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Examining Influences of Pedagogical Practice: A Mixed-Method Study of Science, Technology, Engineering, and Mathematics Faculty at Research Universities

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in Education

by

Edgar Romo

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ABSTRACT OF THE DISSERTATION

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Doctor of Philosophy in Education

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Professor Mark Kevin Eagan, Chair

Increasing the production of Science, Technology, Engineering, and Mathematics (STEM) undergraduate degrees is a critical component of maintaining the U.S.'s scientific edge in the face of increasing global competition in the areas of science and technology. Lagging graduation rates in STEM are a partial reflection of outdated, instructor-centered approaches that fail to engage students in the learning process. Shifting pedagogical practices in STEM undergraduate classrooms from traditional to student-centered teaching strategies has been recognized as a key strategy to avert projected shortfalls in the number of talented, well-trained baccalaureate graduates. As the country faces increasing pressure to boost the number of STEM graduates, a thorough understanding of the factors that influence STEM faculty's use of active learning strategies in the classroom and the barriers that inhibit their adoption is warranted.

This study draws upon cross-sectional data collected in the 2016 administration of the Higher Education Research Institute's (HERI) Faculty Survey and semi-structured interviews with 17 STEM faculty to illuminate the factors that shape the extent to which faculty incorporate active learning pedagogy in their courses. Resource Dependence Theory (Pfeffer & Salancik, 1978) and Organizational Citizenship Behavior (Bateman & Organ, 1983) provide a framework for understanding external and internal factors and characteristics that motivate faculty to opt for student-centered instructional strategies. Situating influential factors and decision-making processes within an institutional and departmental environment provides greater context and clarity to the understanding of how a faculty member's teaching style has evolved throughout the course of their career.

Results indicate that faculty teaching approaches are strongly influenced by intrinsic factors, professional characteristics, and environmental pressures. Faculty who are employed as a non-tenure track faculty member, participate in professional development activities, curriculum development, and interdisciplinary research, and have higher levels of undergraduate engagement are associated with higher levels of student-centered pedagogy. Physical science and mathematics faculty are significantly less likely to incorporate active learning in their courses – relationships that are corroborated by interviews demonstrating the significant role of departmental culture in shaping faculty teaching. While peers, department chairs, and university administrators can promote or inhibit the adoption of more effective teaching strategies via messages, policies, and model behavior, a lack of available time and (dis)incentive system prevent or delay faculty from incorporating more effective teaching practices. Implications for higher education policymakers and research universities include expanding professional development opportunities, rewarding teaching excellence, and changing departmental culture.

The dissertation of Edgar Romo is approved.

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2021

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CHAPTER 1: INTRODUCTION

The United States has long been viewed as a global leader in scientific and technological innovation. Despites its unmatched scientific prowess, the U.S. has faced increased criticism about losing its competitive edge (National Science and Technology Council, 2018; President's Council of Advisors on Science and Technology, 2012). For example, on January 3rd, 2019 (Beijing local time) the Chinese spacecraft Chang'e 4 landed on the "dark side" of the moon, becoming the first man-made object to ever do so (BBC, 2019). This moment represents not only a significant scientific achievement but also a bold statement to go where none has gone before. In the nearly five decades since the National Aeronautics and Space Administration (NASA) last sent manned missions to the moon, several other nations (e.g., China, India) have made and now executed plans to send spacecraft to our nearest neighbor (Chang, 2018). These important scientific developments exemplify growing concerns with underwhelming rates of Science, Technology, Engineering, and Mathematics (STEM) degree production, which in part, are attributed to an uninspiring and ineffective teaching enterprise at the STEM undergraduate level (Handelsman et al., 2004; PCAST 2012; Seymour & Hewitt).

Despite numerous, persistent calls to transform STEM education over the past decades due to projected shortfalls in the supply of talented, well-trained STEM bachelor's degree holders (Brewer & Smith, 2011; Fairweather, 2008; National Research Council, 1999; National Science and Technology Council, 2018), evidence shows that curricula and pedagogy in STEM majors have not been transformed and the production of STEM baccalaureate degrees remains far from optimal. To remain globally competitive and meet the scientific and technological demands of our future workforce, we must find ways to attract more students to STEM and improve degree production at the baccalaureate level.

Problem Statement

A closer look at baccalaureate institutions finds that STEM degree production is further complicated by the state of undergraduate education. The National Center of Education Statistics reports that 40 percent of students who begin as natural science majors (life and physical sciences) change their major by the end of their third year (NCES, 2018). Moreover, less than 40 percent of students who enter college intending to pursue a STEM major subsequently graduate with a bachelor’s degree in a STEM field six years later (PCAST, 2012). These findings are corroborated by Eagan, Hurtado, Figueroa, and Hughes (2014), who also find that less than half (44.5%) of STEM degree aspirants at doctoral/research universities graduate within six years.

