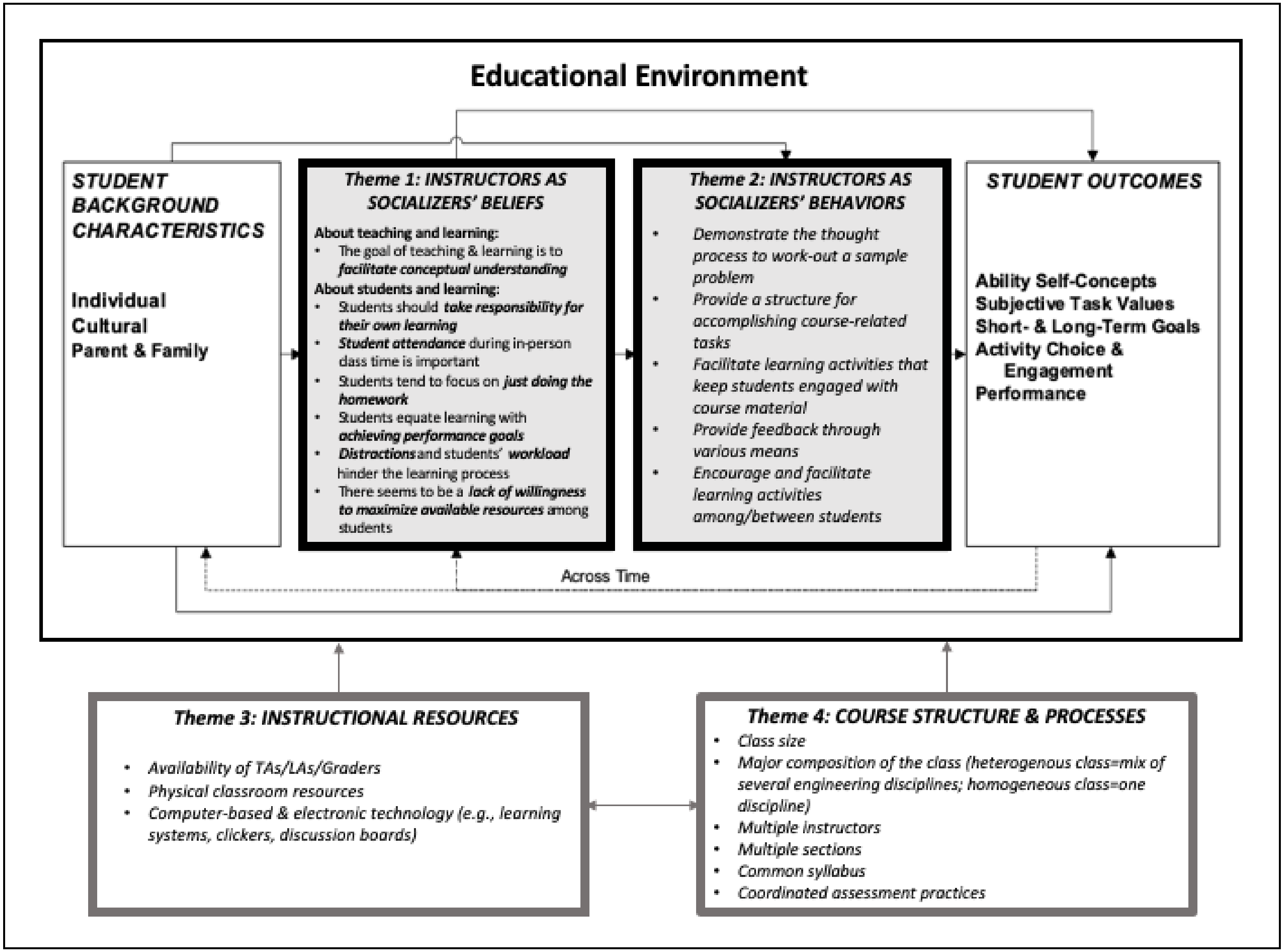

Figure 2.2 Themes from the data

Theme	Code	Definition
1: Instructors' beliefs	1a: Facilitate conceptual understanding	Descriptions of aspirations to facilitate the development of a thorough understanding of course concepts among students
	1b: (Students) take responsibility for their own learning	Descriptions of expectations that students proactively engage with course-related activities inside and outside the classroom
	1c: Student attendance	Descriptions of expectations that students attend class in person
	1d: "Just doing the homework"	Descriptions of beliefs that students only focus on completing homework assignments
	1e: Focus on achieving performance goals	Descriptions of beliefs that students only focus on achieving performance goals, such as receiving a satisfactory grade
	1f: Distractions and workload	Descriptions of beliefs about conflicting demands on students' time that hinder the learning process
	1g: Lack of willingness to maximize available resources	Descriptions of beliefs about students' decisions to maximize learning opportunities and resources
2: Instructors' behaviors	2a: Demonstrate the thought process to work-out a sample problem	Descriptions of behaviors demonstrating the steps and processes to solve work-out problems
	2b: Provide a structure for accomplishing course-related tasks	Descriptions of behaviors providing students with structures to follow for successfully accomplishing learning tasks
	2c: Facilitate learning activities that keep students engaged with course material	Descriptions of behaviors to encourage students to actively engage in the course (e.g., provide practical, relatable examples; games; facilitated discussion)
	2d: Provide feedback through various means	Descriptions of behaviors related to providing feedback through various means (e.g., comments on homework and tests, discussion boards, office hours, e-mails)
	2e: Encourage and facilitate learning activities among/between students	Descriptions of behaviors that encourage peer learning and interaction
3: Instructional resources	3a: Availability of TAs/LAs/graders	Descriptions of availability and access to teaching assistants and graders
	3b: Physical classroom resources	Descriptions of physical classroom resources (e.g., studio classroom, collaborative learning space)
	3c: Computer-based & electronic technology	Descriptions of learning and classroom technologies (e.g., learning management systems, software, online discussion boards)
4: Course structure & processes	4a: Class size	Descriptions of number of students in the class
	4b: Major composition of the class	Descriptions of engineering majors represented in the class (heterogeneous: mix of several engineering disciplines; homogeneous: one discipline)
	4c: Multiple instructors	Sections of the course are taught by more than one instructor
	4d: Multiple sections	There are multiple sections of the course offered in a term
	4e: Common syllabus	A common syllabus is shared across multiple instructors and sections
	4f: Coordinated assessment practices	Assessments are coordinated across multiple sections of the course (e.g., common homework, common time final, coordinated test schedules)

Table 2.2 Salient Themes and Codes

2.5 Results

This research sought to characterize the educational environment in FECs in R1 institutions. We accomplished this by examining participants' *beliefs* (RQ 1) and *behaviors* (RQ 2) as socializers in the learning process, and how patterns between beliefs and behaviors may have shaped the educational environment, anchored on the role of socializers as described in the EVT (Eccles, 2007). We focus on these two constructs because beliefs influence behaviors (Sigel, 1992, 2014), and as significant socializers, instructors' beliefs and behaviors affect student outcomes (Eccles, 2007; Umbach & Wawrzynski, 2004). Our analysis showed that:

- Most participants cared about ensuring that students thoroughly understood fundamental engineering concepts, and believed that students should take more responsibility for their own learning. They acknowledge, however, that distractions and students' workload, where workload encompasses both academic and non-academic responsibilities, may hinder the learning process.
- Participants mostly described theoretically-supported and recommended behaviors related to presenting, explaining, and demonstrating course content. They shared behaviors that were consistent with achieving what they cared about the most–facilitating conceptual understanding of engineering concepts addressed in the courses they taught.

We present salient findings for the two main themes from the data: participants' beliefs (Theme 1) and behaviors (Theme 2). The two other themes (instructional resources and course structure & processes) do not directly answer the research questions but provide context for the environment where beliefs and behaviors occurred, and influence them in meaningful ways. For example, Noah, a participant who teaches Statics, shared how class size (course structure & processes) impacted his ability to provide meaningful feedback (behavior). Thus, we integrate the discussion of instructional resources (Theme 3) and course structure & processes (Theme 4) with participants' beliefs and behaviors when necessary. Italicized phrases correspond to salient codes related to beliefs and behaviors.

2.5.1 Theme 1: Participants' beliefs about teaching, learning, and students

A significant number of participants (81.25%) shared that they cared the most about *facilitating conceptual understanding* among students. Participants from all engineering disciplines and FECs represented in the dataset expressed this belief. These participants usually described facilitating conceptual understanding as the overarching goal that they aspire for as they engaged with students in the learning process because it is more likely that students are able to apply conceptual knowledge in various contexts. Victor, who teaches Thermodynamics, shared:

> To not panic when you don't know immediately how you're gonna solve a problem but to think back to the fundamentals of what you do know about this particular state and what you can figure out on how or why process would proceed in this direction… I try to really emphasize the big picture concepts and then how we can apply those and how you can by just remembering a few of the big picture concepts that you should be able derive or remember all the other ones that sort of follow from that. (Victor, Thermodynamics)

Participants usually commented about wanting students to develop a thorough understanding of concepts addressed in the course while observing that students are mainly satisfied with performing well in the homework and on tests:

> I think there are plenty of students that can do the homework and then perform well on the exam, but they don't necessarily learn the material. Because learning really means that you take it to something else and apply it there to get to a problem that we didn't talk about in class and apply what you learned in that class, then you're able to approach the new problem and actually complete that problem with your understanding from my class, or something like that. It's really more a deeper thing than I think students probably tend to think about it. (Noah, Statics)

The value placed by participants on facilitating thorough understanding of course concepts is consistent with literature on the significance of conceptual knowledge in the academic preparation of engineers (Litzinger, Lattuca, Hadgraft, & Newstetter, 2011; Streveler et al., 2008). This is especially important in FECs because concepts and principles learned in fundamental courses serve as the foundation for understanding and applying concepts in more advanced, design-focused engineering courses (Lord & Chen, 2014).

In as much as participants cared about ensuring that students gain an understanding of engineering concepts, they expect students to do their part and *take responsibility for their own learning*:

> There is real expectation, is you come to class prepared, ready to discuss the examples already… maybe introduce yourself to the concepts, or at least looked at a work and tried to figure out what it meant, or maybe looked at an example problem. (Noah, Statics)

Eleven of the 16 participants shared this expectation and generally talked about wanting students to proactively engage with course material, do the necessary preparation so that they can productively engage in class, and know when to seek help.

Related to this expectation is *student attendance* in the class:

> I expect them to show up in class most of the time… I think when I started teaching, I very much had the attitude, "Yeah, it's up to you, come to class if you want, if that's not what works for you, don't come to class, I don't care." The longer I'm at it, I come to the conclusion that there's enough students who think they can learn it without coming to class, that really can't, or at least don't… that I really have come to expect them to come to class. (Paul, Thermodynamics)

Attendance expectations implemented by Tamara in her class, however, are different from majority of the participants. Instead of encouraging in-person attendance, Tamara gave students in her Circuits for "non-majors" class the option to watch videos of the lecture. Tamara described this strategy as her way to manage the large class setting and build rapport with students who choose to attend class in person:

> Right now I have 320 students in the class… every day that I lecture live, about 20 minutes after my live lecture, the video of that lecture's up online in our course management system. So in front of me I usually see about 60 people, and the rest of them end up watching online. And it's not always the same 60 people, some people float in one week and float out the other week. But I build a relationship with the ones that always come to class. (Tamara, Circuits)

The most widely-held belief about students' study strategies is that students tend to focus on *just doing the homework*, a perception shared by 11 of the 16 participants (68.75%). When asked about what they think learning means to students, half of the participants (8/16) shared the perception that students equate learning with *achieving performance goals (e.g., receiving a satisfactory grade)*. Some narratives also aligned with excerpts highlighting the value participants placed on conceptual understanding and their opposing perceptions of students' approaches to learning:

> A continuing point of frustration for me is like the... especially with the homework, a lot of them have a very cast [set] and goal-based orientation. The goal is to get the homework done and get the right answer, not to necessarily learn from doing it. I haven't found good strategies to change that mindset. I point it out, but it seems to be very deeply ingrained, that they see the homework as like an end in itself to get the homework done. (Paul, Thermodynamics)

Despite the lamentations expressed above, 11 of the 16 participants acknowledge that *distractions* and *workload*–conflicting demands on students' time–may hinder the learning process. Participants posited that these demands may be curricular (other courses), extra-curricular (campus activities not directly related to academic pursuits), and non-curricular (personal responsibilities and concerns, e.g., work, social activities):

> I think there is some element of time: how much time they have allotted or available because of other commitments such as work or school, course load from other courses. That I think directly influences whether or not they're coming to office hours, if they're

> making study groups, if they're going out and finding additional information on the course, if they're trying to clarify issues they have with it. (Finn, Heat Transfer)

Seven of the 16 participants also believed that there is a *lack of willingness to maximize available resources* among students:

> I don't think the students always take advantage of those opportunities and access to be the best learners. I think they oftentimes don't take advantage of the resources that are available to them or the feedback and learning strategies and suggestions that they are presented with. (Finn, Heat Transfer)

In summary, participants generally care about being able to facilitate conceptual understanding in their courses. This belief aligns with how literature describes ideal learning strategies for undergraduate engineers. At the same time, they expect students to proactively engage in the learning process; lament that students tend to take a shallow approach to learning; but recognize that there are concerns beyond the context of the courses that they teach that compete for students' time and attention that may influence students' decisions to maximize learning opportunities and resources.

2.5.2 Theme 2: Participants' self-described behaviors

Our analysis showed that participants' self-described behaviors in the context of the courses they taught consisted mostly of presenting, explaining, and demonstrating course content using a variety of approaches.

All participants described employing scaffolding techniques when asked to describe the activities and interactions facilitated in the courses they taught. Scaffolding consists of strategies that support students' learning processes (Ormrod, 2016). Italicized phrases in parentheses indicate the most commonly-described strategies shared by participants illustrated in that quote. Some strategies are combinations of two or more scaffolding techniques:

> My approach was generally just to try to break down the problems as much as possible (*demonstrating the thought process to work-out a sample problem*), give them lots of methodology that they could follow so that as they're looking at problems and not understand how to do them, they at least have a place to start (*providing a structure for accomplishing course-related tasks*)… introduce the class a problem, try to give them a little bit of background so they could see how things fit together and then do more practical approaches to problem solving. (Vanessa, Statics)
>
> I like to relate the material to the students' experiences (*facilitating learning activities that keep students engaged with the course material,* e.g., provide practical, relatable examples). So in heat transfer there are many applications where they know intuitively about a phenomenon, but don't know in an engineering sense about it. And so I try to connect those two. That builds on their previous learning as a help to their learning mechanism. (Vincent, Heat Transfer)

Some instructors, however, shared an inability to use effective strategies due to such limitations as availability of resources and class size:

> I would like for them to be able to play physically with things, we're teaching a lot of physical concepts, how things move, how things work, it would definitely be beneficial if

> we had some kind of manipulatives for them to use and be able to see things. Definitely some students learn better that way, so I think that would be something also that I could do much easier if it were a smaller class size. (Vanessa, Statics)

Another scaffolding technique that majority of participants (14/16) described is *providing feedback through various means* (e.g., comments on homework and tests, discussion boards):

> One of the features… is an anonymous discussion forum… kind of an anonymous Twitter feed. When the kids have a question, if they don't want to raise their hand, they can write the question to the discussion forum. It shows up on the side board where I can see it, and if it's germane to the topic at hand, I can address it right away. If it's something that's coming up in a minute, or not really germane to what we're talking about, I can choose to ignore that for the time being. It also creates a record of the questions, and not only do I give a verbal answer in class, but I also provide a written answer that they can access any time. (Daphne, Thermodynamics)

> I like to try to also point out… how the exam problems are similar but not the same to a particular example I did in the lecture or something I did on a homework… trying to show the students how the exam problems used some but not all of the same techniques of things they've seen… I think that really what I'm teaching to be able to do is use their whole toolbox of ideas to solve new problems…" (Val, Fluid Mechanics)

We qualify, however, that while participants talked extensively about providing feedback, the narratives included both efforts they made and the challenges they faced. One of the participants, Noah, who taught two sections of Statics with an average total enrolment of 150 students from multiple engineering disciplines, talked about encountering challenges with providing meaningful feedback in what he described as “big” classes. Despite acknowledging the difficulty, Noah shared efforts and opportunities to provide students with the feedback they need:

> Giving meaningful feedback, actually analyzing the students' work in detail, it doesn't happen. It's just too difficult. There's not enough time to do all of those things… But, as much as possible, we try to give them the grade within a week and let them know where the points were counted off… one thing I do allow is anytime that a student wants to come to me after an exam and go over on an individual basis during the office hours or whatever it may be, talk about specifically, "This is how many points I got credit for, and this is why it was that partial credit," and then maybe it should have been less, maybe it should have been more, and me explaining that and possibly giving points back or something... I make that available to the students. And so, kind-of being a little of compensation for the fact that not that much attention can be paid to every single person's exam. (Noah, Statics)

Half of the participants (8/16) talked about providing feedback as a responsibility that they shared with teaching assistants (TAs), learning assistants (LAs), or graders. Participants described this arrangement as a way to manage the need to provide feedback to a large number of students. For example, Steve, who teaches a Fluid Mechanics class of 70–100 students, shared:

> I'm not the one who grades their homework, we have grader that do that. They [graders] are instructed to highlight where students went wrong, and ask them to look at the solutions… We have a group exam and we have an individual exam. The group exam I

> grade the whole thing on all of them, and I will highlight where they went wrong in their approaches. There's an elaborate grading rubric that explains where all the different points were. They are advised to come see us if they're struggling. On the individual exam, again that's a team of people are grading that and again, there's a very elaborate rubric of where all the points were. Then if students have questions they can come see us. (Steve, Fluid Mechanics)

Erwin, an instructor teaching a 200-student Thermodynamics class, shared an interesting combination of utilizing TA support and emphasizing students' accountability towards the learning process to manage providing feedback to a large class:

> I tell them the grader isn't going to look and give you feedback on each and every homework problem. You've turned in one or two homework problems for every class, we're only going to grade one of them. The other two may be right or wrong, done or not done, we don't care, it's up to you to look at the published solutions, and I always have a teaching assistant who's well-versed in how I do a class, and they produce a solution that the student themselves can compare these to and do their own self-assessment. If they have questions, great, email me, come see me, come to office hours, ask other students, but they have to be accountable for evaluating their own stuff. If you make that clear to students in the beginning, then they start doing it themselves. If you don't make that clear to them, they're saying, "Oh, you're not grading, you're being lazy, you didn't give me any feedback." But as soon as I start making that clear on the first day, and I emphasize early on a couple times in the semester, then they start really doing it on their own and now

> they're evaluating their own work. So, yeah, that's how I manage 200 plus students with that much homework… (Erwin, Thermodynamics)

Aside from employing scaffolding techniques, a significant number of participants (75%) described *encouraging and facilitating learning activities between/among students (e.g., facilitating group work, encouraging peer learning strategies)* both within and after the class period:

> There were maybe five or six times during the semester when most or all of the lecture was devoted to a group project, I mean the problem solving. We have a bunch of clicker questions that would walk them through steps of the problem. They would be solving in group and all the TAs came in and we all wandered around to answer questions during the lecture. (Karen, Strength of Materials)

Ulysses, who teaches Fluid Mechanics, encourages students to form small, after-class, study "teams": "I think the idea is that at least occasionally people should have a chance to teach each other as well as learn from each other, because you often learn when you have to teach."

Participants who taught classes with enrolments of more than 100 students (e.g., Karen) and less than 50 students (e.g., Odette) both shared facilitating opportunities for students to engage with their peers, despite literature indicating that this was a challenge in large class environments (Moodley, 2015).

In summary, we found that participants generally described theoretically-supported and recommended teaching behaviors, such as scaffolding and facilitating peer interaction. Even though they shared challenges in implementing some productive strategies due to the structure of the courses they taught, they still described efforts to do the things that they care about, despite difficulties.

2.6 Discussion

Our results indicate that participants primarily care about ensuring that students gain a thorough understanding of engineering concepts introduced in their courses, and describe theoretically-supported behaviors that should allow them to accomplish their goal. However, it is challenging to maximize expected gains if students are not actively engaged in the learning process. Participants' belief-behavior patterns align with optimal strategies for facilitating effective learning environments in FECs.

2.6.1 Participants' beliefs about students' approach to learning

Participants' perceptions about students' beliefs about, and approaches to, the learning process are in keeping with findings from studies on students' learning and study strategies, particularly for students who exhibit low academic performance (e.g., Dawood, Tapia, Trujillo, Guynn, & Wojahn, 2017; Streveler, Hoeglund, & Stein, 2003). Participants' beliefs and perceptions about students indicate a gap between how students are approaching the learning process and what they should ideally be doing. This gap may hinder the realization of expected gains from employing the productive learning strategies described by participants:

> You can lead a horse to water, but you can't make it drink. I can put out videos, I can put out self-guided studies, I can do all these things, but if the students don't use them, I can't do anything about it. (Daphne, Thermodynamics)

Such comments highlight the need to encourage metacognitive and self-regulated learning behaviors among students to maximize the impact of effective teaching strategies and, consequently, alleviate challenges in the learning environment. Self-regulated learning is also an important aspect of promoting conceptual learning, and includes the following behaviors: utilizing effective learning strategies, determining when to seek help, and reflection, among others (Ormrod, 2016). Participants perceive that students do not consistently engage in these behaviors, although there are opportunities for them to do so.

Pike and colleagues (2006) associated attendance in research-intensive doctoral universities with low levels of student engagement, which includes self-regulation and adopting deep and meaningful approaches to learning (Kahu, 2013). Pike and colleagues (2006) partly attributed inadequate student engagement with the complexity of R1 institutional missions and structures, and indicated that there may be less attention given to student engagement at these institutions. Their findings of low student engagement align with participants' perceptions of inadequate metacognitive and self-regulated learning behaviors among their students, suggesting that participants' perceptions about students' approaches to learning may also be an outcome of the educational environments fostered in R1 institutions.

Dataset limitations hinder us from unpacking student attitudes and behaviors that trigger participants' less-than-ideal perceptions of students' study strategies and approaches to learning. Students may face circumstances beyond instructors' purview that impact their ability to actively engage in the learning process:

> I just think that there's a lot of side issues that as educators, we're not always aware of what's going on day to day in their lives… they have good and bad days, good and bad semesters, and good and bad experiences. (Erwin, Thermodynamics)

Analysis did not explicitly yield behaviors that mitigate perceptions about students, although limitations of secondary data analysis prevent us from inquiring further on whether participants attempted to address their concerns about students' approaches to learning. It is important, however, to recognize that perceptions about *distractions*, *workload*, and *lack of willingness to maximize available resources*, when left unexplored, may disproportionately impact disadvantaged students. Most participants' narratives express these perceptions, particularly excerpts indicating *lack of willingness to maximize available resources*, as frustrations, implying assumptions that decisions affecting the extent of student engagement in course activities are within students' control. Studies looking at disadvantaged and underrepresented engineering students (e.g., Foor et al., 2007), however, show that this is not always the case. Some students may face demands on their time and energy that force them to choose non-curricular priorities over productive learning strategies, despite the knowledge that their choices may adversely impact their ability to succeed in the course. Although a detailed examination of these concerns is beyond the scope of this study, we recognize that it is a critical topic for further investigation.

2.6.2 Participants' self-described behaviors and adoption of strategies that promote effective learning

Literature indicates challenges in having faculty adopt productive, evidence-based teaching strategies in engineering classrooms (Finelli & Millunchick, 2013; PCAST, 2012).

Menges (2000) attributes the slow adoption of more effective teaching strategies to the lack of research–and consequently, understanding–of context-specific aspects of instructors' experiences in facilitating learning. Among the areas that we know little about are "why faculty teach the way they do" and "under what conditions do… (faculty) fail to act according to their personal theories" (Menges, 2000, p. 7). Menges posits further that it is important to understand how instructors think about and solve problems in order to identify data and resources that instructors will find useful for overcoming challenges.

Our findings, however, do not reflect slow adoption of effective teaching strategies; our participants shared productive and recommended teaching behaviors, or at least spoke of efforts to exhibit productive behaviors despite challenges in their classroom environments related to class size. While this is a promising finding, we acknowledge that it may be an outcome of limitations in our dataset; most instructors who self-selected into the primary study are part of a community that cares about education and engages in education research. They have access to resources on evidence-based educational practices and some of them have published engineering education research. The behaviors that we found show the integration of productive teaching behaviors and strategies in FECs in the R1 institutions taught by our participants.

We noted that although the self-described behaviors of participants indicate knowledge and use of strategies that promote effective learning, the over-all narrative still implies a primarily linear approach for facilitating learning: the instructor presents a concept using diagrams and the derivation of formulas, and provides sample problems (Seymour & Hewitt, 1997; Soledad, Grohs, Williams, Culver, & Doggett, 2017). The students then attempt to replicate and apply the processes presented by the instructor to various work-out problems and contexts as they independently engage with the course material. It is a process that has remained fundamentally unchanged since the 1900s (Sheppard et al., 2009); instructors described their primary teaching strategy as a deductive and linear process in a previous study (Soledad & Grohs, 2016) and continue to do so based on our data.

2.6.3 Belief-behavior patterns

Extending the distinct discussions on beliefs and behaviors, we now discuss across these main themes. Participants mostly described teaching behaviors supported by literature and considered as strong strategies for facilitating conceptual understanding. These behaviors (e.g., employing scaffolding techniques and facilitating opportunities for interactions with socializers) are consistent with their most salient belief that learning should primarily involve thorough understanding of fundamental concepts and principles so that students can apply this knowledge to various contexts (Streveler et al., 2008).

Scaffolding techniques, for example, promote the development of metacognitive skills and effective learning strategies (Ambrose et al., 2010; Committee on Developments in the Science of Learning, 2000). Our participants' descriptions of facilitating group work in their classes indicate meaningful interaction with socializers in the learning environment: the instructor and their peers. These interactions are valuable; first, interacting with peers will expose students to other perspectives that may not align with their own, which can then trigger sociocultural conflicts that promote conceptual change (Ormrod, 2016; Thompson & Garik, 2015). Second, interacting with the significant, more experienced socializer (i.e., the instructor) contributes to skills development (Ambrose et al., 2010).

Instructors are at the core of the sociocultural dynamics in the learning environment; instructors and peers are socializers who interact with students in a social context within a course (Eccles, 2007). Although interactions with peers are important, instructors are perceived as the more knowledgeable socializer that a student interacts with (Ambrose et al., 2010; Ormrod, 2016). Instructors are responsible for generating and sustaining student interest in both the big picture (e.g., the course in general and its role in students' future plans and goals) and specific tasks related to the course, and facilitating interactions. In addition, faculty behaviors and attitudes significantly impact student beliefs for success in the learning process (Umbach & Wawrzynski, 2004). Our findings indicate that participants' beliefs and behaviors are consistent with what literature recommend for fostering positive learning experiences and student success.

Participants' belief-behavior patterns related to *facilitating conceptual understanding* indicate mostly beneficial interactions between students and our participants as socializers. While participants expressed some frustration over their perception that students are employing shallow approaches to the learning process, we did not find indications in the data that they espoused beliefs that are detrimental to students' expectancies for success and sense of competence. On the contrary, their narratives imply that participants believe that with the appropriate changes to learning strategies and attitudes, such as maximizing learning resources and opportunities that the participants or the institutions they teach in provide, students who are struggling may be more successful in their courses. Recalling EVT as the guiding framework for this study, this finding should consequently result in increased confidence, expectancies for success, and motivation to engage among students. We do recognize, though, that beliefs on *distractions, workload,* and *lack of willingness to maximize available resources* warrant closer scrutiny. The scope and nature of our data hinders us from confirming the impact on students present in the learning environments described in our study. Literature, however, indicates low success, satisfaction, and persistence rates in the learning environments represented in the dataset (Marra et al., 2012; Vasquez et al., 2015), which is contrary to the consequence that we expect to see in the educational environment our participants facilitate given the beliefs they espouse and the behaviors they describe.

2.7 Implications for practice and research

Instructors may consider integrating learning activities that encourage self-regulated and metacognitive learning strategies in their classes, in order to address their belief regarding a lack of ownership of the learning processes among some of their students. As significant socializers in fundamental course learning environments taken during the early years of engineering students' academic careers, instructors are well-positioned to socialize students into both the concepts addressed in their courses and the ways in which they can engage in deep, meaningful learning processes during their undergraduate careers–essentially, integrating strategies that teach students how to learn. An example of such a strategy is to facilitate opportunities for students to reflect on their learning experience, evaluating which learning strategies that they used worked well, and which did not (Cunningham, Matusovich, Hunter, Blackowski, & Bhaduri, 2017). Instructors may also consider explaining the rationale behind the evidence-based teaching strategies that they are implementing in the classroom and the gains that students may derive from adopting these learning strategies. Providing an explanation may help students understand why the instructors are using these strategies and how they may use them effectively in their own learning process, in order to address student resistance to some self-regulated and metacognitive learning behaviors.

We acknowledge that instructors will need support and resources when they facilitate self-regulated and metacognitive learning strategies for students in their classes. An implication for practice at the departmental level is to provide resources to help instructors integrate strategies to teach students how to learn into their teaching practice. For example, departments may opportunities for instructors to engage with instructional consultants and engineering education researchers who can provide guidance and feedback, as well as assist in course planning and instructional design.

2.8 Opportunities for future work

Our findings present opportunities for further research. We found that participants engaged in productive teaching behaviors and implemented evidence-based practices in their classes. It would be interesting to investigate a larger and more representative group of participants, from a wider and more comprehensive sampling frame, to confirm whether our participants' behaviors reflect the behaviors of the greater majority of instructors of fundamental engineering courses in R1 institutions. We also recommend collecting and investigating other primary sources of qualitative data, such as in-person classroom observations, to substantiate self-described beliefs and behaviors.

The gap between expected consequences related to student success based on belief-behavior patterns found in our data and what is prevalent in literature also merits further investigation. What other factors influence students' expectancy for success, motivation to engage in the course, and academic performance if instructors are adopting recommended, evidence-based teaching strategies in their courses, specifically in R1 institutions? Based on our participants' perceptions and observations, some factors worth exploring are students' academic and non-academic workload and academic retention policies (e.g., departmental GPA requirements).

We are unable to corroborate participants' beliefs about students' learning and study strategies against student-provided data from our dataset. Based solely on participants' beliefs, our findings suggest a need to develop metacognitive and self-regulated learning skills among students, in order to maximize expected gains from productive teaching behaviors. The broader project that this study is part of includes ongoing efforts related to promoting self-regulated learning in students, describing and encouraging metacognitive strategies in the classroom, and providing institution- or department-level support to help students shift to a more self-regulated learning mindset (Cunningham, Matusovich, Hunter, & McCord, 2015; Cunningham, et al, 2017; Williams, Morelock, Matusovich, & Cunningham, 2016). A study following these interventions, as well as a study focused on student-provided data, may corroborate and build upon the findings of our work.

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Chapter 3: Manuscript 2

Fundamental courses in engineering curricula: A case study
Target Journal: International Journal of Engineering Education
This manuscript includes intellectual contributions from Homero Murzi and Jacob Grohs (see Attributions) who will be credited accordingly as co-authors in this work

3.1 Abstract

Fundamental engineering courses (FECs) are critical to student success in engineering, but have been associated with challenging student learning experiences. Multiple departments within and external to engineering teach and manage FECs; thus, students perceive the courses as disjointed despite having a shared purpose of developing conceptual knowledge and skills for more discipline-specific courses. Using case study methodology, we considered the suite of fundamental engineering mechanics courses as a common foundational engineering mechanics curriculum and sought to describe the educational environment in these courses using the Academic Plan Model as framework. Results indicated that participants described the educational environment in their courses and the factors that influence curricular decision-making in similar ways, despite teaching distinct courses managed by different departments. Participants also sought more collaboration across multiple departments in order to effectively facilitate learning and transfer in their courses. We recommend a student-focused, collaborative, and holistic academic plan that encompasses all courses in foundational curricula and engages instructors of FECs across multiple departments as equal partners in the learning process.

Keywords: *fundamental engineering courses, academic plan model, continuous improvement, higher education*

3.2 Introduction

Fundamental engineering courses (FECs) are the foundation upon which discipline-specific courses are built (Chen, Whittinghill, & Kadlowec, 2010). They are critical to student success in engineering (Lord & Chen, 2014), but have long been associated with unproductive student learning experiences that lead to attrition (Seymour & Hewitt, 1997; Suresh, 2006; Van Valkenburg, 1990). Examples of these courses are Calculus and Statics, often described as conceptually-challenging, too abstract and theoretical, and having little practical application within the course (Lord & Chen, 2014; Marra et al., 2012; Seymour & Hewitt, 1997). Sometimes, FECs are taught in large class environments in order to manage institutional resources (Coburn & Treeger, 1997; Parry, 2012), a situation which then presents additional challenges for students and instructors. They are also managed by departments that are independent of each other and serve students from across multiple disciplines. Hence, these courses have earned such monikers as “gatekeeper,” “weed-out,” and “barrier” courses in engineering curricula (Gahagan & Hunter, 2006; Suresh, 2006; Van Valkenburg, 1990; Vasquez et al., 2015). It is, however, important to pay attention to providing quality learning experiences for students in these courses because they provide critical foundational knowledge in engineering.

Efforts are being made to mitigate challenges and ensure that positive learning experiences are facilitated in FECs (Barriere, 2002; Catton, Galang, & Bulk, 2016; Christiansen et al., 2009). Research in STEM and engineering education suggest that instructors should implement active learning techniques and inductive approaches to teaching engineering principles (Ellis, Rudnitsky, & Scordilis, 2005; Sheppard et al., 2009). Descriptions of current teaching practices in FECs, however, do not align with the effective strategies suggested by research. There is evidence showing that there has been little change to the way FECs have been taught over the years (Borrego, Froyd, & Hall, 2010; National Academies of Sciences, Engineering, and Medicine, 2016; National Research Council, 2012; Sheppard et al., 2009; M. Soledad & Grohs, 2016). Change is needed, but certain situations (e.g., large class environments, heterogeneity of students in a class, availability of instructional resources) make adopting change difficult.

Complex factors influence curricular decisions, and it is important to understand the context in which these decisions are made (McKeachie, Pintrich, Lin, & Smith, 1987; Stark, Lowther, Ryan, & Genthon, 1988). At the core of the decision-making process is the instructor, who is responsible for designing effective learning environments and experiences for students (Astin, 1993; Jamieson & Lohmann, 2009; Pascarella & Terenzini, 2005; Tinto, 1993). Several elements comprise the learning environment, including instructional activities born out of teaching and learning strategies (Lattuca & Stark, 2009). There is considerable knowledge about teaching and learning strategies (Menges & Austin, 2001), but less focus on the context and factors that affect the decisions that instructors make (Menges, 2000). Evidence indicates that instructors of FECs know about effective strategies (e.g., small group and facilitated peer interaction; providing individualized, timely and meaningful feedback) and the need for change (Besterfield-Sacre, Cox, Borrego, Beddoes, & Zhu, 2014; M. Soledad & Grohs, 2016; M. Soledad et al., 2018), but awareness and personal interest in effective strategies alone are insufficient triggers for sustained changes in behavior and practice. Inherent challenges due to course structure and context are among factors that may prevent instructors from adopting change (Finelli, Richardson, & Daly, 2013). Prior work also focuses mostly on individual courses (e.g., Christiansen et al., 2009); there is less knowledge about how FECs interact as a suite of courses that contribute to each other and collectively build a common foundation for engineering students across several disciplines.

This study considers the suite of FECs as a common foundational curriculum within engineering curricula, taken by students from multiple engineering disciplines before advancing to discipline-specific courses. We anchor this perspective of a common foundational engineering curriculum on Lattuca and Stark's (2009) *Academic Plans in Sociocultural Context* (The Academic Plan Model), which presents the curriculum in the context of an academic plan. An academic plan provides a holistic and comprehensive overview of the learning environment. Lattuca and Stark's model defines elements within an academic plan (*purposes, content, sequence, learners, instructional processes, instructional resources, evaluation* and *adjustment*) that need to be considered when making decisions meant to "foster students' academic development" (Lattuca & Stark, 2009, p. 4). The Academic Plan Model also acknowledges the impact of influences, both *external* (e.g., industry-driven needs) and *internal* (e.g., institutional resources, student characteristics), on developing and implementing an academic plan.

For the purposes of this study, we conceptualized the common foundational engineering curriculum as an academic plan as defined by Lattuca and Stark (2009). This common foundational engineering curriculum consists of fundamental engineering courses that are each enacted through an academic plan developed by the instructors who teach them. It is important to recognize that instructors are both critical decision-makers for their respective courses and stakeholders in a broader academic plan in which they have little ownership or control over (Lattuca & Stark, 2009a; J. S. Stark et al., 1990). Thus, studying instructors' perspectives and experiences in designing the learning environment is an important step to take when thinking about improving student learning experiences in fundamental courses (Ewell, 1997).

Specifically, the study sought to map the common foundational engineering curriculum to the Academic Plan Model based on instructors' descriptions of elements of the academic plan as enacted in the educational environment: *purposes, content, sequence, instructional processes, instructional resources, learners, assessment & evaluation,* and *adjustments.* The following questions guided this study:

1. How do instructors describe the *educational environment* enacted through the foundational engineering curriculum?
2. How do instructors describe the *factors that influence their curricular decision-making process*?

To answer these questions, we used case study methodology to examine interview transcripts and additional sources of data. Our primary data consisted of semi-structured interviews conducted with instructors teaching fundamental engineering courses in a large research institution. This work is part of a larger institutional and community transformation project, which served as the data source for this study.

3.3 Perspectives from Literature

3.3.1 The Academic Plan Model

The Academic Plan Model (Figure 3.1) provides context for how the educational environment in FECs is shaped. The original model was developed by Lattuca and Stark (2009) as a means of thinking about academic curricula, in response to "a lack of a comprehensive definition of curriculum" (p. 4). Presenting the curriculum in the context of a plan provides an overview of the learning environment, the elements that interact and comprise it, and the factors that influence curricular decisions. The Academic Plan Model visualizes the interacting factors that influence how the educational environment is shaped, particularly in terms of decisions made regarding the elements of the academic plan (Lattuca & Stark, 2009).