Concerns about students’ success in STEM intensify when disaggregating the data by race/ethnicity, as underrepresented racial minorities (i.e., Black, Latinx, Native American) have disturbingly higher STEM attrition rates than their White and Asian peers (Chen, 2013; Eagan et al., 2014; Gregg-Jolly et al., 2016). Eagan et al., (2014) find that six-year graduation rates for Black (21.8%), Latinx (29%), Native American (24.9%) STEM aspirants trail their White (43%) and Asian American (52.4%) peers. Despite efforts to shift the teaching enterprise among STEM college faculty towards learner-centered teaching, the vast majority of STEM classrooms at public and private universities continue to feature passive instruction that diverts talented, diverse aspirants to non-STEM fields by failing to engage them through active learning pedagogy (Stains et al., 2018).

Mounting evidence suggests that shifting from traditional lecture-based to student-centered instructional approaches significantly improves student learning outcomes (Armbruster, Patel, Johnson, & Weiss, 2009; Freeman et al., 2014; Haak, HilleRisLambers, Pitre, & Freeman, 2011; Jensen, Kummer, & Godoy, 2015; Udovic, Morris, Dickman, Postlethwait, & Wetherwax, 2002). Although faculty in some STEM disciplines (e.g., biology) have shown a stronger inclination toward adopting student-centered pedagogy (SCP) as their default instructional style, instructor-centered teaching (e.g., extensive lecture) pervades in STEM undergraduate classrooms (Stains et al., 2018). While research has convincingly demonstrated the advantages SCP provides with respect to student learning, the evidence related to the opportunities and barriers related to faculty members' decisions to transition to SCP remains scant. A thorough understanding of the factors that explain variation in the extent to which STEM faculty at U.S. universities adopt active learning strategies and how institutions can best address any barriers while expanding opportunities is warranted. The following questions guide this study:

1. What are the competing time demands, perceptions, contexts, and personal and professional characteristics that explain variation in STEM faculty's utilization of student-centered pedagogies at research universities?
2. How do STEM faculty describe the evolution of their pedagogical approach– what individuals, resources, or contexts have informed their current approach and thinking about their teaching strategies?
3. To what extent do institutional and departmental contexts shape faculty's approach to teaching?

Purpose

By investigating the opportunity structures, time demands, and departmental and institutional contexts that shape STEM faculty members' instructional approaches, this study sought to highlight strategies that college and university leaders can leverage in efforts to shift faculty's pedagogical practices to incorporate evidence-based methods that feature active learning. Previous research has found a variety of factors that explain variation in the choices faculty make with respect to how they prioritize reflecting on their teaching, preparing for class, and innovating how they teach. Incentive structures embedded within higher education overwhelmingly reward faculty for their research productivity, not their quality as teachers (Addis et al., 2013; Dancy & Henderson, 2008; Dancy & Henderson, 2010; Michael, 2007). Faculty may also lack the expertise to implement more innovative teaching practices and thus rely on instructional practices observed during their doctoral training (Major & Palmer, 2006; Wieman, 2017). Unsurprisingly, many STEM faculty may view efforts to improve their teaching as time-consuming and unlikely to be rewarded, which subsequently contributes to faculty investing less time focused on improving their teaching.

The lack of perceived rewards for focusing on enhancing their instruction may undermine the success of professional development initiatives aimed at convincing faculty of the benefits of SCP or the effectiveness of these opportunities at catalyzing faculty to transition their teaching to become more student-centered (Ebert-May et. al., 2015; Owens et al., 2018). However, studies have highlighted how Faculty Learning Communities are a potentially powerful tool for enhancing student-learning in the classroom through the exchange of information and practices, support networks, and improved collaboration (Addis et al., 2013; Daly, 2011). Additional factors that may influence the implementation of student-centered pedagogy include departmental values and expectations, academic discipline, and a faculty member’s personal beliefs and values on teaching and learning (Austin, 2011; Cox, 2004; Michael, 2007; Wieman, 2017) This study expands upon this work and sheds light on specific aspects of the teaching enterprise that have been less frequently explored in the research literature: how faculty arrive at their pedagogical approach, to what extent their teaching has changed throughout their career, and the role of peers in motivating instructional change.

Given that previous research has suggested intrinsic and extrinsic motivation as well as concerns about time and resources as critical factors in determining how faculty teach their STEM courses, this study relied on two frameworks related to motivation and resource constraints to frame faculty's pedagogical decisions. Organizational Citizenship Behavior (Bateman & Organ, 1983; Smith, Organ, & Near, 1983) and Resource Dependence Theory (Pfeffer and Salancik, 1978) frameworks draw from management, organizational behavior, and human resources literature to explain the individual- and organizational-level behavior, respectively. While these perspectives offer alternative explanations for STEM faculty's pedagogical choices, it is possible that instructor behavior may be simultaneously explained by both frameworks.