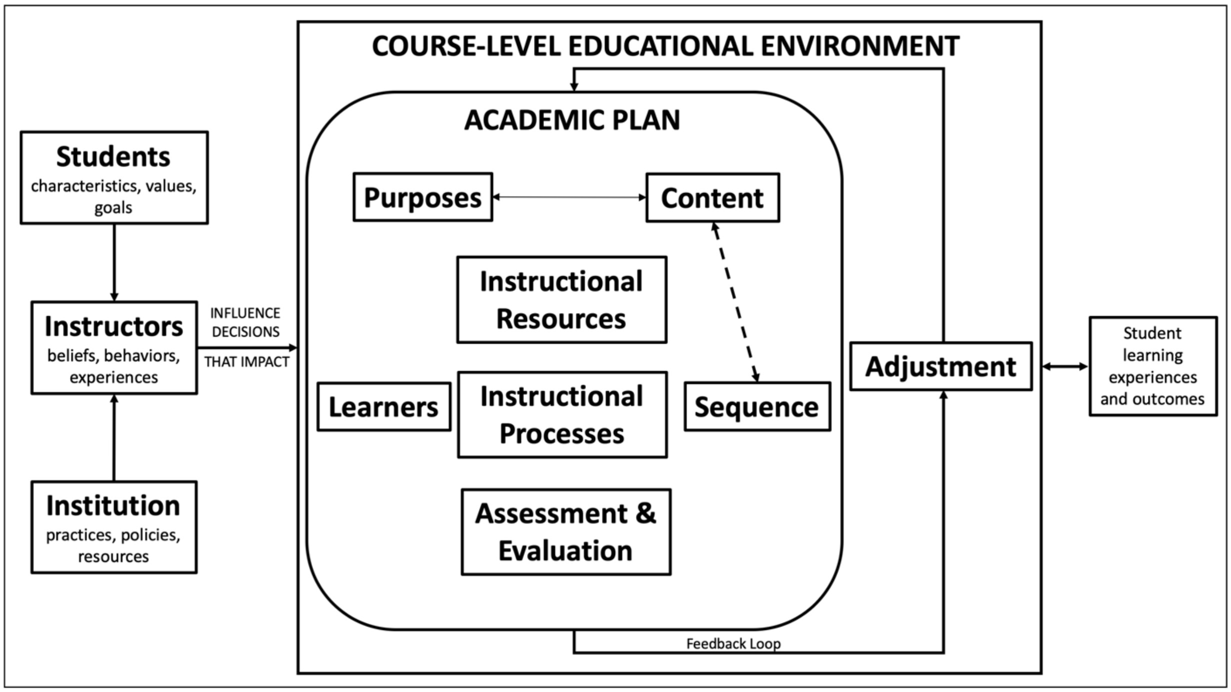

Figure 3.1. Adapted from The Academic Plan Model (Lattuca & Stark, 2009)

An academic plan may be developed for different organizational levels in an institution (e.g., course, degree program, college, entire institution), and it is "purposefully constructed to facilitate learning" (Stark et al., 1990). The plan consists of eight elements (*purposes, content, sequence, learners, instructional processes, instructional resources, assessment & evaluation, adjustments*) that interact and influence the others, ultimately shaping the educational environment and learning experiences of students. *Purposes* refer to the "intended outcomes" (Lattuca & Stark, 2009, p. 4) for the academic plan. *Content* refers to the subject matter that the plan is expected to convey, while *sequence* is how *content* is arranged so that the plan's *purposes* are met. Instructors tend to find a strong connection between *purposes* and *content* (Stark et al., 1990; Stark, Lowther, Ryan, Bomotti, et al., 1988). A similar link also exists between *content* and *sequence,* although instructors do not consistently make this connection.

Lattuca & Stark emphasize that *learners*–a specific group of students–serve as the focal point for designing an academic plan. An academic plan should consider the "characteristics, goals, and abilities" (Lattuca & Stark, 2009, p. 14) of the students it is designed for. Keeping *learners* in mind, the academic plan identifies learning activities that will facilitate the learning process (*instructional processes*) and what is needed to implement them (*instructional resources,* e.g., textbooks, learning management systems, classroom infrastructure). *Assessment & evaluation* techniques determine whether the *purposes* of the plan are met, and yield opportunities for improvement that trigger *adjustments* to the academic plan (Lattuca & Stark, 2009; Stark et al., 1990). As highlighted in the research questions, the primary focus of this study is to understand how the academic plan is currently enacted in fundamental engineering courses. Findings from the study will provide context for the educational environment using elements of the Academic Plan Model and reveal factors that affect instructors' course-level decision making processes as they adjust the academic plan.

3.3.2 Factors that shape the educational environment

The Academic Plan Model (Fig. 3.1) acknowledges instructors as key players in the educational environment. It emphasizes that various factors influence instructors' curricular decisions; that instructors themselves affect the educational environment; and that consequently, their decisions impact students' educational outcomes. It also shows the educational environment as a dynamic process that should have feedback mechanisms that enable continuous improvement (Lattuca & Stark, 2009). However, creating educational environments that foster positive learning experiences, a responsibility placed mainly on the shoulders of instructors, includes non-academic and non-engineering considerations (e.g., student characteristics) that instructors may not have the appropriate support and resources for (Borrego & Henderson, 2014; Lattuca, Terenzini, & Volkwein, 2006; Schreiner, 2010; Stark, Lowther, Ryan, Bomotti, et al., 1988).

When instructors make curricular decisions, they are influenced by the "structures and context of the systems in which they work" (Besterfield-Sacre et al., 2014, p. 191). Finelli and colleagues (2014) found that instructors most frequently talked about "infrastructure and culture" (p. 340) as factors influencing the adoption of effective teaching practices, although they usually referred to these influences as barriers instead of facilitators for change in practice. Instructors also identified "classroom and curriculum," referring to class sizes, physical infrastructure of classrooms, and flexibility of the curriculum as factors that influence changes to teaching practices (Finelli et al., 2014a). While knowledge and awareness of effective teaching techniques is also a factor for the willingness to adopt change (Finelli et al., 2014a), the prevailing structures and contexts in their classes serve as barriers and supersede interest in adopting effective teaching strategies (Henderson & Dancy, 2011). The factors that influence teaching practices may not necessarily translate to implementation in classrooms (Knight, Cameron, Hadgraft, & Reidsema, 2016), partly due to limitations presented by certain contexts (e.g., large class sizes, Grohs et al., 2018) that are beyond the purview of instructors.

3.4 Methods

This study is part of a larger institutional transformation project. We qualitatively analyzed transcripts of a subset of semi-structured interviews conducted with instructors participating in the project and examined additional data sources (e.g., participant-provided artifacts, project documentation & artifacts), following guidelines for case study research (Yin, 2009). We examined instructor experiences to draw out perspectives and descriptions to address the research questions. Analysis followed a single case study approach with embedded units of analysis (Yin, 2009) using the Academic Plan Model as framework.

3.4.1 Research Design

This study used single case study design anchored on The Academic Plan Model (Lattuca & Stark, 2009), a concept formulated from and based on rigorous research (e.g., Stark et al., 1990; Stark, Lowther, Ryan, Bomotti, et al., 1988) and used in various contexts (e.g., Knight et al., 2016). A case is defined and bound by the experiences participating instructors who have taught courses that introduce, address and develop concepts and skills that are fundamental to engineering disciplines in the large research institution where the project is being conducted (Miles & Huberman, 1994).

In examining course structures in the curricula of engineering programs at the study location from a student learning-focused lens, we found that FECs function as a network of interacting courses, particularly from a purely conceptual and skills development perspective. An example of such a networked structure, focusing on mechanics courses, is shown in Figure 3.2. Students need to acquire and develop concepts and skills in Math and Physics to be successful in

Statics. Statics, in turn, serve as the foundation for Dynamics and Strength of Materials, indicated in the figure with broken arrows as not all students need to take these two courses.

For engineering curricula at the study location, FECs are managed by various departments, some of which reside outside of the College of Engineering (e.g., Math, Physics). However, the tendency to take a "siloed" mentality to teaching (Alpay & Jones, 2012) is more likely to occur in a large research institution, something that is counterintuitive to the networked function of FECs. Looking at prevailing structures at the institution where the study was conducted, courses are primarily managed by distinct, independent departments, and it is likely that instructors operate according to the administrative context and processes within that department (Hammond, 2004).

We thus chose the single-case study design with embedded units of analysis because it allowed us to holistically examine the experiences of instructors teaching FECs in a large research-intensive institution with high engineering student populations, while still acknowledging the unique contexts, processes and practices that departmental administrative structures may bring to their experiences. We classified the participants into two clusters: participants teaching courses managed by engineering departments, and those teaching courses managed by servicing departments external to engineering. Although all participants teach fundamental courses in engineering curricula and meet the definition of a case for this study, we acknowledge that there may be unique perspectives worth noting within each cluster. These two clusters constitute our embedded units of analysis.

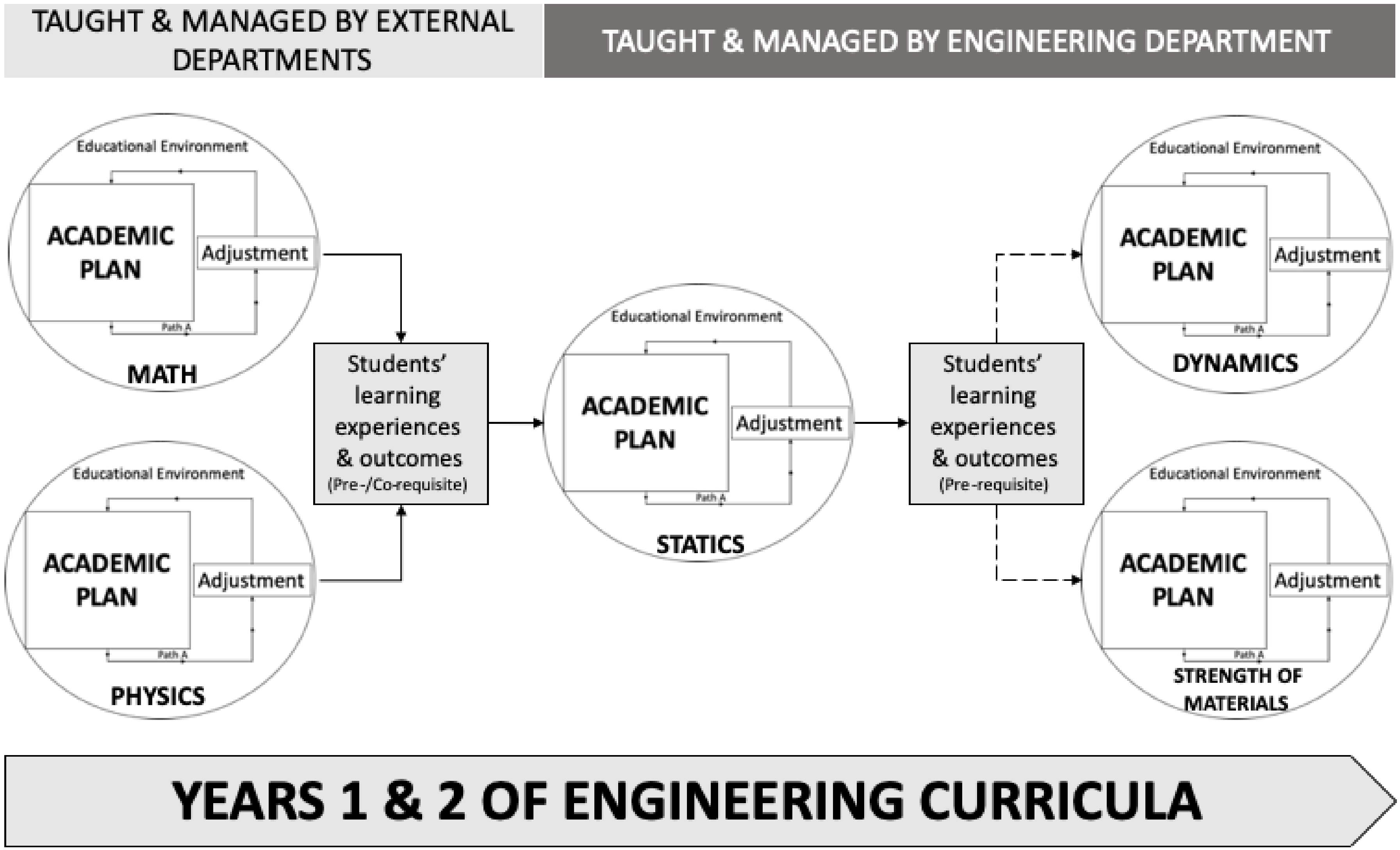

Figure 3.2 Network of interacting fundamental courses in the mechanics track

3.4.2 Description of the Investing in Instructors Project

All the data analyzed in this study were collected as part of the Investing in Instructors project, funded by the National Science Foundation. The multi-year project is studying and working with 15 instructors of primarily large fundamental engineering courses, responsible for teaching approximately 4,800 undergraduate engineering students in a large, public, research university. The 15 project participants engage in research activities (e.g., as interview participants), provide documents and artifacts (e.g., course syllabi, course schedule), and participate in the large foundational courses summit conducted by the project team every summer for the duration of the project. Activities during the summer summit are rooted in the data collected during the academic year, and includes collaboratively defining problems across instructors and courses, providing feedback on tools and analysis generated by the project team, suggesting adjustments to data analytics protocols, and creating faculty action plans. The project seeks to answer research questions related to learning analytics and faculty change. It hopes to leverage institutional data and facilitate opportunities for participating instructors to work collaboratively towards improving undergraduate engineering education.

3.4.3 Participants and research location

This study analyzed data collected from seven project participants teaching fundamental engineering courses; Table 3.1 shows participant information. For this study, we focused on project participants who have taught and/or have managed the following courses: mathematics (math), physics, and mechanics (statics, dynamics, strength of materials). These courses are part of what we operationally define as the foundational engineering mechanics curriculum (Figure 3.2).

All engineering programs at the institution where we conducted the study require students to take specific math (e.g., multivariable calculus) and physics (foundations of physics) courses that serve as pre- and/or co-requisites for fundamental and discipline-specific engineering courses, including mechanics. Five of the institution's fourteen engineering programs require the entire suite of courses included in the study, and an additional six programs require at least one of the mechanics courses, in addition to math and physics. We acknowledge that not all students required to take statics go on to take dynamics and strength of materials by indicating this part of the curriculum with broken lines in the figure.

We chose to focus on the foundational engineering mechanics curriculum because it is a suite of courses required of a significant number of engineering students at the institution where we conducted the project. The courses included in this study have significant total enrollments; math and physics cater to approximately 2000 students, while total enrollment in each of the mechanics courses are about half that number. Thus, there was an opportunity to examine the academic plan that impacts a significant number of learning environments and experiences. All participants were teaching in a large, public, research university located in the southern regional division of the United States (United States Census Bureau, 2010) at the time of the study. We assigned pseudonyms to ensure the confidentiality of the participants.

Table 3.1 Participant Information

Pseudonym	Course taught	Class size	Primary role
Victoria	Mechanics	40-140	Professional teaching faculty
Marie	Mathematics	40-50	Professional teaching faculty
Kevin	Mathematics	40-50	Professional teaching faculty
Mike	Mechanics	40-140	Professional teaching faculty
Diane	Physics	150-180	Professional teaching faculty
William	Physics	150-180	Adjunct teaching faculty
Vanessa	Mechanics	40-140	Professional teaching faculty

To accommodate all students required to take these courses, departments managing the courses offer multiple sections of each course, taught by multiple instructors. There is a designated course coordinator, usually an instructor who is actively teaching and/or has taught the course, who assumes course management responsibilities. Course management includes coordinating the course syllabi, schedule for the semester, and assessment activities, among other responsibilities. Three of our participants were serving in this capacity at the time of their interview.

3.4.4 Data collection

Primary Data Source. We used semi-structured interview transcripts from the larger project, conducted when participants joined the project. As members of the project team, we helped develop the interview protocol (Appendix B), conducted interviews, and had access to project data, documentation, and artifacts. The interview protocol includes prompts focused on participants' teaching experiences, available resources to support their teaching, and specific resource needs. Participants were also asked about the kind of data (e.g., information about students, teaching strategies) that they felt they needed or found helpful, and how they might use this data to more effectively facilitate learning in their classes.

The interview protocol and data collection procedure received IRB approval. Interviews lasted for about one hour, documented using audio recordings and field notes, and transcribed by a professional transcription service.

Additional Data Sources. Case study research guidelines include the need for multiple data sources (Creswell, 2012; Stake, 1995; Yin, 2009). We examined field notes (notes taken during interviews, project cohort meetings, and summer summit on teaching large foundational engineering courses), memos (during analysis), participant-provided artifacts (e.g., course syllabi, course schedule), project artifacts (e.g., brainstorming outputs from project cohort meetings and the summer summit), and institutional data (e.g., checksheets, historical timetable of classes). Field notes and memos complement and corroborate statements documented in interview transcripts. Artifacts supplement and provide context for descriptions and perceptions given during the interviews.

3.4.5 Data analysis

Primary Data Source. Data analysis consisted of two coding cycles, acknowledging the iterative nature of qualitative data analysis (Miles & Huberman, 1994; Saldana, 2016). Two project team members concurrently and independently conducted analysis, and periodically engaged in case analysis meetings to discuss coding decisions, definitions, and themes (Miles & Huberman, 1994). To ensure the integrity of analysis across multiple researchers, the first author conducted first cycle coding, using the Academic Plan Model as the framework for analysis, on a subset of the project dataset. This generated an initial list of codes and observations about the data. The first case analysis meeting consisted of a discussion of the initial analysis and observations with the other researcher, generating an agreement for approaching coding, prior to concurrent analysis by both researchers. Both researchers coded using Dedoose™, a cross-platform online qualitative research analysis tool.

First cycle coding assigned labels to meaningful excerpts, supplemented by memos when appropriate. Second cycle coding employed pattern coding (Saldana, 2016) to the labels and excerpts from first cycle coding. We used elements of the Academic Plan Model (see Fig. 3.1) as provisional categories for coded interview data, classifying first cycle coding outputs under each element.

In looking within and across categories, we created tabular displays (Miles & Huberman, 1994). We merged similar codes and excerpts when appropriate, ensuring that we documented each decision so that we can still trace back all consolidated codes to its original form.

Additional Data Sources. We used additional data sources, consisting instructor-provided documents, project artifacts, and accessible institutional data (e.g., course schedules, summer summit workshop outputs, program checksheets) to support and complement statements made in the primary data source. We referred to additional data sources as they relate to, support, and provide context for the findings from the primary data source.

3.4.6 Research Quality and Limitations

It is important to discuss how research quality and trustworthiness were ensured when conducting case study research (Yin, 2009, p. 14). We used three methods to establish research quality and trustworthiness, using descriptions by Leydens, Moskal, & Pavelich (2004). First, two researchers employed a code-recode process for first cycle coding. Code-recode consists of initial coding, waiting for a period of time, then recoding to ensure that all meaningful excerpts were coded appropriately and reconfirm initial coding decisions. Second, we conducted member checking by providing participants with the results of analysis as part of a project report. Third, we employed triangulation through multiple researchers and sources of data.

This study was limited to project data provided by participants who willingly engaged in a project examining the large class environment in fundamental engineering courses. We acknowledge that there may be inherent biases in responses since participants all show a commitment to providing positive student learning experiences by being part of the project. Their perspectives remain valuable, however, as an initial insight into the teaching experience across fundamental engineering courses in the same institution. The findings from this study may be presented to the appropriate stakeholders as a baseline for further examination of the fundamental engineering course learning experience and for identifying opportunities for improvement.

3.5 Results

This study sought to view the suite of courses in the foundational engineering mechanics curriculum (Figure 3.2) as an academic plan, guided by the Academic Plan Model (Figure 3.1). Participants' perceptions and descriptions of the various elements of the Academic Plan Model (Figure 3.1) describe the *educational environment,* addressing RQ1. Triggers that lead to adjustments to the academic plan describe the *factors that influence instructors' curricular decision-making processes,* addressing RQ2. As indicated in our Methods section, we have two embedded units of analysis: 1) Courses taught and managed by external departments (Math and Physics), and 2) Courses taught and managed by an engineering department (Mechanics – Statics, Dynamics, and Strength of Materials).

In keeping with using the Academic Plan Model (Figure 3.1) to frame our study, we organize our findings by presenting participants' descriptions of the elements of the academic plan. We discuss the enactment of each element of the academic plan, sharing perspectives from each embedded unit of analysis as derived from the data. We share participants' perceptions and self-described experiences, supported by selected quotes from the interview and information gleaned from additional sources of data when appropriate. In general, we found that despite teaching distinct courses managed by different departments, participants described the educational environment in their courses and factors that influence curricular decision-making in similar ways.

3.5.1 Purposes

All participants shared that they cared about conveying fundamental course concepts and commented on the introductory and foundational nature of the courses that they taught. They also shared that they care about ensuring that students are able to connect and apply what they learned to other contexts:

> Understanding fundamental physics is extremely important for engineers… having them sort of understand the concepts of physics that underlies a lot of engineering disciplines. (Diane, Physics)

> What I'm looking for is that they're understanding the main concepts that we're talking about, especially in these fundamental, introduction courses. If they can get just a few basic concepts down, that should support them through all the rest of their courses. (Mike, Mechanics)

Two of the four participants teaching in the external service departments expressed, however, that it can be challenging to help students make connections and ensure that their teaching is relevant to the engineering degrees students intend to pursue, because they (the participants) lack an engineering background:

> Definitely conveying the topics is my main concern, but also keeping the students interested in what I'm talking about… I also want to have the material I'm teaching somehow relevant to them, and that's something that I struggle with a little bit, because I don't have the engineering side. (Marie, Math)

3.5.2 Content and Sequence

We present content and sequence together, as all excerpts address these two elements together as well. This is in keeping with the link between content and sequence as indicated in the Academic Plan Model (Figure 3.1). Although Lattuca & Stark (2009) indicated that this link is not always evident to instructors, we found that participants narratives address both elements as a combined entity, a likely outcome of the coordinated nature of departmental course management.