Organizational Citizenship Behavior (OCB) refers to individual-level actions which are generally not required nor expected of an employee yet contribute to organizational functioning. OCB would predict that some faculty utilize student-centered teaching in order to exceed employee expectations and promote organizational effectiveness vis-à-vis improved student outcomes. In the case of Resource Dependence Theory, whether faculty embrace student-centered teaching or instructor-centered approaches can be understood as a function of their perceptions about the sufficiency of their resources (e.g., time, instructional support) and institutional reward systems (e.g., promotion and tenure considerations). Faculty who determine they have sufficient time to invest in improving their instruction based upon an evaluation of how such an investment may be rewarded by their department or university may have a greater inclination to shift toward SCP. By contrast, those who lack the time, do not feel supported by their campus, and perceive current incentive structures will reward them for spending more time in activities not related to instruction may instead opt not to invest in enhancing their teaching strategies. Importantly, while RDT has generally been utilized to examine organizational behavior (e.g., how institutions respond to external pressures), this study drew from it to examine how departmental and institutional pressures and incentives contribute to faculty's pedagogical choices. Collectively, these frameworks aim to highlight why some faculty may choose to go "above and beyond" expectations for teaching by adopting SCP practices while some of their colleagues rely upon comfortable, instructor-centered approaches that emphasize passive learning.

Significance

Understanding the barriers to the implementation of SCP may provide the impetus towards shifting instructor-centered teaching to learner-centered instructional practices at public and private universities. Research universities are centered in this study given the large number of STEM degrees that are produced at these institutions (National Science Board, 2018). As has been shown, the style in which these institutions teach their STEM courses may explain, in part, the observed variation in STEM success rates (Handelsman et al, 2004; Seymour & Hewitt, 1997). At public universities especially, large introductory courses are commonplace, and if taught ineffectively, these courses can have a lasting impact on hundreds of students at a time. Considering the size of public and private universities and their current STEM success rates, improving STEM success via a shift to more student-centered teaching at these institutions may have the greatest impact on the production of STEM baccalaureate degrees. By increasing engagement in the classroom, student-centered pedagogy has the potential to increase retention and graduation rates for all students and especially for URM students (Freeman et al., 2014; Haak et al., 2011; Jensen et al., 2015). Catering to the needs of learners may not only boost current levels of STEM degree production at public and private universities, but also contribute to the closing of equity gaps in STEM baccalaureate achievement. Doing so can help ensure that a robust and diverse group of STEM-talented individuals are prepared for the jobs of the future and can contribute to American scientific innovation and capacity (National Science and Technology Council, 2018). Catalyzing the production of STEM baccalaureate degrees at public and private research universities may revitalize our scientific capabilities at a national level and re-assert our international dominance on the global scientific stage.

Method

To achieve the aims described above, this study used a sequential mixed-method design. This approach was preferred over a single method because there was a need to both uncover factors that explain variance in how faculty teach and better understand the contextual experiences and teaching trajectories of individual faculty members. Moreover, the qualitative data provided greater insight into the unique ways in which faculty made decisions with respect to teaching while providing additional context to the quantitative data. Accordingly, the research questions were best suited to the use of mixed methods. Quantitative findings primarily addressed the first research question while qualitative findings primarily answered the second and third questions.

The first phase of this study relied upon a secondary data analysis of the 2016-2017 administration of the Higher Education Research Institute (HERI) Faculty Survey. Institutional-level variables were also merged from the Integrated Postsecondary Education Data System (IPEDS), the most comprehensive data system for colleges and universities. Descriptive statistics, cross-tabulations, and correlation tables provided an initial glimpse into the relationships between faculty's time demands, personal and professional characteristics, perceptions about departmental and institutional values related to teaching, and departmental and institutional contexts. Primary analyses employed hierarchical linear modeling (HLM) to examine individual- and institutional-level factors that explain variation in faculty's use of student-centered teaching. Since a principal concern of this study was examining the context in which teaching takes place, HLM represented the most appropriate analytical method as it takes into consideration the structural nature of data (Raudenbush & Bryk, 2002). In this case, STEM faculty were nested within public and private research universities.

The dependent variable was a construct composed of nine variables that capture the extent to which faculty include students in the learning process during their class time. While student-centered pedagogy can be understood as inclusive of practices outside the classroom (e.g., assessment, grading practices), this study limited the scope of the outcome to how faculty spend their time in the classroom. This decision was both a practical choice given the limitations of the survey instrument and intentional as this study was primarily concerned with explaining the variation in faculty's engagement of students in the learning process. These considerations lend themselves to a narrower understanding of student-centered pedagogy that draws from Bonwell and Eison's (1991) definition of active learning as "…instructional activities involving students in doing things and thinking about what they are doing" (p.2).

The second phase of this study involved collection and analysis of interview data that supported, clarified, and expanded upon quantitative findings. Respondents from the HERI Faculty Survey formed the potential interview pool for the second phase of the study, which conducted semi-structured interviews with STEM faculty. The interview protocol was partially influenced by the quantitative results, with special attention given to particularly interesting findings and results that deviated from the reviewed research literature. These semi-structured interviews provided insights into the teaching experiences of faculty and the variation in their use of student-centered pedagogy. Qualitative analyses relied on analytical memos, multiple rounds of initial and axial coding, and understanding relationships between analytical coding categories.