Participants' descriptions indicate department-level course management for both units of analysis. Consequently, all participants shared that they followed a common syllabus and course schedule shared across multiple sections and instructors; that their students take a common time final; and that certain policies, including that of assessment, are coordinated at the department level, although to varying degrees. This indicates that departments largely determine course content and provide a common syllabus for instructors to follow, in an effort to give students a common learning experience and ensure that similar student outcomes are addressed across multiple sections and instructors:

> There is a central syllabus… assignments are chosen by the course coordinators according to the syllabus with assigned dates across all 50 sections. There's no deviating from that… even the exams are common. Not only the final, but every exam is common. (Marie, Math)

Both participants teaching physics gave a similar description to the one given by Marie above.

Coordinating course schedules and assessment policies varied by course, even within departments managing multiple courses. For example, Marie qualified that for math, instructors' autonomy varies depending on the course. The description given above is for the first course in the calculus sequence; instructors teaching the other courses, such as multivariable calculus, have a little bit more flexibility in terms of assigning homework and writing exams. For some courses, only the central syllabus and the common time final are the same across multiple sections; the instructor may then assign homework and administer other tests of their own design and choosing:

> We are given a syllabus… We do not have to exactly follow that syllabus, so we have some freedom in... structuring things a little differently. What is set is the grading structure, and they ask that you don't deviate from policies in terms of substituting exams for test grades and stuff like that. And then, the exam is a common time final that's sort of handed to you to give to your students. But there is some freedom in how you teach the

> course and how you handle the topics, but you need to cover all the topics. (Victoria, Mechanics)

3.5.3 Instructional processes

Participants shared instructional activities related to solving word problems, and caring about ensuring that students are able to apply the skills learned through these activities to other contexts:

> We're trying to help them learn how to solve problems, to think critically, to look at a situation and sort of figure out what is extraneous information, what's the most relevant to the problem, being able to apply some fundamental situation to different circumstances that might have different surface features, but realizing there's some deeper thing. (Diane, Physics)

> I will explain a concept, talk about how it relates to what we were doing last week and what we're going to do next week, then I'll relate it to a problem out of the textbook. I'll solve one and then I'll have them solve one. They can learn the concept, they can see how to apply it, and then they get some practice doing that. Then these homework problems will relate to that same topic so they get a bit of practice by themselves. (Mike, Mechanics)

Participants did not expound much on the specific activities and interactions that are going on in the classroom, a possible limitation of the interview prompts. They did, however, share some instructional activities that they would ideally like to do but find difficult, such as effectively facilitating peer interaction in class:

> One thing that I want to happen in my classes, and some semesters it happens, and some it doesn't, is having conversation between the students and interaction in the classroom… I just have found that I don't end up having them work in groups as much. You definitely give up certain things, when you get in these big classroom [class] sizes. (Marie, Math)

> I really think making students talk and learn in groups is really important for these harder concepts, because I guess it goes from the old adage, if you want to learn something, you have to teach somebody that something. If they're teaching each other, I feel it ingrains better. I don't think the course as structured right now allows for a lot of that, because there's so much content to go through. (Vanessa, Mechanics)

Diane, however, shared the approach she used to facilitate peer interaction in her class:

> I would present a question or a problem, and I would say, "Okay, work with your neighbor, see what you can do." It was me and an undergraduate learning assistant who would run around the classroom trying to help people, and that worked pretty well considering, you know, there was 150-ish students in there and just the two of us. At least by having them grouped, you know that if you can get at least one person in a group to understand what's going on, they can disseminate sort of what's happening. (Diane, Physics)

There is much more to learn from participants about the instructional processes that they implement in their courses, however, that the data was unable to address. Since this is part of an ongoing project, there are opportunities to follow up with participants to gather more information, which we will address in future work.

3.5.4 Instructional resources

Instructional resources are the "materials and settings used in the learning process" (Lattuca & Stark, 2009, p. 5). Participants all mentioned the following instructional resources available for students, to support their learning process: a common textbook, a learning management system, an online homework system, and office hours. Since the choice of learning management system is an institutional decision, the two embedded units of analysis use the same system. All participants referred to using an online homework system, but we noted that homework systems and practices varied across departments. Math and physics shared very coordinated use of the online homework system; mechanics instructors, on the other hand, can opt out of using the suggested online homework system, although all three of our participants teaching mechanics chose to use it.

Participants shared several opportunities for students to seek help, including descriptions of how their departments conduct office hours:

> You can get help outside of lecture, and that's either in my office hours, we have recitation, which is a kind of homework help resource, then they also have common office hours. (William, Physics)

> When they come in here and they work and I keep my door open. At least with the handful of students that utilized that in the fall, it was a very free experience for them to come in here and work. If they had a question, they just came in and ask. They came back out, worked some more… I try to keep a lot of office hours for that reason too, because it is a thing where you can't accommodate everybody's learning styles. Some people really

> just need that ... really to be able to sit down and show them on paper something, and it helps them. (Victoria, Mechanics)

It is interesting to note that Victoria's office is located within a larger space that includes a common area that students can use for study purposes. This is not true for the other participants.

Teaching assistants (TAs) may serve as graders, assist in class, or independently conduct office hours to ensure that students had access to help and feedback, although the function of TAs vary across departments and courses. For example, participants teaching Physics do not get grading assistance from TAs "mainly because all our tests have to be multiple choice" (William, Physics), but TAs help conduct common office hours:

> This is a service provided by the Physics department where there's a couple of TAs in a room in [building], and any introductory physics students can go there and get help. (William, Physics)

The Math department, on the other hand, assigned graders depending on class size:

> Once I got to the larger class I qualified for a grader and while it was a huge benefit in terms of time, because I didn't have that, there is obviously a little bit of a setback to that because then I'm not looking at my students' papers. (Marie, Math)

Diane and William (Physics) also mentioned using clickers in their classes:

> Most instructors I think employ at least a few clicker questions or something throughout. (Diane, Physics)

The use of student response technology, such as clickers, is a means of encouraging and facilitating student engagement in the classroom, particularly in large classes (Martyn, 2007).

Mike, however, made an interesting comment regarding clickers. Mike acknowledged the potential benefits that may be derived from using them in the classroom, especially for encouraging student engagement, but expressed concerns about cost and undue burden that requiring these tools may place on students:

> Things like clickers or these days you can go on your phone and there's various different technologies out there. Using something like that to encourage participation would be great. The only reason I don't do it in my classes is I don't want students to have to buy one more thing to have to attend this university. They have to buy laptops, they have to buy textbooks… If it's something that everybody did, I wouldn't mind doing it for my class. At least it's useful to them for their whole four years here, but I'm not going to make them buy something just for my class. If it's something that we decided to do as a department and all of the courses used it, I might be a little more interested in it. I just don’t want to make students pay for it. (Mike, Mechanics)

3.5.5 Learners

Lattuca & Stark (2009) emphasize that academic plans should include efforts to accommodate varying student goals, characteristics and abilities. In this section, we focus on participants’ descriptions of students in their classes, to get a sense of who the instructors are interacting with and how they might impact instructors’ decisions. We found that our participants' interactions with learners are closely tied with small adjustments that they make to the course throughout the semester, which we discuss in the Adjustments section.

Participants, particularly those teaching math and physics, recognized that students in their classes come from a variety of backgrounds and levels of preparedness for college in general and their courses in particular. For example, Marie mentioned that some students may already have credits for calculus 1: "They've had AP credit, they've got dual enrollment credit." But there are also students who, for a variety of reasons that include performance in the SATs and high school math GPAs, are not considered "math-ready" and would have been required to take a precalculus class, unless they are able to pass a readiness test: "Some that really want to be in engineering or math are not ready for [calculus 1] as we declare them, they don't pass their math readiness test. They would start in [precalculus]."

Participants also acknowledged that because they are teaching required fundamental courses, there may be differences in students' motivations for taking the course:

> I understand that not everybody… loves mathematics, that this is something that they have to take because their major in some other department says they have to take it, and they may love that, but they don't really love this. (Kevin, Math)

Since students who take fundamental courses usually do so in the first few academic terms of their undergraduate careers, participants also commented on how students are still going through a period of adjustment and may need guidance in learning how to learn:

> With teaching freshman classes, you know another goal I think is just to get them to learn how to be students, and get them ready for the next step… build in some assessments of

> their conceptual understanding, and have that be a valuable piece of the course, and not just doing the math and just getting a right answer… I've never been an engineering student at [institution] so I don't know, but just from my interactions with the students that I've had, I think students can feel really lost as engineering students, just because their departments are so large. At the beginning, they haven't picked their track, so it's just like they're one big mass. (Diane, Physics)

There was a dearth in excerpts specifically describing students and the current ways in which student characteristics are integrated into course planning. This may be due to limitations of the interview protocol, as well as prevailing departmental practices related to course management and coordination. For our participants, course planning, especially in terms of purposes, content, and sequence, is an exercise that seems to be beyond individual instructors' purview.

Participants did identify data on students that they wished they had access to and how they might use it to make curricular decisions:

> I guess it would be helpful to know what the students think about ... What did they respond to, what approach to learning something that they find the most helpful. Is that something that's universal across all sections or maybe just pockets of students? It would be helpful to know if there are particular concepts that they're stuck on that are sort of hindering understanding the broad concepts or being able to apply them correctly... if I find that students are responding better to having more active time in class and really even teaching them the background material or the derivations or whatever are not really that helpful at all that it might be, then I can certainly adjust my approach into focusing

more on one thing than the other. So for sure, it just changed how I focus on things, and what I spend my class time doing. (Victoria, Mechanics)

I don't know that I get a lot of data about them [students]. I mean, outside of what they're doing in my class. Obviously I know everything about how they do in my class and when I look at the tests I get an idea of what concepts they're okay with and what they're not so okay with. Other than that, from outside of the class, I get almost nothing on them. I get all kinds of personal data that I have no use for. I can log into [learning management system] and find the name and their address and their phone number and that kind of thing, and their major, but I don't know what other classes they're taking. Students will come in, there are certain prerequisites for our classes for sure, but you know, some of them will have taken other classes beyond that where they might have already covered a lot of the material. If lots of students are at that point, maybe I don't need to spend so much time on a certain topic. Obviously we don't want to leave anyone behind and not everyone will have covered that, but it would help me kind of tweak the schedule a little bit I guess. [But] I don't have things like that. I don't necessarily know what level or how they've been performing in their other classes. I don't know what their GPA is, or at least I don't think I have access to that. I mean, it's probably a good reason I don't, but if everyone in my class has a GPA of 3.8 then that tells me something about the class. If everyone is down at 2.6, maybe I need to spend more time on the fundamentals. (Mike, Mechanics)

3.5.6 Assessment & Evaluation

Assessment & evaluation refers to "strategies used to determine whether decisions about the elements of the academic plan are optimal" (Lattuca & Stark, 2009, p.5). Participants who taught physics mentioned using the Force Concept Inventory (Hestenes, Wells, & Swackhamer, 1992) for course assessment purposes:

> We do something called a Force Concept Inventory test… that helps us gauge the efficacy of the course and that helps us determine what we need to change about it. So they [students] take it at the beginning of the semester, and at the end of the semester, and we see how they improve. (William, Physics)

Participants also shared the ways they personally sought student feedback to assess the impact of instructional activities on students' learning processes:

> Periodically, not every semester, I'll do like a mid-semester survey to the students and just say, "Hey, what's working, what's not working?" and I've made changes based on those findings before. (Diane, Physics)

> Sometimes when I can sense that the students are struggling a bit, especially with certain topics just at the beginning of class, asking how did the homework go? What did you think of that? Then if they're still confused about the certain topic, taking that class to go over that topic again. (Vanessa, Mechanics)

Beyond the Force Concept Inventory, which was unique to physics, and personal attempts by participants to elicit feedback from students, we found little evidence of prevailing practices related to course assessment & evaluation that feed into decisions on adjustments to the academic plan.

The institution, however, periodically administers end-of-semester student evaluations of teaching surveys (SETs), which collects data on students' perceptions of their experiences in the course. SETs are a convenient source of institutionally-collected data on students' perceptions of the course and the educational environment, but it has been associated with issues and challenges (Marsh & Farrell, 2015). Participants comments indicate that despite the availability of this institutionally-collected assessment data, they encounter challenges with using them meaningfully and constructively for course planning:

> I don't feel like it's honestly helped me at all. My scores have been fine. I'm very happy with the scores that I get, but I get like a 30-something percent response rate… Generally, all they're saying is that I go too fast, when I'm always behind with the schedule I should be, so I don't know how much slower I can go… they're not really giving me anything constructive… I have to cover all the material, so when they're saying I'm going too fast, I don't know. (Marie, Math)

The institution allows departments to append course-specific items to SETs, and Mike (Mechanics) gave the following comments on mechanics-specific SETs data:

> We ask the students to rate their ability on how they can, or how well they understand the different topics that they wanted to cover… all of the skills that we wanted them to have, we get them to tell us how good they think they are at that skill. We have those on the [SETs]. I don't know how many people use it. I don't know even that I do a whole lot

> with it… If there's something that every single section is not coming across properly, that would be nice to know. I don't know that at the moment. That would be nice to know because then I can kind of change the schedule around and make a point to tell people we need to spend more time on this. If it's just for an individual instructor, it's not coming across well, I can use the same schedule and they hopefully will know themselves that they need to spend a little more time on it. Yeah, so like I said, we have that at the individual level. We don't have it at the group level. I'm sure it's something we could do. I don't see any reason we couldn't get that data, we just don't do it right now. (Mike, Mechanics)

Kevin (Math), on the other hand, expressed a desire to evaluate the course he taught based on students' perceptions of how the course prepared them for success in the succeeding course:

> [SETs] are collected right at the end of the semester, while they're still thinking about the course, and thinking about the final. It doesn't incorporate… I'd like to have some student-generated data on how effective was I at my goal of connecting this course to what came later. I'd like to know if I teach Linear Algebra in the fall semester, I like to hear back at the end of the spring semester, now that you've taken Differential Equations, now that you've had a semester to process this with your other classes, how successful was I at that goal? (Kevin, Math)

Participants' comments above indicate missed opportunities to leverage student-provided course assessment data productively. In the absence of course-level practices that inform adjustments-related decisions to the academic plan based on the data, it indicates a need to strengthen the link between assessment and adjustments, at least for the courses included in the study.

3.5.7 Adjustments

Participants shared that interaction with students, which generates student-based feedback in various forms, primarily inform the curricular decisions and adjustments that they make for the course:

> As I teach something on Monday, my students, there are things that they have questions about, or not sure about, and now I have to rethink what I'm going to do on Friday to incorporate that feedback…. If there is something I have attempted differently, I might ask them specifically, I would like to see your comments… That's the part that's valuable for me. I will sometimes ask them to comment on some specific aspect that I've had to change, or adapt, or something. (Kevin, Math)

> Every class is so different depending on the students that are in there. They all kind of have a different personality, and so it's purely driven by what I'm feeling like what I'm getting back from the students. If it's clear that they're not getting something, then hopefully that somehow becomes obvious to me and I work through that, but I don't really know what else to look at. It's really just driven by the things that... students that were coming in to ask. The things that they still didn't get when they walked in my office and asked for help for something... And also, just from the tests. I could clearly see which things that they got, and which things that they really didn't get that they just were not following. (Victoria, Mechanics)

Although participants mentioned making adjustments to their courses, the data did not address what these specific adjustments where, to what elements in the academic plan these adjustments were made, and how the course changed because of these changes. Most narratives imply changes to instructional activities, and mostly referred small changes to the planned activities for the day to accommodate the need to address difficulties or the need to clarify specific topics. Adjustments to the purposes, content, and sequence, for example, were not discussed; we consider this as an outcome of the close coordination implemented in the courses, which render these elements stable because planning for them is beyond individual instructors' control. The general narrative is that details and plans regarding these elements are prepared at the department and course coordinator level and given to instructors for them to follow, in an effort to provide students with common learning experiences across multiple instructors.

An interesting comment we noted related to course planning and curricular decision-making is the idea of collaborating with instructors from other departments:

> So, as a resource that I would like, like from the department from the university is maybe to afford us some time to connect with colleagues outside of the department when we're teaching a class that services other departments, to get some input from those departments on why their students are in my room. (Kevin, Math)

Kevin spoke of this suggestion as a means of getting input for planning what course topics to emphasize and what skills are critical for succeeding courses taken in other departments. Kevin also really cared about making the examples he discusses in class and the learning activities he facilitates be relevant to students' disciplines, so that they may more easily make connections between the math concepts and skills that they learned and developed in his class with how these are applied to discipline-specific contexts:

> I want them to come out of this class with a sense of understanding why their department decided that this was an important class for them to take. That, they have some confidence about how this class fits into their profession, and their field… that this isn't just a bureaucratic hoop they had to jump through. (Kevin, Math)

In particular, he asks the following questions:

> The challenge for me is that if I want to make this course meaningful, connected to the other field of study, and it's not a field of study that I know much about, I want to know enough about these other fields to get an insight as to why they made their students take a [math] class, where are they going to be using this? So, I find myself asking, what kinds of things do you cover in statics, and what kind of things do you cover in crystallography, and what other topics do you cover that cause a student to have issues with this? (Kevin, Math)

Marie (Math), Diane (Physics) and Mike (Mechanics) also shared Kevin's sentiments about the potential benefits of collaborating across departments during their interviews. Mike, in particular, commented:

> Being able to get instructors of these different courses together, usually even different departments which is probably why we don't do it, getting them together, talk about exactly what's covered, what isn't covered, what they expect, and what they don't teach as

> well, would probably make our instructors' lives a lot easier, especially the new ones coming in the first couple times they teach these courses. (Mike, Mechanics)

This idea of collaborating across departments was also discussed during a project cohort meeting and received agreement from other project participants who were not part of this study.

3.6 Discussion and Recommendations

We observed similarities across embedded units of analysis, for all elements of the Academic Plan Model, which confirm our earlier assertion that institutions may consider the suite of interacting fundamental engineering courses as a common foundational engineering curriculum within engineering curricula, at least in the context of the institution where we conducted this study. We highlight the following key findings:

1. Courses within foundational engineering curricula have a shared purpose, strive to provide a common learning experience for students, and contribute to achieving student outcomes that promote student success in succeeding discipline-specific courses, based on our participants' perspectives. We found that this shared purpose transcended current institutional structures, where departments managing the courses operated in silos. Thus, it may be beneficial to consider these courses collectively and establish an overarching governance structure focusing on students, enacted through an academic plan designed for streamlined course planning across a foundational engineering curriculum. Such a structure may facilitate the design of effective learning environments at this stage of undergraduate engineering students' academic careers.

2. The fundamental concepts and skills developed in each fundamental course are critical for success in courses within and beyond the foundational engineering curricula. Thus, fundamental engineering courses are closely related. There are opportunities for synergy across these courses that will be beneficial for instructors teaching the courses and for students' learning processes and experiences.
3. Results confirm that instructors are both critical decision-makers and stakeholders in a broader academic plan where they have limited control. Promoting continuous improvement through an overarching student-focused academic plan for a foundational engineering curriculum will benefit from engaging instructors across multiple departments as equal partners in course and curriculum planning.

3.6.1 Shared purposes, learning experiences, and outcomes: An academic plan for Foundational Engineering Curriculum

Participants' descriptions of the *purposes, content, sequence, instructional processes, instructional resources, assessment & evaluation,* and *adjustments* indicate that Academic Plan Model (Figure 3.1) elements are enacted in a similar manner across courses in the foundational curricula, and impact the same group of *learners*, despite institutional structures indicating that courses are managed in a siloed manner. Thus, it is feasible to develop a student-focused, consolidated academic plan that creates similar and streamlined educational environments and learning experiences encompassing all courses in the foundational curriculum. We found that it may be beneficial to develop both a coordinated and collaborative course planning process that: concurrently and collaboratively designs academic plans across the interacting courses in foundational curricula, managed by multiple departments; includes active participation and input from the instructors who teach these courses; and considers the goals, characteristics and abilities of the students who take these courses sequentially and/or concurrently.

Fundamental engineering courses have been described as seemingly unrelated courses that develop critical skills (Lord & Chen, 2014). Our results indicate that this notion of un-relatedness may be an outcome of the siloed management of these courses, despite their common goal of cultivating conceptual knowledge and skills, and the fact that these concepts and skills are crucial for success in other courses (Streveler et al., 2008), including those within the foundational curricula. The silo mentality for teaching and managing courses is more likely to occur in large research-intensive institutions (Alpay & Jones, 2012). It was thus important to understand prevailing teaching and learning experiences in FECs, in a "bottom-up" approach, in order to develop the appropriate course planning structure (Hammond, 2004) that will provide students with effective learning environments and positive learning experiences across FECs.

It was interesting to note how participants teaching distinct courses across multiple departments, and who have little to no opportunities for collaboration with each other, expressed similar aspirations of working together and learning from each other as they strive to facilitate meaning- and connection-making for students across their courses. The need to facilitate connections for students is supported by literature; at this stage of their academic careers, undergraduate engineers are still in need of assistance in connecting what they already know to how their knowledge and skills can be applied to new contexts (Ambrose et al., 2010). Thus, helping students make connections across courses is an important point for an instructor to consider (Sheppard et al., 2009). Some participants found it challenging to help students make connections between fundamental course concepts and applications, particularly when they need information beyond their discipline-specific backgrounds; developing a holistic academic plan by collaborating with other departments will help streamline efforts at meaning-making and transfer across courses. It also addresses the perception of disjointed but scaffolded fundamental courses by providing students with opportunities to see how the knowledge and skills developed in one course are applied in their other courses, and encouraging students to take a deeper approach to learning engineering. Furthermore, developing a holistic and integrated academic plan addressing fundamental engineering courses may serve as initial steps towards taking a networked approach to the academic preparation of engineers (Sheppard et al., 2009).

3.6.2 Opportunities for synergy across courses

There are three main considerations when engaging in course planning, as espoused by Posner & Rudnitsky (2006): *what* should be learned, *why* it should be learned, and *how* to facilitate the learning process. Instructors commonly address these considerations within their own courses. Based on our participants' narratives, we found that *what* should be learned is largely determined by the department, through course coordinators, and provided to instructors. *How* to facilitate the learning process depends on instructors' preferences and experiences (Stark, Lowther, Ryan, & Genthon, 1988); factors that influenced our participants' decisions include available instructional resources and interactions with students. Their information on *why* students need to learn is largely based on their department's discipline-specific lens and the intended learning outcomes for the course they are teaching as outlined in the common syllabus provided to them. They recognize, however, that as instructors of foundational courses, their role involves facilitating opportunities for students to develop knowledge and skills that are critical to meeting not only the learning outcomes of the courses that they are teaching, but of succeeding discipline-specific courses as well. The outcomes of succeeding discipline-specific courses, however, are usually beyond the purview of instructors teaching fundamental courses in servicing departments, particularly those external to engineering.

Shared course planning efforts across silos through a broader foundational engineering curriculum would seem to address the disconnects described by participants. For example, mechanics courses may share learning outcomes, course content, sequence, and instructional processes with math and physics, so that instructors in these servicing departments may know *what* skills are important for students to develop and *why* they need them. Sharing information on sequence (i.e., arrangement of course content) is particularly critical for co-requisite courses taught by service departments that students may concurrently take with engineering courses, to ensure that students are able to develop knowledge and skills in a timely manner. Sharing instructional processes and course material may help instructors determine *how* to facilitate learning in ways that students will find meaningful and relatable. Efforts to address the concerns raised by participants on information-sharing and collaboration across departments may lead to a more robust learning experience for students.

We also noted opportunities to share instructional resources and synergize technology-based learning tools. Through project cohort meetings and summits, participants learned about the practices and resources of the departments represented in the project, and identified best practices that may inform departmental decisions. Expanding and institutionalizing opportunities for collaboration beyond our project may maximize the use of institutional resources and streamline processes. An example related to our findings may be the use of student response systems; departments may come together and agree to using the same technology so that associated gains for students are realized across multiple courses that share similar course structures.

3.6.3 Continuous improvement in the foundational engineering curriculum: engaging instructors

Participants narratives indicate that they make critical decisions about learning activities within the confines of department-coordinated course structures. For example, comments about the "need to cover all the topics" (Victoria, Mechanics) indicate that instructors have limited flexibility when making decisions regarding instructional processes and course schedules to accommodate learners' needs. For the participants and courses included in this study, designing the academic plan consists mainly of determining the instructional processes they will implement in the course, which is in keeping with observations made in literature (Lattuca & Stark, 2009). Other elements – such as purposes, content, sequence – are stable and beyond their control. Consequently, adjustments and continuous improvement are limited to what they can feasibly implement in their day-to-day classes. We also noted missed opportunities to productively and meaningfully use data generated from institutionally-administered assessment processes in curricular decision-making and continuous improvement (e.g., student feedback from SETs).

Although course coordinators are also instructors and thus have intimate knowledge about teaching and learning experiences in the course, there are benefits to institutionalizing and consolidating course planning across fundamental engineering courses, and engaging all instructors in the process. Instructors play a critical role in providing students with positive learning environments and experiences (Pascarella & Terenzini, 2005), mainly because of close and direct interaction with students, and are well-positioned for impact. Each instructor has unique knowledge, perspectives and experiences that, when shared with colleagues, may result in best practices that benefit students in general. Facilitating opportunities for instructors across departments to participate in course planning gives them more agency and allows them to bring their unique perspectives and experiences into the decision-making process for all elements and courses included in the academic plan.

Among the advantages of using the Academic Plan Model is its “dynamic view” (Lattuca & Stark, 2009, p. 21) of course planning. The Academic Plan Model integrates assessment and adjustments to the academic plan in the planning process, shown as Path A in Figure 3.1. Participants’ narratives indicate, however, that course-level academic plans may need to strengthen the link between assessment and adjustments in the feedback loop (i.e., Path A). Assessment practices that trigger adjustments to the academic plan in general were not evident in the data, and participants indicated missed opportunities to productively use institutional and student-provided course assessment data, such as data collected through SETs. Participants shared challenges related to interpreting the data, particularly students’ perceptions of their learning experiences, as among the reasons for underutilization of SETs. This observation is in keeping with prevailing sentiments regarding SETs and their utilization, particularly with regards to qualitative responses (Marsh & Farrell, 2015). Addressing the findings of course assessment processes, however, is not an easy and straightforward task, and instructors can benefit from institutional support in making sense of the data (Marsh & Farrell, 2015). A collaborative and consolidated academic plan, overseen by a designated overall coordinator, may ensure that assessment processes are conducted and used productively, and identify the appropriate support services and resources to facilitate change.

3.7 Implications

Findings from this study highlight the need for instructors to be more actively engaged in departmental course planning and management processes, as well as collaboration across departments managing interacting fundamental courses. An implication for practice at the department level is to facilitate these opportunities for instructors, acknowledging that fundamental engineering courses function as a network of interacting courses, and allowing instructors to collaborate when planning learning activities and align course coverage according to the needs of succeeding courses. The institution may consider exploring what organizational structures and resources are needed, as well as identify possible constraints, to develop an overarching governance structure for coordinated course planning across fundamental engineering courses managed by different departments. This approach of acknowledging the networked nature of fundamental engineering courses is in keeping with recommendations for the academic preparation of engineers offered by Sheppard and colleagues (2009).

3.8 Opportunities for future work

Our results indicate that it is beneficial to consider the suite of fundamental engineering courses as a common foundational engineering curriculum. We determined that it may be beneficial to develop a student-focused, collaborative, and holistic academic plan that encompasses all courses in the foundational curriculum and engages instructors across multiple departments as equal partners in the planning process. We presented the foundational engineering mechanics curriculum as a model, but acknowledge that there are other foundational curricula, determined by the engineering programs that require them, such as the suite of fundamental thermal sciences courses and the suite of fundamental circuits courses. The institution where we conducted this study may use our work as impetus for conversations towards identifying and setting up an entity to develop, enact, and facilitate collaboration among stakeholders through an academic plan for foundational engineering curricula.

Inherent limitations in our data present opportunities for future work within the project and to build upon the findings of this study. We intend to conduct follow-up interviews with our participants to further expound on our observations and further substantiate our assertions, particularly in terms of instructional processes, assessment & evaluation, and adjustments. We share proposed prompts for this follow-up interview in Appendix C.

We have initiated opportunities for collaboration among instructors teaching in multiple departments through our project, and will continue to facilitate similar opportunities for the duration of the project. We will also disseminate our findings from this study, as well as from other research activities, to department administrators (e.g., department heads) and other stakeholders at the institution where we conducted our study to provide evidence-based recommendations that may be infused into decision-making processes. It will also serve as impetus for discourse regarding leveraging evidence-based recommendations and institutional data for continuous improvement in undergraduate engineering.

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Chapter 4: Manuscript 3

Amplifying students' voices: Analyzing qualitative data in student evaluations of teaching to integrate student feedback into course planning
Target Journal: Assessment & Evaluation in Higher Education

4.1 Abstract

Institutions routinely collect student perceptions of their learning experiences through comments in end-of-semester student evaluations of teaching (SETs). Student comments, however, are often not used by instructors because of challenges related to interpretation and analysis. We performed qualitative content analysis on 1,325 responses to open-ended SETs items, applying the Academic Plan Model as an organizing framework, to explore ways to constructively interpret student comments and facilitate the meaningful use of student comments in course planning. We found that student comments provide useful information for course planning, particularly about instructional processes and faculty characteristics that contribute to (or hinder) positive learning experiences. Instances of contradictory and dissonant comments, however, underscore the need to provide instructors with support and resources to make sense of the data and mitigate challenges. We found that using a framework such as the Academic Plan Model facilitates a structured analysis process to examine data more meaningfully. We acknowledge, however, that the substantial amount of time required to manually analyze qualitative data is an impediment to providing instructors with meaningful input derived from students' comments in a timely manner. To address this concern, we recommend using our work to explore opportunities to automate the qualitative analysis of student comments in SETs.

Keywords: *student evaluations of teaching, content analysis, continuous improvement, higher education*

4.2 Introduction

Students are essential to curriculum planning and design (Lattuca & Stark, 2009), and it is important to consider students' perceptions about their learning experiences as input for continuous improvement in the educational environment. Institutions have collected data on student perceptions of learning experiences through end-of-semester student evaluations of teaching (SETs) since the 1920s (Marsh, 1987; Remmers, 1927; Wachtel, 1998). Evaluation instruments typically consist of survey items that ask students to numerically rate the course and the instructor, as well as provide written feedback via open-ended questions (Marsh, 1987; Sproule, 2000).

In some studies, student evaluations have been described as valid and reliable (Marsh, 1987; Wright & Jenkins-Guarnieri, 2012), and quantitative student ratings are commonly used by institutions as a measure of teaching effectiveness when reviewing faculty performance (Chen & Hoshower, 2003; Williams & Ceci, 1997; Zabaleta, 2007). However, issues such as usability, gender bias, and attributional bias in SETs have also been raised (Gigliotti & Buchtel, 1990; MacNell, 2015; P. Stark & Freishtat, 2014), calling their validity and reliability into question. Researchers have been critical about basing administrative decisions on hiring, salary, promotion, and tenure on student ratings (Hornstein, 2017; Zabaleta, 2007), including those who consider student evaluations as valid and reliable instruments when developed appropriately (e.g., Aleamoni, 1987). In the engineering education context, instructors have lamented that student ratings may not be accurate indicators of teaching quality, and may be used inappropriately against them (Kerst, Pfershy, DeMonbrun, & Finelli, 2017; Turns, Eliot, Neal, & Linse, 2007).

Although the validity and reliability of student ratings in teaching evaluations may be debatable, students' comments provide authentic routinely-collected information about their learning experience and environment (Stark & Freishtat, 2014; Stewart, Goodson, Miertschin, & Faulkenberry, 2005). Furthermore, literature indicates that students are motivated to participate in teaching evaluations by the opportunity to contribute to improving teaching, course content, and format (Chen & Hoshower, 2003; Giesey, Chen, & Hoshower, 2004) or to share their perceptions about their learning experiences in the class (Hoel & Dahl, 2019). Students are less motivated by the impact that their ratings have on tenure, promotion, and salary decisions (Giesey et al., 2004; Spencer & Schmelkin, 2002), but a number of institutions primarily use student ratings for this purpose (Abrami, d'Apollonia, & Rosenfield, 2007; Hornstein, 2017). This suggests a disconnect between *why* students engage in the teaching evaluation process and *how* institutions use the data that they provide. It also indicates that institutions are missing the opportunity to leverage institutional data for purposes aligned with students motivation to engage in the evaluation process–to catalyze change in teaching practice and improve the learning experience.

In the spirit of leveraging institutional data for continuous improvement in the educational environment, researchers recommend examining narratives in student evaluations to gain insight into the student learning experience (Abrami et al., 2007; Hornstein, 2017; P. Stark & Freishtat, 2014), going beyond looking at "student-reported numbers" (Hornstein, 2017, p.5) . Our study used SETs to infer students' descriptions of their learning experience in fundamental engineering courses in a large Research 1 (R1) institution. We chose this context as the focus for investigation because literature has associated educational environments in these courses and institution type with unproductive learning experiences and challenges to both instructors and students (e.g., diminished ability to provide and receive timely, meaningful feedback and develop meaningful mentoring relationships; grade penalties) (Matz et al., 2017; Seymour & Hewitt, 1997; Soledad & Grohs, 2016). This study examined comments made through open-ended questions in SETs using content analysis (Hsieh & Shannon, 2005; Krippendorff, 2004), guided by the Academic Plan Model (APM) (Lattuca & Stark, 2009), to answer the following research questions:

1. How do engineering students describe the *student learning experience and educational environment* in *institutionally-collected data on student evaluations of teaching (SET)* of fundamental engineering course at a large Research 1 (R1) institution?
2. What *opportunities for continuous improvement* arise from descriptions of student learning experiences and environments in institutionally-collected SET data at a large R1 institution?

By exploring these research questions, we offer a way to analyze, present, and explore opportunities to leverage institutionally-collected and student-provided qualitative data, so that decision-making and continuous improvement processes impacting students' learning experiences and environments may use them meaningfully.

4.3 Perspectives from literature

4.3.1 Qualitative analysis of open-ended responses to student evaluations of teaching

Student comments in response to open-ended questions are a formal and institutionalized means for students to express their thoughts about their learning experience in the class, and to make these observations known to the instructor (Stark & Freishtat, 2014). However, there are fewer efforts to meaningfully examine student comments in SETs, both for research purposes and as part of institutional practice. Attempts to analyze student comments underscore the value that these data have to offer, especially in terms of input for formative evaluation (Braskamp, Ory, & Pieper, 1981; Supiano, 2017). In general, students are willing to meaningfully engage in the evaluation process (Ahmadi, Helms, & Raiszadeh, 2001), consider it important (Spencer & Schmelkin, 2002), and are the best source of information regarding their experience (Stark & Freishtat, 2014). They view participation in SETs as opportunities to provide feedback on the learning environment (Chen & Hoshower, 2003; Hoel & Dahl, 2019). However, studies also found that students doubt whether instructors and administrators value and actually use their feedback to effect change (e.g., Brown, 2008; Spencer & Schmelkin, 2002). There may be basis for this skepticism–instructors consider students' comments as "useful diagnostic information for making course changes" (Ory & Braskamp, 1981, p. 281), but expressed difficulty in interpreting feedback and using them productively (Caudill, 2002). This challenge, along with biases regarding the ability of students to evaluate pedagogy (Stark & Freishtat, 2014), may result in a tendency to pay less attention to student comments. This study will address the underutilization of student-provided institutional data, and curb skepticism over the value placed by institutions on student feedback by focusing on written comments in SETs.

4.3.2 Leveraging institutional data for decisions affecting the educational environment

The issue of underutilization of data may lie in attitudes towards the use of data for decision-making in academic contexts and the way they are presented to instructors. Data are playing less significant roles than expected in decisions regarding the educational environment (Knight, 2018; Lattuca, Terenzini, Litzinger, & Walser, 2008). In the case of data from SETs, the difficulty of interpreting both ratings and comments in a meaningful way is a barrier to their effective use (Caudill, 2002; Marsh & Farrell, 2015). For example, at the institution included in this study, instructors receive responses to open-ended items in SETs as a list of comments. When presented that way, there may be a tendency for instructors to focus on a few specific responses (e.g., "The instructor was terrible") (Caudill, 2002), while instructors of large classes or multiple sections may find the amount of data too overwhelming to process and use in a meaningful way. Institutions are encouraged to go beyond simply generating results and provide instructors with the necessary support to help them make sense of the data (Marsh & Farrell, 2015). This may be accomplished through consultations with experienced peers or experts on understanding prevailing contexts in the educational environment and identifying teaching strategies that are appropriate in that context (Daly, Finelli, Al-Khafaji, & Neubauer, 2012; Kerst et al., 2017; Stewart et al., 2005). McKeachie & Kaplan (1996) emphasized the importance of intentionally and meaningfully using data from SETs to improve practice, describing it as an institution's ethical responsibility: "our failure to ensure that student ratings are used *effectively* is an ethical breach" (p. 7).

Using an established framework will facilitate qualitative analysis of SETs comments (Creswell, 2014). The Academic Plan Model provides a comprehensive view of the educational environment and recognizes that students play a crucial role in this environment (Lattuca & Stark, 2009). An adapted version of the model (Figure 4.1) presents the elements that interact and comprise the educational environment, as well as factors that influence curricular decisions. It also shows a path for evaluation and adjustment (Feedback Loop, Fig 4.1), indicating feedback loops for continuous improvement (Lattuca & Stark, 2009). APM has informed prior work that investigated students' learning experiences and instructors' curricular decision-making processes (e.g., Knight, Cameron, Hadgraft, & Reidsema, 2016; Knight et al., 2012). Thus, it is a useful framework for analysis in this study, and for presenting SETs comments to instructors in more structured, constructive, and useful formats that may serve as input for decision-making processes that impact student learning experiences.

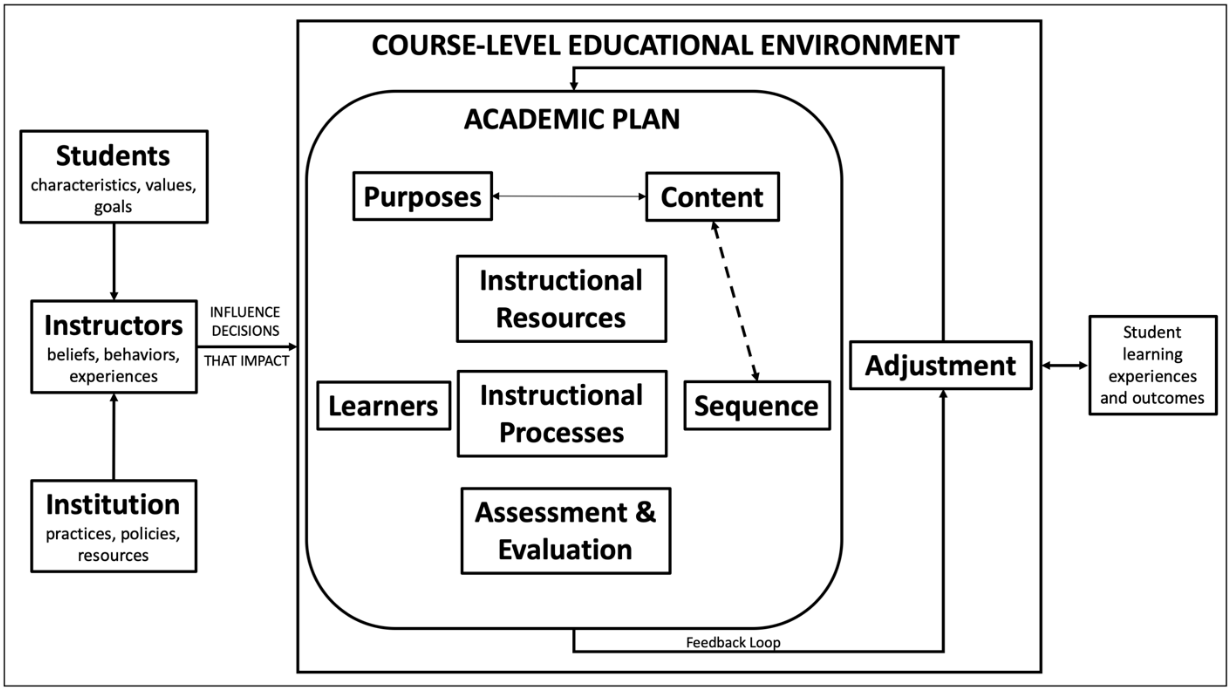

Figure 4.1. Adapted from The Academic Plan Model (Lattuca & Stark, 2009)

4.4 Methods

4.4.1 Research Design

The study examined responses to open-ended items in SETs in a R1 institution, to present how students describe their learning experience and environment in fundamental engineering courses. It utilized institutionally-collected data to understand the student experience and facilitate productive use of the data for decision-making as part of curriculum planning.