Scope

The quantitative phase of this study relied on the 2016-2017 administration of the HERI Faculty Survey and additional IPEDS variables from the same academic year. Since the Faculty Survey is administered once every three years, this represented the most recently available data. The survey data was limited in several ways in accordance with the purpose and goals of this study. First, only faculty who were employed in STEM fields were considered as part of the sample. STEM departments included: life sciences, physical sciences, engineering, mathematics and statistics, and computer sciences and technologies (See Appendix A for a full list of STEM departments). Second, only faculty employed at public or private research universities were included in the sample. These are institutions defined as either Research 1 or Research 2 institutions by the Carnegie classification. This restriction was based on the important role that these institutions play in STEM degree production at the baccalaureate level (National Science Board, 2018). Faculty outside the ranks of assistant professor, associate professor, and professor were excluded from this sample since ladder faculty face very different pressures and expectations at a departmental and institutional level than their peers in other academic positions (i.e., instructor, lecturer). Therefore, non-ladder faculty were outside the scope of this study along with all faculty members at community colleges and teaching institutions. The final sample included 1063 faculty members across 15 public and six private institutions. Of these 1063, a total of 564 faculty members provided their consent and e-mail addresses for further research. This group was then invited to participate in one-on-one semi-structured interviews and a total of

17 interviews were completed. Interview participants varied with respect to their academic discipline, institutional type, and professional characteristics (e.g., rank, tenure).

Positionality

Like many undergraduate students, I took several STEM courses on the road to a baccalaureate degree. While I enjoyed some of these classes, others failed to grasp my attention and instead reinforced my decision to pursue other academic disciplines. If these courses had been more intimate and academically engaging, perhaps I would have considered majoring in a STEM discipline. As a researcher, I now find that many students like myself are uninspired by what they experience in a science classroom. At the Higher Education Research Institute at UCLA, I had the opportunity to work under a National Science Foundation-Improving Undergraduate STEM Education (NSF-IUSE) grant. Under this capacity, I was introduced to literature surrounding the state of STEM education, active learning, flipped classrooms, and URM students in STEM. Additionally, I received training in documenting classroom teaching practices and observed numerous faculty members' teaching practices over the course of two years. More recently, I had the opportunity to dive into student-outcomes data related to diverse teaching practices. Collectively, these experiences sparked my interest in improving STEM faculty instruction and led me to pursue this study. However, it is important to reiterate that I was not a STEM graduate and that I have limited experience as an instructor or teaching assistant. To some extent, these facts situate me as an outsider in this study – examining STEM practices while having limited personal experience in these classrooms. Despite this, an outsider perspective may enable me to observe nuances in the ways in which STEM faculty approach their teaching.

Overview

The following chapters detail the background, theoretical foundations, and methodology of this study. Chapter 2 begins with a review of the history, key arguments, and evolution of Organizational Citizenship Behavior, one of the frameworks underlying this study. The following section directly examines how OCB is applied to this study. The chapter then moves on to a discussion of the roots and key concepts of Resource Dependence Theory, how it has been used in higher education research, and how it is applied to this study. The final section of Chapter 2 reviews research literature that examines factors related to the implementation of student-centered pedagogy, pedagogical change, and barriers to more effective teaching practices. Specific topics that are reviewed include: professional development, faculty learning communities, academia's (dis)incentive system, departmental culture, faculty science identity, and pedagogical change processes.

Chapter 3 provides a detailed roadmap of the methodological strategy that guided this study. First, the specific goals, purpose, and research questions will be reviewed. Next, the sequential explanatory research design is introduced and justified. The third section discusses, in detail, the quantitative phase of the study beginning with the data source and construction of the sample. Subsequently, both faculty-and institution-level variables are reviewed. This section ends with a discussion of missing data and a summary of the quantitative approach (hierarchical linear modeling). Fourth, the qualitative phase is discussed. This begins with a discussion of the analytical strategy and the participant selection process. The section concludes with a detailed look into the data collection and analytical strategy. The chapter concludes with a review of key methodological limitations of this study.

Chapter 4 presents the results of the quantitative portion of this study, beginning with a descriptive analysis of all participants in the 2016 administration of the Faculty Survey. Next, descriptive statistics broadly explore items at the faculty and institutional level, as well as the outcome of interest, student-centered pedagogy. Hierarchical Linear Modeling is then introduced and the model is successively built, beginning with an unconditional model and progressing through each block of variables. As each block of items is added, variables' statistical significance, directionality, and influence on the dependent variable is discussed in detail. Finally, interaction effects between professional characteristics and key variables of interest are explored and discussed.

Chapter 5 presents the results of the qualitative phase of this study, exploring the lived experiences of STEM faculty at research universities. The chapter begins with an overview of the faculty participants before diving into the factors that influence teaching. Next, faculty describe the evolution of their teaching approach, with some articulating a consistent approach and others depicting an evolving pedagogical style. Faculty share the barriers and influences that shaped the transition to their current approach. The chapter concludes with an examination of the environmental context of faculty teaching, specifically focusing on the influence of the institution, faculty peers, and departmental culture on teaching approach.