The study used qualitative content analysis due to the nature of the data and the purpose of analysis. Content analysis "provides a systematic and objective means to make valid inferences from verbal, visual, or written data in order to describe and quantify specific phenomena," and "is concerned with meanings, intentions, consequences and context" (Downe-Wamboldt, 1992, p. 314). It has been used in prior studies that examine written comments in student evaluations of teaching (e.g., Braskamp et al., 1981; Caudill, 2002).

Directed content analysis (Hsieh & Shannon, 2005) is appropriate for this study because analysis is anchored on the Academic Plan Model (Lattuca & Stark, 2009b), a framework that provides context for the educational environment where learning experiences are formed–the focus of the research question. Directed content analysis uses existing theory to focus the research question and identify initial coding categories, and its outcome may contribute further knowledge on the theoretical framework and how it is enacted in a specific context (Hsieh & Shannon, 2005). In exploring the research question through APM, we present student experiences according to elements of the academic plan.

4.4.1 Description of the Data

The dataset used in this study consists of responses to SETs at a large R1 institution (3,927 unique responses from 1,265 respondents) from two academic years (2014-15, 2015-16) and the following courses in the Mechanics sequence of fundamental engineering courses: Statics, Dynamics, and Strength of Materials. We chose this sequence because a significant number of engineering majors offered at the institution we studied (57%) require their students to take these fundamental courses. Thus, there is an opportunity to learn about the experiences of a significant number of engineering students at the institution. Furthermore, each of the identified courses develop crucial skills and competencies for courses within and after the sequence, making them critical to student success in succeeding courses.

We analyzed a stratified random sample of 1,325 unique responses from 452 respondents, from two consecutive regular semesters (Fall 2014, Spring 2015), and focused on responses to open-ended questions (Table 4.1). We employed stratified random sampling (Krathwohl, 1993) to ensure that all sections of Statics, Dynamics, and Strength of Materials taught in Fall 2014 and Spring 2015 were represented in the sample analyzed.

Table 4.1. Items included in analysis

What did the instructor do that most helped in your learning?
What could you have done to be a better learner?
Please add any additional comments regarding the course and/or instructor
Please add any comments about the physical environment here

4.4.2 Data Analysis

The Academic Plan Model (Lattuca & Stark, 2009) guided data analysis. The framework provided context for how the educational environment is shaped. Academic plans may be developed for different levels in an institution (e.g., course, degree program, college) (Lattuca & Stark, 2009); this study focused on academic plans at the course level and across multiple interacting courses. Furthermore, it focused primarily on examining student-provided institutional data on their learning experience and environment, so that student feedback may be infused into decision-making processes for adjusting the academic plan (Feedback Loop, Fig. 4.1).

Content analysis drew inferences from students' responses about the educational environment in the courses included in the study (Krippendorff, 2004). The unit of analysis was individual responses to the open-ended questions. We examined each response based on how they align with descriptions of the elements of an academic plan, as indicated in APM (Table 4.2). Preparing a provisional list of labels is the preferred method of conducting the early stages of qualitative analysis (Miles & Huberman, 1994). APM elements served as provisional categories for systematically classifying responses and deriving contextual meaning from each cluster of responses (Hsieh & Shannon, 2005). Although one would expect constructs to align with specific questions, this was not true for this dataset. Because we conducted secondary analysis on existing data, prompts were not designed to explicitly yield responses for the APM elements that guide this study. The nature of open-ended items also meant that respondents have flexibility with their answers, and we observed that prompts elicited responses that aligned with varying APM elements even if these elements did not intuitively align with the prompts.

Table 4.2 Elements of the Academic Plan Model

Element	**Description**
Purposes	Consists of the knowledge, skills and attitudes to be learned
Content	The subject matter selected to convey specific knowledge, skills and attitudes
Sequence	The arrangement of subject matter and experiences towards achieving specific outcomes for learners
Learners	The group of students with unique characteristics, goals and abilities who need to develop knowledge, skills and attitudes to meet learning outcomes
Instructional processes	The instructional activities by which learning may be achieved
Instructional resources	The materials, technologies settings used in the learning process
Evaluation	The strategies used to determine whether decisions about elements of the academic plan are optimal
Adjustments	Enhancements to the academic plan based on experience and evaluation

The analysis process consisted of two phases. First, we classified responses using provisional categories based on APM elements (Table 4.2). Using open-ended coding techniques (Saldana, 2016), we also assigned descriptive labels to meaningful excerpts to further describe the categorized data. Sometimes, we found several meaningful excerpts within a response and coded those accordingly. We also distinguished between statements of praise or critique, and indicate this distinction in our results.

Second, we examined labels and responses within categories, drawing inferences regarding the students' descriptions of their experiences and related these inferences to literature. We observed that a significant proportion of meaningful excerpts consisted of perceptions of faculty characteristics, identified in APM as an internal influence on the educational environment (Figure 4.1). We decided to add faculty characteristics as a category because we observed that the meaningful excerpts closely tied faculty characteristics with respondents' perceptions of the quality of their educational experience in the course, a connection supported by literature (McKeachie, 2007). We thus accounted for responses that could not be classified under the provisional categories, in keeping with directed content analysis techniques (Hsieh & Shannon, 2005).

4.4.3 Limitations and Research Quality

With content analysis, it is important to acknowledge that there are inherent limitations in the data (Krippendorff, 2004). In this study, the fact that we analyzed data that consists of short, written responses to open-ended questions indicates that the data will be unable to provide the same depth as interviews and focus group discussions, where there are opportunities to engage and follow-up with participants (Bengtsson, 2016). Despite these limitations, the data for this study is able to provide insights from a significant number of participants that would be difficult to manage through interviews and focus groups, with virtually no time spent on data collection. It also provides an opportunity to productively use institutionally-collected data as recommended in literature (McKeachie & Kaplan, 1996), and if procedures could be efficiently routinized, it could suggest future institutional practices to drive continuous improvement from SETs.

Data analysis was the sole responsibility of the first author. To ensure trustworthiness of research findings, the researcher kept detailed notes on provisional and open-coding decisions to create an audit trail and establish dependability, and facilitate peer examination and an external audit of findings and interpretations derived from analysis (Leydens et al., 2004). A project team member familiar with the data and an external auditor who is engaged in educational research but is not part of the project team examined the results of analysis.

4.5 Results

This study sought to describe the educational environment and student learning experiences in fundamental undergraduate engineering courses using institutionally-collected SETs data. Respondents mostly provided descriptions of instructional processes implemented in their courses and their perceptions of characteristics that describe their instructors. They also commented on instructional resources they had access to and provided perceptions of how they can improve as learners. In general, statements of praise outnumbered critiques on instructional processes, faculty characteristics, and instructional resources. Respondents' (learners) self-described learning behaviors were mostly critiques, which we attribute to the structure of the prompt (What could you have done to be a better learner?); we focus our discussion of results, however, on their learning experiences and environments because such information can more readily inform curricular decision-making processes. There were very few descriptions related to purposes, sequence, content and adjustments, and none on evaluation, a limitation posed by the prompts that guided students' responses.

In presenting our results, we provide representative excerpts for salient categories and codes that we identified. Appendix D shows salient codes in each category, and their corresponding descriptions. After each excerpt, we indicate the respondent identifier and the instructor identifier for the course to provide context for the response. The first three symbols in the respondent identifier refer to the semester when the respondent gave the response (F14–Fall 2014, S15–Spring 2015). We italicize key findings from the analysis process, which we expound further in the Discussion section.

4.5.1 Instructional processes

Respondents praised instructional processes that demonstrate structures and processes to solve work-out problems, and employed scaffolding techniques:

> handwritten book homework problems were ideal for this class - it made me more focused on learning the material correctly rather than just finding the right number to plug in… (F14_213, Instructor E)

> I loved that we did review problems at the beginning of the class to refresh our memory of what we did last class. Very helpful. (S15_127, Instructor A)

Respondents were critical of strategies that they perceived as deviating from their preferences or expectations:

If he could focus more on using what we have learned in class and how to apply it, that would have helped me out a lot more. Seeing how to get numbers and data and where to put them into the equations helps me a lot more than seeing the derivation of the equations or general forms of equations with only variables and no numbers. (F14_178, Instructor E)

Respondents were also critical of some assessment practices implemented in the course:

I think it is unfair to have such a large portion of our tests be graded without partial credit. Some questions it is reasonable… However, later on like during test 3 and 4, most of the no partial credit questions required a lot of steps. Making a mistake leads to the wrong answer even though a student may have done say half of the work correctly. (F14_70, Instructor D)

The testing approach… was a bit ridiculous. It covered material that we were learning the week of the test and they almost always fell at the end of a week where at least 2 other classes would have tests. (S15_148, Instructor A)

The class structure is set through the department, which is completely ineffective. Students stress about grades much more than they need to based on the "all or nothing" mentality with tests representing 85% of the grade. It is college, and that is the way the cookie crumbles, but I feel like there are plenty of other ways to assess knowledge other than this sort of class structure. (S15_125, Instructor A)

Some comments on assessment practices acknowledge that certain class policies and procedures are determined at the department level and beyond the control of the instructor, but not all responses do. The same holds true for some comments on pre-determined course schedules, coverage and timeline, as well as teaching loads; we share results on these topics in succeeding sections on faculty characteristics and content. Mechanics courses at this institution follow a common syllabus, coordinated assessment schedules and practices, and a common time final (Soledad, Murzi, & Grohs, 2019). These critiques from respondents imply *systemic issues beyond instructors' control* that may impact students' perceptions of their learning experiences, and, consequently, how they respond to SETs.

In looking across comments within codes, we noted *dissonant comments*–inconsistencies with statements of praise and critique–for certain professors. For example, respondents in the same section gave conflicting observations for Instructor F:

> Seldom did he offer examples and actually worked through the problems with the class. (F14_316, Instructor F)

> Professor F is BRILLIANT. He worked a lot of examples in class which is exactly how I learn. He would go through every step so you had a really good understanding of every step. (F14_321, Instructor F)

We also observed *disagreements between instructors' use of evidence-based learning strategies and students' perceptions of their effectiveness in the learning process*. Instructor A, for example, received several critiques from students for demonstrating only the first half of the solution to some problems:

> I would find it helpful if you fully finished in class problems. Or if not finishing in class, giving the numerical answer so I could work it out on my own time as a exercise. While

> the setup of some of the more complex problems is helpful, I find completely solving one to be more beneficial. (F14_262, Instructor A)

However, this is a valid technique that combines cognitive modeling (Zimmerman, 2013) with utilizing the zone of proximal development (Vygotsky, 1978). The conflict indicates challenges with realizing intended outcomes for evidence-based strategies that influence students' perceptions of learning strategies implemented in the class.

Respondents provided significantly more praises than critiques in general, although this was not collectively true at the instructor level. We did not see discernable patterns between the mean rating for overall effectiveness and the ratio of praises to critiques received by instructors (Figure 4.2). The number of praises received by instructors may be a limitation of the open-ended item; the prompt (What did the instructor do that most helped in your learning?) uses a positive tone, which may also trigger a positive response from respondents. We noted that most critiques were expressed in the prompt 'Please add any additional comments regarding the course and/or instructor here,' which had a more neutral tone. The praise-to-critique ratio may also be a limitation of the profile of students who choose to participate in SETs; average response rates (30%) indicate that perspectives represented in the dataset do not constitute majority of the total number of students enrolled in each class.

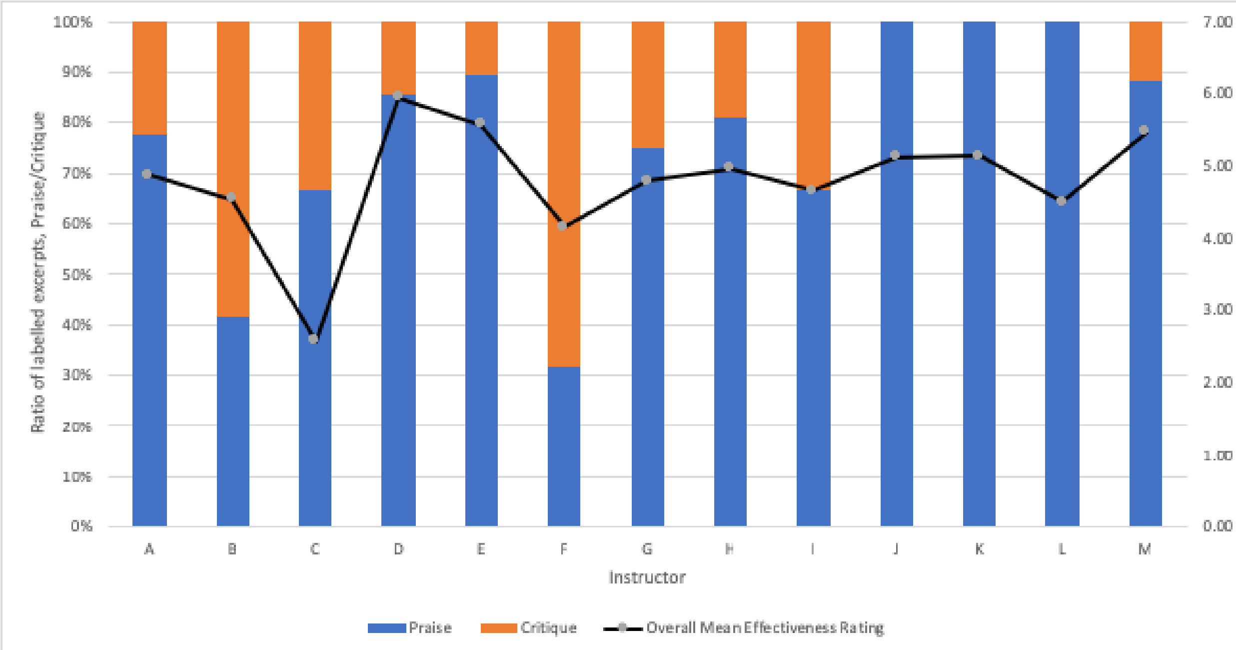

Figure 4.2 Qualitative and Quantitative Data, Instructional Processes

4.5.2 Faculty characteristics

Among the key characteristics that garnered student praise was faculty availability and approachability:

> He made himself more pear [peer] oriented toward students, which made it easier to approach him with questions you would otherwise feel stupid for asking. (F14_136, Instructor A)

> Instructor D is truly dedicated to teaching and makes sure students questions never go unanswered. He is the most respectful teacher I have had at [Institution] and I have come to him with questions from other classes and he has always been willing to help. (S15_55, Instructor D)

Similarly-coded responses included instructor's perceived approachability, willingness to help, and general perceptions about positive qualities (e.g., 'effective,' 'easy to understand,' 'taught extremely well'). The tone with which respondents gave praises on instructors' availability and approachability traits implied that instructors who possessed these traits had a good impact on respondents' learning experiences. In contrast, critiques that indicated traits that gave an impression of unavailability and unapproachability imply less-than-ideal learning experiences, some of which affect persistence:

> When I went into office hours, he just stared at me asking how I did not understand how to solve the problems… As a result of his poor teaching abilities and condescending attitude towards myself and the class as a whole, I had to withdraw from the course. I refuse to ever have him for any class again. (F14_253, Instructor C)

Although not pervasive in the sample, we found comments on the teaching vs research focus of instructors interesting. On one end, some respondents highlighted and appreciated the fact that their instructor was a teaching-focused faculty:

> Being an instructor as his primary role at the university, his office hours are comprehensive, and he is always available to answer questions and provide assistance. (F14_65, Instructor D)

> I'm really happy I got him as a professor. He's super easy to talk to and is always in his office since he doesn't do research. (F14_180, Instructor E)

In contrast, a respondent critiqued an instructor's focus on research, something that the instructor apparently expressed in class:

> The professor said we could not come to him with questions since he was not hired to teach this class but for research. He was not opened [open] to answer questions and went over material when the hw was due the next day. (F14_261, Instructor B)

Although this was a unique comment in the sample analyzed, a search of the complete dataset yielded five more comments of a similar nature for Instructor B. These comments imply *systemic issues* arising from responsibilities and expectations that instructors face. Tenure and promotion guidelines at R1 institutions may perpetuate perceptions about the value of research vs teaching that influence the decisions that instructors make in their classes. These decisions may then impact students' perceptions of their learning experiences and responses to SETs.

We found that comments on faculty characteristics align with those given for instructional processes in that respondents are more likely to praise and express preference for behaviors that help them succeed in the course.

4.5.3 Instructional resources

Due to the nature of the open-ended item that will most likely elicit responses on instructional resources (Please add comments on the physical environment here) and the prompt for the Likert-type survey item (How would you rate the physical environment in which you took this class based upon your ability to see, hear, and participate?), responses focused mainly on comments on the physical classroom environment (general perceptions, classroom size, acoustics, thermal comfort, visibility, and technology available in the classroom). We observed that the open-ended item for physical environment has the lowest response rate (average of 11% across instructors and semesters) among the four open-ended items. While analysis revealed interesting comments, it is challenging to understand the physical environment solely using existing data; however, collecting data through other means (e.g., visiting the classroom, conducting classroom observations) is outside the scope of this study.

We noted an interesting cluster of responses critiquing the physical environment that was unique to a specific instructor: the availability of seats in class. Respondents lamented about having to make do with attending class without the benefit of proper seating:

> Nearly every day the seats were full. Students from other statics classes frequently attended Dr. D's lecture, so there were no seats left for his students to sit in on many days. (F14_8, Instructor D)

> Most of the time, seats would be full as a result of students in different classes attending this lecture. I have had to sit on the floor during a class where I was on time. (F14_23, Instructor D)

While these were technically comments on students' experiences in the physical environment, the underlying cause may warrant a look into *systemic issues* related to classroom & departmental policies and ensuring similar positive learning experiences for students across sections.

Instructional resources, though, constitute more than just the physical environment. The most commonly-mentioned resource other than physical environment, mentioned by 141 of the 452 respondents, is the availability of office hours, with students generally praising instructors who devote a significant amount of time to accommodate students through this resource:

> He always has office hours that are open for anyone. If I was stuck on a problem or concept he always was willing to help me until I understood. (F14_32, Instructor D)

Comments on office hours are in keeping with observations made in other categories: students value instructional resources that contribute to their success.

4.5.4 Purposes, Content, Sequence and Adjustments

Some respondents expressed perceptions regarding the purpose, content, and sequence of the course, and adjustments made. There were fewer comments of this nature in the sample, but we noted some interesting perspectives.

Most comments related to content and sequence were critiques, such as:

> Lots of material to cover and very easy to get lost (F14_229, Instructor G)
> If the test average is an F, then something is wrong with the course not the teaching. (F14_96, Instructor A)

> Homework assignments should be due after material has been discussed in class. Since some homework assignments were due before, homework completion took much longer than it should have. (F14_223, Instructor G)

> The only thing I would change about the course would be to possibly go more quickly through some of the earlier material on point problems so that more time could be devoted to rigid body analysis at the end. (F14_228, Instructor G)

Some respondents shared how instructors made adjustments while teaching the course:

> He treats his students like equals, listens to feedback, and immediately changes whatever needs to be in response to that feedback. (F_142, Instructor A)

An interesting comment related to adjustments to the course acknowledged the efforts made by the instructor to adjust based on student feedback, but also expressed perceptions about limitations that their instructor faced in managing the course:

> Did the best he could given his limited flexibility to teach the class. I think he would have had more success if given more control to teach the class according to in-class feedback. (F14_99, Instructor A)

Comments clustered around purposes, content, sequence and adjustments also indicate importance placed by students on qualities that contribute to their success in the course.

4.6 Discussion

Our analysis indicated that students mostly described their student learning experience and educational environment in qualitative responses to institutionally-collected SETs data by sharing descriptions of instructional processes implemented in the course and their perceptions of faculty characteristics shown by their instructors (RQ1), although we were able to categorize responses under seven of the eight APM elements (Figure 4.1). Having a framework allowed us to think meaningfully across responses, with an eye for integrating student feedback into course planning and continuous improvement processes. For this study, APM provided a structure for clustering responses and a way to examine responses in a more intentional manner.

Based on our analysis, students found the following instructional processes and faculty characteristics important to their learning experience: the learning strategies used by instructors that students felt set them up for success in the course, and the availability and approachability of instructors. These are in keeping with findings from previous work on students' perceptions of classroom practices that promote success (Daly et al., 2012).

However, we found instances where instructors implement theoretically-supported strategies, but responses indicate disagreements between instructors' strategies and students' perceptions of the impact of these strategies to their learning process. We also noted dissonant comments given to instructors and systemic issues that arose in the open-ended feedback. Both of these observations underscore the need to provide instructors with support and resources to process and understand students' comments, so that instructors may productively use student feedback for course planning.

Overall, responses provided insight into students' perceptions of instructional strategies and behaviors that foster positive learning experiences, especially when compared against the quantitative ratings given alongside the comments. Institutionalizing the analysis of qualitative SETs data facilitates *opportunities for continuous improvement* (RQ2) by amplifying students' voices and closing the feedback loop in course-academic plans. It also bridges the gap between how institutions use SETs and why students engage in course evaluation processes. We expound on these opportunities in the Future Work section.

4.6.1 Understanding and interpreting students' perceptions of teaching

Although responses provide useful information for course planning purposes, it was evident in our examination of students' responses that an additional layer of analysis beyond reading through comments is necessary to use the data purposefully and meaningfully. Instances of disagreements between instructors' use of evidence-based learning strategies and students' perceptions of the strategies' effectiveness, as well as conflicting comments, mean that instructors cannot interpret comments at face value at all times. To be more helpful, the possible underlying triggers for the responses should be determined, by consulting prior work and literature, to provide meaning and context to the perceptions expressed by students and address them accordingly. This corroborates prior work that advocate for faculty support to understand and interpret the SETs data (Marsh & Farrell, 2015).

Disagreements between instructors' use of evidence-based learning strategies and students' perceptions of their effectiveness in the learning process indicate: a) that students may need some orientation about the purpose of the strategy; b) that students may need general guidance about metacognitive and self-regulated learning strategies; and c) a need for further examination on how the instructor implemented the strategies in the classroom. Students have been found to be resistant to strategies anchored upon self-regulated learning (Prince & Felder, 2006), a phenomenon that has been found to be more likely to occur in R1 institutions (Pike, et al, 2006); classroom observations and consultations between instructors and instructional consultants are a great way to confirm the effective implementation of strategies, determine areas for support and improvement, and mitigate challenges related to student resistance to innovative, evidence-based learning strategies.

4.6.2 Dissonant comments and systemic issues beyond instructors' control

Some instructors received dissonant comments. When conflicting perceptions arise among a list of SETs comments, there may be a tendency for the instructor to fixate on either just the praise or the critique (Caudill, 2002), which can then result in non-action or frustration. Dissonant comments also indicate a need for orienting students on how instructional strategies positively contribute to their learning experience; enhanced guidance on self-regulated learning strategies among students; and support for instructors on implementing effective learning strategies in the classroom through faculty development programs and working with instructional consultants, as discussed in the preceding section. Occurrences of dissonant comments highlight the importance of adding a layer of analysis to qualitative comments to help instructors make sense of the data and use it productively (Marsh & Farrell, 2015).

We also noted systemic issues beyond instructors' control that surfaced from course-level feedback. These include comments that are results of coordinated assessment practices; pre-determined course schedules, coverage and timeline; and teaching vs. research loads. These factors affect instructors' agency and flexibility in the course planning and decision-making processes, leading to compromises that may not align with the instructors' personal goals for facilitating learning. It was interesting to note that despite perceptions of lack of student ability to assess teaching (Stark & Freishtat, 2014), we noted comments from respondents that acknowledged situations that were beyond the instructor's control. Despite this observation, we find that instructors may be disproportionately critiqued because of students' general frustration as a result of systemic issues. It is thus important to understand the constraints instructors face and their impact on how students rate instructors, considering the institutional use for quantitative ratings generated through SETs: as a measure of teaching effectiveness and basis for hiring, tenure and promotion decisions.

4.7 Implications and Future Work

4.7.1 Opportunities to leverage SETs data for continuous improvement

The analysis conducted by this study can help instructors and departments recognize and understand systemic issues for a particular course–and formulate strategies to mitigate these concerns–by helping instructors make sense of qualitative SETs data. Instructors and key decision-makers may use the results of such an analysis as impetus for systemic changes at the course level and developing programs that support faculty in implementing productive and effective learning strategies.

Faculty development programs are particularly interesting as they are also an approach towards addressing inconsistencies between instructor strategies and students' perceptions of how their instructors' teaching strategies impact their learning process. A study conducted at the University of Michigan found that instructors who participated in a faculty development program that sought to mitigate barriers to the adoption of active learning strategies in the classroom saw improvements in their quantitative ratings in SETs over time (DeMonbrun, Kerst, Pfershy, & Finelli, 2018). The program included discussions on implementations strategies, managing large classes, and student motivation, among others, facilitated by instructional consultants (Finelli & Millunchick, 2013). Such a program, conducted alongside efforts to educate students on self-regulated and effective learning strategies (e.g., Cunningham, Matusovich, Hunter, & McCord, 2015), may help instructors take proactive steps towards bridging the gap between the strategies that they implement in the classroom and how students perceive their efforts to facilitate learning (Finelli, Daly, & Richardson, 2014). Institutions may benefit from adopting similar programs, in addition to productively using student perceptions provided in SETs.

An implication for institutional practice as a result of this study is to examine the current SET instrument to ensure that prompts will elicit helpful responses for course planning and continuous improvement purposes. The findings of this study may be used as impetus for re-writing, re-structuring, or adding prompts to the current SET instrument used by the institution, considering a balance between instructors' characteristics, teaching approaches, students' approaches to learning, institutional support and instructional resources (Rowley, 2003). The institution may also consider re-evaluating the timing and frequency for administering SETs. Appendix E outlines recommendations for possible changes to the SET instrument, and process for administering SETs as a result of the aforementioned proposed changes for the institution included in this study. Appendix F proposes possible research directions considering changes to the SET instrument suggested in Appendix E.

4.7.2 The Academic Plan Model and exploring opportunities to automate qualitative content analysis

Overall, respondents' perceptions aligned with the educational environment as presented in the Academic Plan Model (APM). While the frequency at which respondents talked about each APM element varied greatly, elements mentioned less often may be due to the limitation inherent in secondary data analysis (e.g., reliance on existing data with no opportunity for follow-up). We particularly noted that respondents' descriptions showed how students' perceptions of internal influences (e.g., faculty characteristics) impact students' perceptions of their learning experiences in the educational environment. We also noted how departmental policies and practices (e.g., pre-determined course schedules, coordinated assessment) influence the instructional processes that students experience in the course. Thus, APM was a useful lens for examining SETs and, ultimately, using qualitative SET data meaningfully in decision-making processes impacting students' learning experiences and environments. Responses to open-ended items may be analyzed efficiently by clustering them according to APM elements, addressing concerns and challenges related to meaningfully interpreting and using qualitative SETs data (Caudill, 2002; Marsh & Farrell, 2015). SETs comments examined using APM can provide specific, student-given information that may serve as basis for adjustments to the course-level academic plan. This flow of information closes the feedback loop, shown as Path A in the academic plan (Figure 4.1), and ensures that student voices are integrated into course planning.

We acknowledge that qualitatively analyzing SETs manually, as performed in this study, is a time-consuming effort. The amount of time required to analyze data will hinder the ability to provide instructors with meaningful input derived from students' comments in a timely manner. Available technology and analysis techniques, however, may address concerns over the amount of effort and time required to analyze written comments. SETs are increasingly being administered electronically (Avery, Bryant, Mathios, Kang, & Bell, 2006), and the availability of data in electronic form, qualitative analysis software, and computer-based tools may facilitate analysis (Krippendorff, 2004). Although a considerable amount of skills, expertise and rigor will still be required to examine and interpret the qualitative data (Miles & Huberman, 1994), there are opportunities to significantly reduce the length of time required for analysis. Our utilization of APM as a framework for analyzing SETs comments may serve as a model for interpreting and presenting student comments (Caudill, 2002). We recommend exploring opportunities to automate qualitative analysis; our manually-categorized and -labelled responses may serve as baseline data to train algorithms to qualitatively analyze large amounts of text data, using such computing processes as natural language processing, machine learning, and sentiment analysis (dos Santos & Gatti, 2014; Liu & Zhang, 2012; Soledad et al., 2017).

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Chapter 5: Discussion and Conclusion

5.1 Introduction

The purpose of this dissertation was to understand the teaching and learning experience in fundamental engineering courses. It sought to describe the educational environments in these courses from the perspectives of the key players interacting in these environments – instructors and students – using qualitative research methods. I conducted three studies that examined the fundamental engineering course educational environment from the following sites and perspectives: multiple institutions across the United States, from the perspective of instructors (Manuscript 1); a particular institution, from the perspective of instructors (Manuscript 2); and a particular institution, from the perspective of students (Manuscript 3). Manuscripts 2 and 3 were conducted in the same research location as part of a larger project; this research location is among the institutions represented in Manuscript 1, although each manuscript analyzed distinct data sources. The dissertation research thus progressed from examining faculty perspectives and educational environments from across multiple institutions, then focusing on faculty perspectives and educational environments at a particular institution, then considering students' perspectives at the same institution.

Manuscript 1 described the educational environments as shaped by the *beliefs* and self-described *behaviors* of 16 participants from across the United States. This provided context-specific information about the educational environment in fundamental engineering courses at various Research 1 institutions. In Manuscript 2, I focused on faculty perspectives in a specific Research 1 institution, and explored the idea of considering the suite of interacting fundamental engineering courses as a common foundational engineering curriculum within engineering curricula. The study resulted in a concept for an overarching governance structure to facilitate a student-focused and collaborative course planning process for fundamental engineering courses managed by multiple departments that engages instructors as equal partners in that process. After examining faculty perceptions in the first 2 manuscripts, I then focused on student perceptions of their learning experience in fundamental engineering course environments in Manuscript 3. I qualitatively analyzed responses to open-ended items in student evaluations of teaching surveys (SETs) at the same institution that served as the research location in Manuscript 2. The study yielded a model for analyzing and interpreting qualitative SETs data so that these may be used meaningfully and productively in fostering effective educational environments and positive learning experiences for students.

5.2 Implications

Each study conducted as part of this dissertation resulted in implications for research and practice. These implications are discussed in the succeeding sections; Figure 5.1 provides an overview across the three manuscripts.

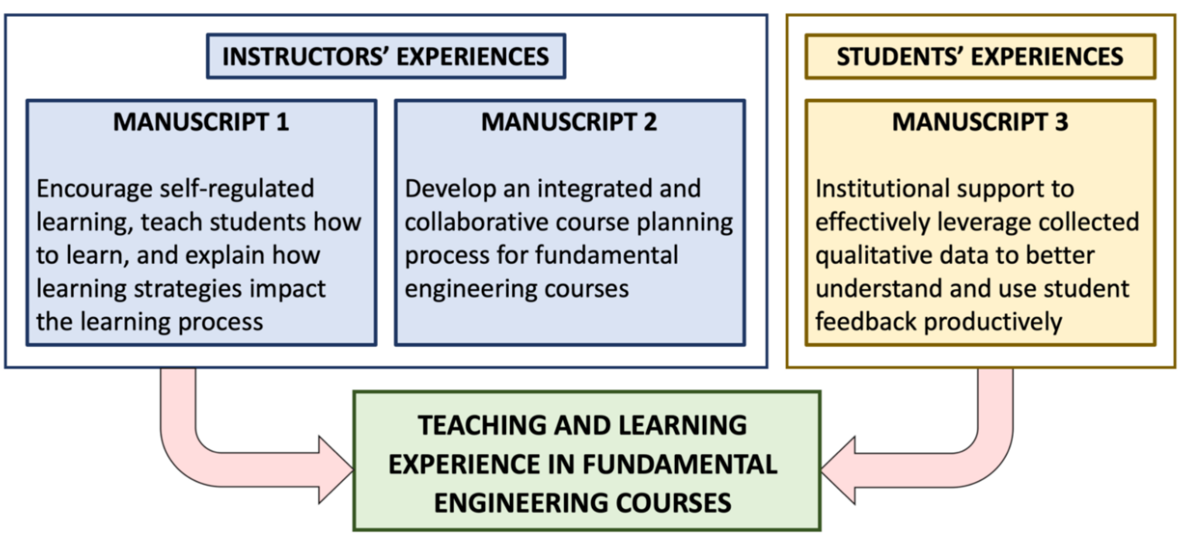

Figure 5.1 Overview of implications of the dissertation

5.2.1 Implications for Practice

Manuscript 1 found that participants' beliefs about students' study strategies suggest that it may be beneficial for institutions to provide students with the help and support that they need to develop metacognitive and self-regulated learning strategies (e.g., Cunningham, Matusovich, Hunter, Blackowski, & Bhaduri, 2017). In addition, instructors may integrate, with institutional support, ways to encourage metacognitive strategies in the classroom. The appropriate support for both instructors and students may help realize expected gains from recommended teaching behaviors. Instructors may also consider explaining the rationale behind the evidence-based teaching strategies that they are implementing in the classroom and emphasize the gains that students may derive from adopting these learning strategies. Providing an explanation may help students understand why the instructors are using these strategies and how they may use them effectively in their own learning process, in order to manage student resistance to adopting self-regulated learning behaviors.

Manuscript 2 suggests the concept of an overarching governance structure to facilitate a student-focused, collaborative and streamlined course planning process for fundamental engineering courses may change how departments, both within and external to engineering, engages in course management and planning. Both our data and literature describe fundamental engineering courses as disjointed and challenging (Lord & Chen, 2014; Streveler et al., 2008), resulting in less-than-ideal educational environments for students (Vasquez et al., 2015). Fundamental engineering courses, however, introduce key concepts and develop critical skills that students need for succeeding courses and/or courses that they are concurrently taking (Streveler et al., 2008), regardless of the department that manages the course. To change these perceptions about fundamental engineering courses, it is thus appropriate to consider the suite of fundamental courses collectively, in order to better facilitate opportunities for transfer and help students to make connections across courses. This dissertation contributes further by operationalizing the suite of inter-related and interacting fundamental engineering courses as a foundational engineering curriculum within engineering curricula.

Manuscript 3 offers a method for analyzing and interpreting responses to open-ended items in student evaluations of teaching surveys, so that they may be used productively and meaningfully in course planning and continuous improvement. Qualitative data collected through SETs is currently underutilized at the institution where I conducted the study. In looking at results across the three studies, I found that instructors have access to the data, but analysis, interpretation and utilization of the data varies. Some participants shared challenges with interpreting the data and using them meaningfully, which resulted in underutilization. Literature suggest that instructors may benefit from institutional support when making sense of the data (Marsh & Farrell, 2015), including interpreting feedback so that it can be presented more constructively and using the feedback to inform curricular decisions, through faculty support services such as instructional consultants. The framework for analysis and interpretation presented in this dissertation may be considered by the institution as a means of addressing the underutilization of qualitative SETs data. Another way to leverage SETs data more effectively is to periodically re-evaluate the SET instrument, in keeping with continuous improvement practices (Rowley, 2003). It is necessary to ensure that data collection instruments remain relevant to both respondents and data recipients; in the case of SETs, to students and the instructors who will use the data (Adams & Umbach, 2012). Revisiting the SET instrument and making modifications when necessary will improve data quality, analysis, and interpretation.

5.2.2 Implications for Institutional Policy

A common theme across all three manuscripts is the need for institutional support in order to allow instructors to accomplish the things that they care about and their aspirations. An implication for institutions is to revisit prevailing policies and procedures for continuous improvement and make the necessary changes that will provide instructors with curricular space–the space for cognitive, reflective, and creative thinking, and autonomy in curricular decision-making processes (Blasco, 2015). The process for revisiting and revising institutional policies and procedures should engage instructors as equal partners in the process and should result in an institutional effort to facilitate opportunities for collaboration across departments, particularly in processes that involve shaping student learning environments.

Research 1 institutions, in particular, should examine their organizational structures, paying particular attention to the tendency to take a silo mentality to teaching, despite progress in terms of interdisciplinary collaboration in research (Alpay & Jones, 2012). The establishment of an overarching governance structure that acknowledges and addresses the network function of fundamental engineering courses and setting up systems for effectively leveraging institutional data to support instructors in informed decision-making will rely heavily on institutional policies that will support these endeavors.

5.2.3 Implications for Research

This dissertation utilized frameworks and approaches to examining contexts and data that have not been extensively applied in prior work. Thus, it offers ways to examine similar data and phenomena to generate distinct perspectives and evidence that contribute to existing body of knowledge.

Manuscript 1 acknowledged the critical role that instructors play in shaping the educational environment and student learning experiences by focusing on their role as significant socializers as presented in the expectancy value theory (EVT) of achievement motivation (Eccles, 2007). The study offers a way to generate data on a specific set of factors (instructors as socializers' beliefs and behaviors) that impact students' values, goals, and expectancies for success. Most prior work that utilized EVT as a guiding framework generates data on values, goals and expectancies for success (e.g., Matusovich, Paretti, McNair, & Hixson, 2014); the approach used in this dissertation, on the other hand, generates data on specific factors (e.g., socializers' beliefs and behaviors) impact students' values, goals, and expectancies for success, providing insight into how these constructs developed.

Manuscript 2 found it beneficial to consider interacting fundamental engineering courses as a common foundational curriculum within engineering curricula. Engineering education researchers may also consider examining the context and phenomenon of fundamental engineering courses at both the individual course level (e.g., Pitterson & Streveler, 2016; Brown, Lutz, Perova-Mello, & Ha, 2019) and holistically as a network of interacting courses. This research lens aligns with the idea of a networked approach to the academic preparation of engineers (Sheppard et al., 2009), and may serve as initial steps towards achieving that structure by focusing first on fundamental courses. Studying fundamental engineering courses collectively and using that as a lens to examine educational environments and student learning experiences provides opportunities to develop a holistic understanding of these phenomena that may then be used to inform efforts to improve student learning experiences and persistence in engineering.

Manuscript 3 found that while qualitative SETs data yield valuable information, the qualitative analysis process is tedious and hinders the ability to provide instructors with useful data in a timely manner. An implication for research is to explore automated text data analysis, interpretation, and crafting of SETs reports with synthesized qualitative data for distribution to instructors. Several data analytics processes may be pursued, including natural language processing and sentiment analysis. Researchers may also build a more robust database consisting of manually-analyzed and categorized qualitative data that may be used to train algorithms to automate the analysis process. Beyond data analysis automation processes, gaps found in the data during analysis indicates a need to examine the use of SETs in continuous improvement processes in higher education learning environments, particularly in terms of ensuring that instruments remain relevant to students' experiences and are able to generate useful and meaningful information.