The final chapter of this dissertation presents a summary of the results of this study. Significant results are explored in depth and situated within both the research literature and the theoretical framework guiding this study. The following sections explore implications for both the federal government and research universities while offering concrete recommendations that could significantly influence teaching at research universities. The chapter concludes with a discussion of potential areas of further investigation and the author's final thoughts.

CHAPTER 2: REVIEW OF THEORY AND LITERATURE

This study is focused on the factors and characteristics that shape faculty members' use of lecturing and student-centered pedagogy, how their pedagogical approach has evolved over time, and how their institutional environment may influence their teaching. This chapter reviews two theoretical frameworks and relevant literature that informs our understanding of how faculty make pedagogical decisions. Three major sections compose this chapter. The first section begins with a review of the historical and theoretical underpinnings of Organizational Citizenship Behavior (OCB). Subsequently, key studies on the application of OCB to higher education are discussed before linking this framework to the present study. The second section reviews the theoretical principles of Resource Dependence Theory (RDT), including the external influence of organizations and the influence of dependency on internal sub-units. Focus then shifts towards reviewing studies that integrate RDT principles in the analysis of higher education organizational behavior. This section concludes with an overview of how RDT informs this study. The third and final section of this chapter reviews key studies and literature that highlights additional factors and characteristics which may influence how faculty teach undergraduate courses. This includes professional development, learning communities, the (dis)incentive system, departmental and professional culture, and change processes.

Organizational Citizenship Behavior

Faculty who engage their students with a more interactive curriculum might be perceived as going above and beyond standard expectations of teaching excellence because of the additional training, preparation, and time that is required for student-centered teaching (Michael, 2007). Since it can explain intra-organizational behavior that exceeds an individual's prescribed role, Organizational Citizenship Behavior (OCB) provides an appropriate lens for understanding faculty members' disposition (or not) towards student-centered teaching. Acknowledging the theoretical underpinnings of OCB may help to frame why faculty members employ specific teaching practices within STEM classrooms. Moreover, OCB will help uncover the personal attributes and environmental conditions that facilitate a faculty member's use of student-centered teaching.

Bateman and Organ (1983) introduced OCB as a means of understanding a classic problem for organizational psychologists – the relationship between job satisfaction and job performance. Over the past few decades, OCB has emerged from this literature and established its own niche, providing researchers the tools to examine a broad range of theoretical and practical considerations related to employees and the workplace, and several of these points seem well aligned with conditions of faculty's work in colleges and universities.

The OCB Construct

Classical and modern organizational theorists argued that extra-role behavior was an important part of a functioning organization (Barnard, 1938; Katz, 1964; Katz and Kahn, 1966; Roethlisberger & Dickson, 1939). Barnard (1938) wrote of individuals' "willingness to cooperate" as being a critical component of functioning organizations, and this willingness was motivated not by contractual obligations nor was it induced by material considerations; it was purely voluntary in nature. Similarly, Roethlisberger and Dickson (1939) used the term *cooperation* to refer to behavior that included spontaneous social gestures towards the needs of others within the organization. Building on these ideas, Katz and Kahn (1966) argued that the relationship between organizational rewards and cooperative behavior is mediated by a sense of citizenship. This sense of citizenship motivates individuals to contribute beyond that which is required of their role and to do more to promote the success of their organization.

Drawing from these theorists, Bateman and Organ (1983) coined Organizational Citizenship Behavior in their examination of the relationship between job satisfaction and job performance. Later that year, Smith, Organ, and Near (1983) advanced our understanding of OCB by taking a closer look at its antecedents. Although these early essays by Organ and his colleagues introduced the concept of OCB, they did not provide an exact definition of this behavior. Five years later, Organ (1988) introduced a five-factor OCB model (altruism, courtesy, conscientiousness, civic virtue, and sportsmanship) and formally defined the concept:

> OCB represents individual behavior that is discretionary, not directly or explicitly recognized by the formal reward system, and that in the aggregate promotes the effective functioning of the organization. By *discretionary* (emphasis original), we mean that the behavior is not an enforceable requirement of the role or the job description, that is, the clearly specifiable terms of the person's employment contract with the organization; the behavior is rather a matter of personal choice, such that its omission is not generally understood as punishable.

Key insights from Bateman and Organ (1983) and Smith, Organ, and Near (1983) illuminate the connection between OCB and the motivation of some faculty to go "above and beyond" in their teaching approach. Smith, Organ, and Near describe OCB as behavior that cannot be accounted for by the same motivational bases (e.g., salary) that induce people to join, stay, and perform within their prescribed role. Similarly, faculty who choose to employ a student-centered teaching approach might be motivated not by direct tangible benefits, but by more personal attributes and environmental conditions within their department. In addition, OCB encompasses behavior that is not easily enforced by the threat of sanctions (Smith, Organ, and Near, 1983). Although institutions and departments place some requirements on faculty with respect to teaching (e.g., teaching loads), *how* and *what* faculty teach remains largely within the discretion of the individual faculty member. The following section explores specific predictors of OCB in greater detail. Understanding what individual- and organizational-level factors and characteristics have been found to influence OCB may yield important insights for understanding how faculty arrive at their teaching approach.