5.3 Future Work

The results of all three studies provide opportunities for future work:

- Investigate a larger and more representative group of instructors of fundamental engineering courses across multiple institutions, incorporating other primary sources of qualitative data (e.g., in-person classroom observations), to confirm whether findings on participants' beliefs and behaviors reflect those of the greater majority of instructors and to substantiate self-described beliefs and behaviors.
- Belief-behavior patterns found in the data indicate that participants are adopting recommended teaching strategies in their courses. Future work may take this finding into consideration and explore other factors that influence students' expectancy for success, motivation to engage in the course, and academic performance by examining phenomena

such as students' academic and non-academic workloads, and institutional academic retention policies.

- Conduct follow-up interviews with project participants in Manuscript 2 to further expound on findings from the current data and further substantiate assertions, particularly in terms of instructional processes, assessment & evaluation, and adjustments.
- Explore opportunities to automate qualitative analysis, utilizing the manually-analyzed and classified responses to open-ended items in SETs generated by this study as baseline data to train algorithms to qualitatively analyze large amounts of text data, using such computing processes as natural language processing, machine learning, and sentiment analysis.

5.4 Concluding Remarks

This dissertation was inspired by my experience as an instructor and department chair. I thought of all my students, particularly those who may have fallen through the cracks–students who wanted to be engineers but did not, or could not, persist. I thought of what I could have done better as an instructor, and what I should have done as department chair to ensure that instructors are well-equipped to provide students with the educational environments and learning experiences that they needed and deserved. I realized that in order to answer my questions, I needed to understand students' and instructors' experiences, both of which contribute to the shaping of educational environments. Completing my dissertation highlighted the importance of institutional support, collaboration, and integrating student feedback in the quest for facilitating effective educational environments and positive learning experiences in engineering, particularly in the fundamental courses taken during the first two years. I hope to see more opportunities for collaboration among instructors of fundamental engineering courses, and the integration of student feedback into course planning by meaningfully and productively leveraging underutilized institutional data.

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Appendices

Appendix A Mapping of interview prompts to modified EVT (instructors as socializers) constructs

EVT Socializer Construct	Interview Prompt
Instructors as socializers' beliefs	What are the things that you care about the most when you are teaching a class?
	Please describe how you plan and make decisions for class. What role do your students' beliefs play in these decisions?
	Do you think that all students are given enough opportunities to be the best learners they can be? If yes, how is this accomplished? If not, what do you feel are the barriers preventing students from achieving their learning potential?
	I would like to ask you again to think about your students. As you interact with them in the context of your class, what are the things that you think they value about being in your class?
	Thinking about your students: Why do you think they are in your class? What do you think drives them to come to class? What drives them to do the work they are asked to do? What, from your perspective, do they want to get out of your class?
Instructors as socializers' behaviors	What happens in a typical class period? (The prompt encouraged participants to describe activities that the class usually engages in and the kind of interactions that happen in the classroom)
	Do you feel that you have the resources to allow you to do the things that you care about in class? (The prompt encouraged participants to describe the things that they get to do and/or have difficulty doing given the structure/context of the class that they are teaching)

Appendix B Interview Prompts

What are the things that you care about the most when you are teaching a class? Do you feel that you have all the resources that you need to allow you to do the things that you care about in class? • What are the things that you will get to do in class given your current class size/s? • What are the things that you cannot do / will find difficulty doing?
Please describe how you are planning/planned for the class: • What information/data did you use to make decisions? *(prompts if participant asks for guidance)* o Topic sequence o In-class activities o Types of learning interactions (in-class and outside of class) • Where did you get this information/data? • What role do students (information/data from students) play in making these decisions?
• What support services/resources/data/information for teaching a large class do you have access to/are provided to you right now? • What data/information about students do you have access to/are provided to you right now? • What kind of data/information to you informally collect/observe/take note of? • How do you use these support services/resources/data/information? • Imagine that I had the authority to provide you with any support services/resources/data/information that you need to create the learning environment that you want for your students. What will you ask from me? • Why do you need these support services/resources/data/information?

Appendix C Suggested Interview Prompts – Follow-up Interview

Prompt
Instructor's perceptions about students in the class – Please describe the students in your class (you may talk about them in clusters or groups if necessary) in terms of: • Behavior in the classroom • Attitude towards course work • Other information that you feel is relevant to include in your description. How did you receive this information?
Expected outcomes from feeder/pre-requisite courses – What skills and competencies do you expect students to have when they take the course that you are teaching? How are these skills used/applied in the course? Based on your experience, please describe the level of skills and competencies that students have when they start taking the course that you are teaching, and how they compare to your expectations (you may talk about them in clusters or groups if necessary).
Expected outcomes from course being taught – What skills and competencies are your students expected to develop while taking the course that you are teaching? How were these expected competencies identified? How and when will students use these skills and competencies? Based on your experience, please describe the level of skills and competencies that your students are able to develop at the end of the semester, and how they compare to your expectations (you may talk about them in clusters or groups if necessary).
Class structure – In our last conversation, you talked about (structural and departmental practices implemented in the course). Has anything changed in the way the class/course is structured (e.g., class size, course content, departmental practices for assessment) since then? Please describe these changes and how they were implemented. What was your role in designing and implementing these changes? *If there were no changes*: Please describe how you determined 1) whether the goals for the class were met 2) opportunities for change/improvement. What data or information did you use as you engaged in this process?
Teaching practices – In our last conversation, you talked about (learning activities and strategies implemented in the course). Has anything changed in the way you teach (e.g., learning activities in the class, how you provide feedback) since then? What influenced, facilitated, or supported these changes?
Resources – Since our last conversation, have you attended a professional development program/course/workshop, or are you planning to? Can you please describe this program? What influenced you to choose this program? Since our last conversation, have you received information regarding professional development programs, including seminars/workshops related to teaching and pedagogy? From what entities? Please provide general feedback about the types of development programs available to you. Are there programs that you would have found helpful but are not available? Please describe/elaborate.

Appendix D Salient Categories and Codes

Salient Category*	Salient Code*	Definition
Instructional processes	Structures and processes to solve work-out problems	Descriptions of processes that model steps to analyze word problems and perform the necessary calculations to determine the answer
	Scaffolding techniques	Supportive techniques to help students accomplish challenging tasks (Ormrod, 2016)
	Assessment practices	Policies and procedures related to assessment (e.g., frequency of homework, grading tests) implemented in the class
Faculty characteristics	Availability and approachability	Perceptions about instructors' willingness to help, engage, and meet with students within and outside of class hours, and general perceptions about positive qualities (e.g., effective, easy to understand, taught extremely well)
	Teaching vs research focus	Perceptions about the instructors' primary role in the university – teaching-focused instructors do not engage in research, while research-focused faculty need to do research on top of teaching
Instructional resources	Availability of office hours	Descriptions of opportunities to engage with the instructor outside of class time
	Availability of seats in the class	Descriptions of seating availability in the classroom
Purpose	Develop problem solving skills	Descriptions of the development of skills to solve word problems illustrating course concepts
Content	Course coverage	Descriptions of the concepts addressed in the course
Sequence	Time management	Descriptions of time allocation for the concepts addressed in the course
Adjustments	Student feedback-based adjustments	Descriptions of efforts by instructors to adjust course activities based on student feedback

* Analysis classified responses around 7 of the 8 elements in APM (Table 4.2); the categories included in this table represent salient categories discussed in the results section. Similarly, analysis generated a total of 73 codes across 7 categories; only salient codes addressed in the results section are included here.

Appendix E Suggestions regarding the SET instrument and administration

An implication for practice for this study is for institutions to revisit the current SET instrument and evaluate the instrument's ability to provide instructors with constructive and meaningful feedback. The institution uses SETs as a measure of teaching effectiveness for hiring, salary, tenure and promotion decisions, but students are primarily motivated to accomplish SETs to contribute to continuous improvement in the learning environment (Chen & Hoshower, 2003; Giesey, Chen, & Hoshower, 2004). When used for purposes of improving teaching and the learning environment, open-ended items are considered as more likely to provide needed and more useful information (Rowley, 2003). Considering the challenges associated with analyzing and interpreting responses to open-ended SETs items in a timely manner, some items in the SET instrument may be revised to yield more manageable helpful information and be more relevant to student respondents. Additional items may be added to the instrument as well.

Rowley (2003) recommends considering a balance between items on: a) instructors & teaching; b) instructional resources (e.g., facilities, course learning materials); c) student learning; and d) institutional support. The current instrument at this institution addresses items a) through c) to a certain degree, although revisions to some items may help improve the quality of responses and alleviate some of the challenges associated with analysis and interpretation. Revisions to how open-ended prompts are structured may also help with presenting dissonant and misaligned comments in a more constructive manner. Revisions also include context-specific items, referencing situations that students are likely to experience in their classes (e.g., solving work-out problems), making the instrument more relevant to students' experiences and likely to generate specific, useful, and meaningful information.

Suggested revisions to closed-ended items. The first four items in the current SET instrument ask students to rate the instructor's preparedness, clarity in presenting the subject matter, ability to provide feedback, and whether the instructor fostered an atmosphere of mutual respect on a 6-point Level of Agreement Likert scale (Strongly Disagree to Strongly Agree). These items address instructors & teaching. Based on data analysis, students valued instructors' approachability and being available for consultation, guidance and support. Students also valued traits that indicate that the instructor is committed to helping them succeed in the course. Table E.1 shows a suggested revision and the addition of another prompt in the set of items on the instructor & teaching, using the current Likert scale, incorporating observations made from our data.

Table E.1 Suggested revisions to closed-ended items

Current Prompt	**Suggested Revision**	**Suggested Additional Prompt**
The instructor provided feedback intended to improve my course performance.	The instructor provided timely feedback intended to help me succeed in the course.	
		I am comfortable with approaching my instructor for questions and clarifications.

The open-ended item "What could you have done to be a better learner?" has received some critique from students based on our data, questioning its relevance to the evaluation process. I suggest restructuring the prompt to highlight the goal of guiding students to adopt learning strategies that will contribute to their success in the course by asking students to evaluate closed-ended items using a 6-point Frequency Likert Scale (Never to Very Frequently). Table E.2 shows the suggested revision to this prompt.

Table E.2 Suggested revision to the prompt "What could you have done to be a better learner?"

Current prompt	Closed-ended prompt
What could you have done to be a better learner?	*(Introductory statement)* In order to help us understand students' study strategies and its impact on the learning process, kindly reflect on how you studied for this class. For each study strategy below, how frequently do you engage in this study strategy?
	1. Independently review class notes and/or solutions to past homework problems
	2. Independently re-solve past problems or new assigned problems
	3. Work with peers to study and prepare for the test
	4. Leverage office hours to seek help from instructors and/or teaching assistants
	5. Other – please specify

Suggested revisions to open-ended items. The challenges associated with analyzing and interpreting responses to open-ended items may also be addressed by re-structuring these items without sacrificing the ability to generate rich data from free-form responses. One such option is to use anchored open-ended questions (Lee & Lutz, 2016). Anchored open-ended (AOE) questions use a closed-ended prompt as an anchor for an open-ended question, leveraging the simplicity and ease of analysis of a closed-ended item while generating free-form answers that provide more specific insights into a prompt. Lee & Lutz (2016) shared AOE questions structured as a closed-ended prompt with fixed answer choices and an accompanying open-ended question. The open-ended item allows the respondent to explain their response to the preceding closed-ended prompt, thereby providing more insight into the response during analysis. I suggest using the same structure to revise the open-ended items in the current SET instrument. Table E.3 shows the suggested restructuring of open-ended items using the AOE approach (Lee & Lutz, 2016), guided by findings from the study. The revisions also address gaps in needed information when using the current instrument based on our data, particularly regarding instructional resources and institutional support that students can access.

Due to the suggested shift to AOE questions, some closed-ended items have been integrated into AOE prompts and may be removed from the instrument. These items are: a) The textbook or course readings made a valuable contribution to my learning; b) The out-of-class assignments were educationally valuable; and c) The instructor related theories and concepts to practical issues.

Timing and frequency of SET surveys. Response rates and the quality of responses may be impacted by the number of surveys administered to students and when these surveys are administered (Galesic & Bosnjak, 2009; Adams & Umbach, 2012). Students may encounter survey fatigue as the number of surveys they have to respond to increase, and they are likely to not respond, or spend less time and effort, on surveys that are administered last, such as end-of-semester SETs (Adams & Umbach, 2012). Despite these concerns, conducting SETs more than once a semester, using more focused and constructive prompts that will allow instructors to immediately use student feedback to adjust learning activities and provide students with the guidance and support that they need to be successful in the course, may be a valuable change for the institution to consider. Conducting a mid-semester SET to provide instructors with formative feedback will also allow students to see improvements in the course while they are still taking it, thus meeting their primary motivation to engage in the course evaluation process – to contribute to course improvement (Chen & Hoshower, 2003; Giesey, Chen, & Hoshower, 2004).

Table E.3 Suggested revisions to open-ended items

Current Prompt	Anchored open-ended questions		
	Closed-ended prompt	Fixed response choices	Open-ended follow-up question
What did the instructor do that helped the most in your learning?	Consider how your instructor facilitated the learning activities below. Which of these statements do you agree with?		
	1. Introduced and discussed course concepts	a. The way the instructor facilitated this activity positively impacted my learning process. b. The way the instructor facilitated this activity had no impact to my learning process. c. The way the instructor facilitated this activity negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?
	2. Demonstrate the structures and thought processes needed to solve work-out problems	a. The way the instructor facilitated this activity positively impacted my learning process. b. The way the instructor facilitated this activity had no impact to my learning process. c. The way the instructor facilitated this activity negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?
	3. Assigned homework problems.	a. The way the instructor facilitated this activity positively impacted my learning process. b. The way the instructor facilitated this activity had no impact to my learning process. c. The way the instructor facilitated this activity negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?
	4. Related theories and concepts to practical issues.	a. The way the instructor facilitated this activity positively impacted my learning process. b. The way the instructor facilitated this activity had no impact to my learning process. c. The way the instructor facilitated this activity negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?
	5. Other – please specify	a. The way the instructor facilitated this activity positively impacted my learning process. b. The way the instructor facilitated this activity had no impact to my learning process. c. The way the instructor facilitated this activity negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?

Table E.3 Suggested revisions to open-ended items *(Cont'd)*

Current Prompt	**Anchored open-ended questions**		
	Closed-ended prompt	**Fixed response choices**	**Open-ended follow-up question**
Please add any comments about the physical environment here:	Please reflect on the following learning resources that you may have access to. Which of these statements do you agree with?		
	1. The textbook and/or course readings.	a. This resource positively impacted my learning process. b. This resource had no contribution to my learning process. c. This resource negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?
	2. The learning management system used in this course (e.g., Canvas)	a. This resource positively impacted my learning process. b. This resource had no contribution to my learning process. c. This resource negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?
	3. The homework management system used in this course (e.g., WileyPlus)	a. This resource positively impacted my learning process. b. This resource had no contribution to my learning process. c. This resource negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?
	4. Office hours	a. This resource positively impacted my learning process. b. This resource had no contribution to my learning process. c. This resource negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?
	5. Institutional resources for student success and academic improvement – please specify	a. This resource positively impacted my learning process. b. This resource had no contribution to my learning process. c. This resource negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?
	6. Other – please specify	a. This resource positively impacted my learning process. b. This resource had no contribution to my learning process. c. This resource negatively impacted my learning process.	Based on your response to the previous statement, why did it have this impact on your learning process?

I suggest conducting a mid-semester and end-of-semester survey using different instruments. The mid-semester survey will focus on items related to instructional processes and student study strategies; the results of this survey will be formative in nature and provide instructors with information on what is working in the course and what is not. This may then serve as triggers to adjust course learning activities and schedules. The information on students' study strategies, when examined in conjunction with performance on homework and tests, may be used by instructors to provide students with advice on what study strategies may help improve course performance (Grohs, Young, Soledad & Knight, 2018), or facilitate opportunities for students to engage more effectively in the learning process outside the classroom (e.g., help sessions, study groups). Table E.4 shows suggested items to be addressed in mid-semester and end-of-semester SETs.

Table E.4 Items for inclusion in mid-semester and end-of-semester SETs

Mid-semester SET	**End-of-semester SET**

• AOE - Consider how your instructor facilitated the learning activities below. Which of these statements do you agree with? (Table 4.B.3)
• AOE - Please reflect on the following learning resources that you may have access to. Which of these statements do you agree with? (Table 4.B.3)
• Closed-ended items - In order to help us understand students' study strategies and its impact on the learning process, kindly reflect on how you studied for this class. For each study strategy below, how frequently do you engage in this study strategy? (Table 4.B.2)
	• Closed-ended items:
	  • The instructor was well-prepared.
	  • The instructor presented the subject matter clearly.
	  • The objectives of the course were clearly explained.
	  • The instructor fostered an atmosphere of mutual respect.
	  • I have a deeper understanding of the subject matter as a result of this course.
	  • My interest in the subject matter was stimulated by this course.
	  • Overall, the instructor effectively facilitated learning in this course.
	  • How would you rate the physical environment in which you took this class based upon your ability to see, hear, concentrate and participate?
	• Open-ended item: Please add any additional comments regarding the course and/or instructor here:

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Appendix F Research directions

Considering the suggested revisions to the SET instrument and the frequency of administering SETs outlined in Appendix E, I recommend four research directions that may be pursued using data from the modified SET instrument and data collection process. Since the modifications suggested in Appendix E resulted in a more targeted and context-specific instrument, all the suggested research steps discussed below are for analyzing the responses of students taking Statics, Dynamics, and Strength of Materials at the institution studied in Manuscript 3.

The institution may conduct student focus groups to gather students' feedback regarding the new instruments and data collection processes. This study will focus on describing the impact of the increased frequency of conducting course evaluations on students' motivation to participate in the evaluation process and students' perceptions on the relevance of the new instruments to their experiences. The institution and department should conduct this inquiry as part of a pilot study to test the new instrument and data collection process so that appropriate adjustments may be made to the instruments if necessary.

I suggest examining the responses to the anchored open-ended (AOE) items in the mid-term survey on instructors' teaching strategies and students' perceptions of how these strategies impact their learning process (Table E.3). This approach will categorize responses to the open-ended section of the AOE (Based on your response to the previous statement, why did it have this impact on your learning process?) according to the closed-ended prompt and fixed response choices. The purpose of the study is to identify which teaching strategies are more likely to be perceived by students in ways that do not align with the expected gains that may be derived from implementing these strategies in the classroom, and qualify why students have these perceptions. The results of analysis may serve as input into course planning, particularly when instructors work with instructional consultants to adjust teaching strategies and behaviors enacted in the classroom in conjunction with other sources of information, such as classroom observations.

Responses to the mid-term survey instruments may be examined alongside trends in test scores at that point in the semester. The purpose of the study will be to understand how prevailing teaching strategies, students' study strategies, and available instructional resources are impacting students' test scores. It specifically examines data during a period of the semester when it is still possible for instructors and students to make the necessary adjustments to the learning process so that students can achieve their learning and performance goals for the course. The results of the study may be used to inform adjustments to teaching strategies and learning activities, as well as instructors' efforts to foster student success by providing students with guidance to identify and adopt effective study strategies for the remainder of the semester. The study is modelled after efforts to leverage institutional data for reflective teaching in large classes (Grohs, Young, Soledad & Knight, 2018).

The three studies suggested above all focus on using SETs for continuous improvement in course planning and designing effective learning environments. I acknowledge, though, that SETs play a significant role in administrative processes related to hiring, tenure and promotion. I suggest pursuing a study focusing on responses to the revised end-of-semester survey instrument. The study will use exploratory factor analysis to validate what factors related to teaching are addressed by the survey, and which factors and items drive scores for overall teaching effectiveness, which is used as input to the tenure and promotion at the research location. This study will replicate the factor analysis approach to analyzing SETs scores introduced by Barth (2008) in the context of the institution studied in Manuscript 3. Barth (2008) found that students' ratings on instructors' quality of instruction most significantly impacts ratings on overall teaching effectiveness, and that instructors' willingness to provide help beyond the classroom positively impacts their overall effectiveness rating. These findings align with salient themes in Manuscript 3, and it will be interesting to see how the results of a similar study conducted using data from the modified SET instrument will compare with Barth's (2008) findings.

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