Predictors of Organizational Citizenship Behavior

Bateman and Organ (1983) collected survey data from professional staff and their supervisors at a large midwestern university to measure the extent to which job satisfaction influenced OCB. The authors conceptualized job satisfaction as the extent to which employees were satisfied with their work, pay, promotion, coworkers, and supervision. Meanwhile, supervisors evaluated their employee's recent behavior using measures that tapped into behaviors such as compliance, dependability, housecleaning, cooperation, and punctuality. Utilizing two time points and cross-lagged regression analyses, the authors found a strong relationship between the various measures of job satisfaction and OCB. As Bateman and Organ (1983) predicted, employees who were more satisfied with their role and occupational environment were more likely to display organizational citizenship behavior. Similarly, job satisfaction may play a role in the extent to which college and university faculty seek out and develop a specific pedagogical approach. Faculty who feel more satisfied with their role and workplace environment may be more inclined to invest additional time learning new teaching techniques, revising their curriculum, and implementing active-learning strategies in their classrooms.

Utilizing Organ's (1988) conceptualization, early empirical literature sought to discover the antecedents of Organizational Citizenship Behavior. Following the example of the earliest

OCB literature (Bateman & Organ, 1983; Smith, Organ, & Near, 1983) empirical studies have examined the relationship between job satisfaction and OCB with various methodological and conceptual approaches. Podsakoff, MacKenzie, Moorman, & Fetter, (1990) postured that transformational leadership behaviors – articulating a vision, high performance expectations, individualized support, intellectual stimulation – would have both direct effects on OCB and indirect effects mediated by trust in leadership and job satisfaction. Using path analysis, the authors found significant effects between individualized support and intellectual stimulation on employee satisfaction but no significant effects on OCB's. Importantly, job satisfaction was not found to have a direct effect on OCB's (Podsakoff et al., 1990). In a study of two medium-sized companies in the Midwest, Moorman (1991) explored the relationship between perceptions of fairness and OCB's. The author defined organizational justice as the ways in which employees determine if they have been treated fairly in their jobs and the ways in which those determinations influence other work-related variables (Moorman, 1991). The key finding of this study is that once you isolate perceptions of fairness from job satisfaction, the former but not the latter is a significant predictor of OCB. This would suggest that the decision to behave as an organizational citizen may be a function of the degree to which an employee believes that he or she has been treated fairly by the organization (Moorman, 1991; Organ & Konovsky, 1989). Moreover, it suggests that perceptions of fairness take much of the variance of OCB's away from job satisfaction. For faculty, perceptions of the fairness of their departmental environment, and specifically the behavior of leadership, may have an influence on whether they exceed teaching expectations. For example, faculty who perceive unfairness in academic incentive structures might be expected to minimize their OCB's.

Williams and Anderson (1991) took a different approach in their conceptualization of OCB. While they still relied on Organ's (1988) operationalization, they bifurcated OCB based on the perceived target of the behavior (individuals vs. organization). Like Podsakoff et al., (1990) Williams and Anderson (1991) also relied on surveys to measure employees' organizational commitment and job satisfaction and supervisors' evaluations of OCB. Yet, unlike Podsakoff et al., (1990) and to some extent (Moorman, 1991), Williams and Anderson (1991) found job satisfaction to be an important predictor of both individual- and organization-oriented OCB.

Studies focusing on specific dimensions of OCB have provided a more nuanced understanding of OCB, its antecedents, and likely outcomes. In a meta-analytic review of 55 studies examining predictors of altruism and generalized compliance (OCB sub-scales), Organ and Ryan (1995) deliver several key findings. On the question of job satisfaction vs. perceptions of fairness, they not only highlight a modest relationship between job satisfaction and altruism but also note that job satisfaction is a better predictor of altruism than perceived fairness. The authors also found moderate relationships between leader supportiveness and organizational commitment and both altruism and generalized compliance. Personality factors (agreeableness, positive affectivity, negative affectivity), tenure (years at organization), and being female were found to be weakly correlated with both measures of organizational citizenship behavior. Importantly, how the OCB data was collected (self-reported vs. manager reported) had a moderating influence on the relationship between predictors and both altruism and generalized compliance.

While much of the previous literature assumed that engaging in OCB was a result of an individual's perceptions of their role and their organization, Rioux and Penner (2001) take a slightly different approach. The authors investigate whether personal motives – organizational concerns, prosocial values, and impression management – play a role in OCB. Items in the organizational concerns factor include motives such as: wanting to understand how the organization works, caring what happens to the company, and wanting to be fully involved in the company. Prosocial values included feeling it is important to help those in need, believing in being courteous to others, and being concerned about other people's feelings. Impression management included items such as: to avoid looking bad in front of others, to avoid looking lazy, and to look better than their coworkers. OCB was defined using the five sub-scale taxonomy developed by Organ (1988). Results indicate that each of the three types of personal motives was significantly correlated with altruism, civic virtue, and sportsmanship. Additionally, impression management showed a significant relationship with conscientiousness.

These results have important implications for understanding the motivations of faculty members who display OCB through their teaching. First, prosocial values indicate the need to be a helpful individual, to be accepted, and to interact smoothly with one's peers (Rioux & Penner, 2001). Such motives may be partially responsible for why some faculty go above and beyond standard expectations of teaching to integrate more time-consuming content-delivery methods. Similarly, a desire to help the organization because one identifies and takes pride with it and because it is seen as vital to one's personal and professional welfare may underlie motivations to enact student-centered teaching. Lastly, impression management items would seem to suggest that how a faculty member may be viewed by their peers is an important predictor of their behavior. This study has shown that a person is motivated to enact OCB not only by their needs, but because such behavior meets certain needs for them (Rioux & Penner, 2001).

In summary, studies found conflicting results for the impact of job satisfaction and several other key predictors of OCB (e.g., organizational commitment, perceptions of fairness).

This study shed light on this question by controlling for measures of job satisfaction during the quantitative phase and exploring faculty members' feelings of satisfaction with their role and their environment in the semi-structured interviews. Across these studies, several key limitations were apparent. First, most of these studies surveyed participants from for-profit organizations (banks, companies, etc.). While this is not surprising considering the management and organizational roots of OCB, it does limit the generalizability of the findings. Whether similar findings would be observed within institutions of higher education remains to be seen. Second, many of the reviewed studies relied on supervisor-provided OCB data. Observing OCB through the eyes of a supervisor may not fully capture the extent of an employees' organizational citizenship behavior since managers may be biased towards behaviors that satisfy their needs as an organizational leader. Further, there may be discrepancies between what is or is not considered beyond the scope of job responsibilities, a difference which may be especially acute for faculty members whose occupation involves minimal direct supervision. Third, early studies conceptualized OCB as vague, limited, and trivial behavior. For example, common items used to capture OCB included: helping new employees, consistent attendance, punctuality, does not take extra breaks, avoids creating problems for coworkers, etc. (Bateman and Organ, 1983, Moorman, 1991; Podsakoff et al., 1990, Williams and Anderson, 1991).

Redefining Organizational Citizenship Behavior

Organizational Citizenship Behavior was conceptualized along three primary tenets: behavior that is discretionary, not formally rewarded, and that in the aggregate promotes the effective functioning of the organization (Organ, 1988). However, empirical findings and conceptual arguments led to a reconceptualization of Organizational Citizenship Behavior. First, findings suggested difficulty in differentiating between in-role and extra-role behavior

(Morrison, 1994). While Organ (1988) relied on job descriptions and contractual language to explicitly define this binary, in many cases, linguistic ambiguity (perhaps intentional) led to a blurry distinction between required and voluntary behavior. As noted above, who described the behavior (manager vs self-reported) influenced what may be considered OCB. Second, the working definition of OCB rested on the principle that extra-role behavior could not be formally rewarded, therefore implying that in-role behavior could and indeed was systematically and contractually rewarded. Organ (1997) himself dismissed this notion by arguing that very few rewards are contractually guaranteed, effectively ensuring that this aspect of OCB would be reconceptualized (see below).

Third, several researchers proposed alternative conceptualizations of Organizational Citizenship Behavior that pushed our understanding of this framework. Williams and Anderson (1991) discussed two types of Organizational Citizenship Behavior; OCB-O referred to behavior that benefitted the organization while OCB-I referred to behavior benefitting the individual. This conceptualization provided greater clarity about the distinctive antecedents associated with each type of behavior, depending on the target of such actions (Williams & Anderson, 1991). Similarly, Van Dyne, Graham, and Dienisch (1994) argued for a broader conceptualization of Organizational Citizenship Behavior, as these authors suggested that OCB encompassed all positive organizationally-relevant behavior, including in-role behavior. In other words, this expanded definition of OCB included both expected and voluntary behavior at the workplace.

In response to empirical findings and diverging conceptualizations that pushed the boundaries of his original definition, Organ (1997) acknowledged the difficulty in distinguishing between in-role and extra-role behavior and conceded the limited presence of contractual language guaranteeing rewards. Organ rephrased the first two principal tenets within his original definition of OCB, describing OCB as *less likely* (emphasis added) than task performance to be considered both an enforceable job requirement and behavior that would confidently lead to systematic rewards (Organ, 1997). This revised definition has remained consistent up to present times:

> At the most general, all-encompassing level, OCB can be defined as the set of behaviors that sustain or enhance the cooperative system of the organization but are not systematically or generally recorded in the formal system of the organization or tied in any consistent way to specific rewards (Organ, 2018, p. 9).

The key words *generally* and *consistent* in the present definition provide the wiggle room Organ envisioned two decades prior. This new approach to OCB leaves open the possibility that such behavior may be expected and possibly rewarded, but admittedly, at a much lower rate than in-role behavior. This is precisely the ambiguity that exists with STEM faculty's choice of teaching practices. As later sections of this chapter explore in greater depth, institutions may place certain requirements on the number of courses or contact hours faculty teach each year, but the decisions of how to teach those courses and the amount of time to invest in preparing for teaching rest with the faculty. Before diving completely into how OCB frames our understanding of STEM teaching practices, it is important to review recent literature on OCB.

OCB and Organizational Performance

Over the past two decades, research drawing on Organizational Citizenship Behavior principles has generally shifted from discovering the antecedents of extra-role behavior to understanding the influence of OCB on organizational performance. Several studies have found that OCB leads to more effective organizational functioning (Koys, 2001; Podsakoff, Ahearne, & MacKenzie, 1997; Podsakoff & MacKenzie, 1997). Research within organizational behavior and industrial-organizational psychology to rely on Organ's (1988) taxonomy to sub-categorize OCB. For example, both Podsakoff, et al. (1997) and Koys (2001) conceptualized OCB as behavior that reflected helpfulness, civic virtue, or sportsmanship. In the first study, the authors used employee questionnaires to examine the effects of OCB on the quality and quantity of work-group performance of more than 200 factory workers. Three factors of OCB were conceptualized: helpful behavior, civic virtue, and sportsmanship. Civic Virtue items included providing constructive suggestions about improving effectiveness, attending and participating in meetings, and a willingness to risk disapproval to express beliefs about what's best for the workgroup. Sportsmanship included negatively coded items such as always focusing on what is wrong rather than the positives, complaining about trivial matters, and always finding fault with what other employees are doing. Ordinary least squares regression results indicated that sportsmanship improved the quantity produced while helping behavior improved both quality and quantity of work group performance.

In a study of restaurant employees, Koys (2001) hypothesized that OCB's would have a positive impact on profitability and customer satisfaction. OCB was measured using items such as, "The people here treat each other with respect", "The people I work with have a "can do" attitude", and "I can count on my coworkers when I need help". Utilizing manager-reported OCB data, cross-lagged regression analyses demonstrated a significant relationship between employee attitudes and behaviors at time one and organizational effectiveness (profitability, customer service) at time two. Results from both Podsakoff, et al. (1997) and Koys (2001) would suggest that OCB has a positive impact on organizational performance. Similarly, faculty who engage in SCP may also contribute to organizational effectiveness by improving student learning, engagement, and retention in STEM.

Podsakoff, Whiting, Podsakoff, and Blume (2009) conducted a meta-analysis of 206 studies between 1983 and 2007 that studied the relationship between OCB's and individual- and organizational-level consequences. This analysis has important implications for this study of faculty behavior with respect to teaching practices. At the individual level, OCB's were found to be positively related to job performance ratings and reward recommendations. Importantly, although OCB's were also positively related to reward allocations, this relationship was noticeably weaker than reward recommendations. This seems to suggest that even though OCB's are highly valued in the workplace, they are not always rewarded to the same extent. This finding is particularly important for faculty who go above and beyond in their teaching practices. While faculty may be commended for utilizing innovative teaching practices, rarely are they rewarded for the time and effort that is required to transform and maintain student-centered teaching (Wieman, 2017). Consistent with the hypothesized relationship between OCB's and organizational performance (Bateman & Organ, 1983), OCB's were found to positively impact organizational performance and specifically, profitability (Podsakoff et al., 2009). This provides additional support for the hypothesis that SCP would have a stronger influence on organizational outcomes than instructor-centered teaching. Finally, as hypothesized by Podsakoff et al. (2009), OCB's were also found to have a negative influence on organizational turnover. While the authors fail to analyze this finding in-depth, these results may be due to a positive influence of OCB's on organizational culture. As we will see below, faculty who employ innovative teaching methods in their classrooms also have a positive impact on their faculty peers. Furthermore, employees who perceive turnover as unlikely may be more likely to exhibit OCB's. This brings to question the important role of faculty rank and tenure at the institution. As literature demonstrating the positive organizational effects of OCB has proliferated, organizational citizenship behavior has expanded from its origins in businesses to higher education institutions.

OCB in Higher Education

Studies have specifically examined the organizational performance of institutions of higher education. Empirical research has utilized Organizational Citizenship Behavior to study diverse aspects of higher education: students (LeBlanc 2014), professional staff (Curran & Prottas, 2017), admissions decisions (Sinha, Oswald, Imus, & Schmitt, 2011), administrative committees (Farris, 2018), and faculty (Eagan, Sharkness, Hurtado, Mosqueda, & Chang, 2011; Lawrence, Ott, & Bell, 2012; Morales, Grineski, & Collins, 2017). Eagan et al. (2011) applied an OCB framework in their investigation of STEM faculty members' willingness to engage undergraduates in research, and they find the decision to work with undergraduates on research projects varies by several institutional and individual factors. Having more frequent contact with students through advising student groups, receiving funding in the form of grants, and working at a more selective institution correlated with a higher likelihood of working with undergraduates on research. In a related study, Morales et al. (2017) surveyed faculty who conducted health and biomedical research and found, not surprisingly, that those who placed greater value on the opportunity to increase diversity in the academy through mentorship of underrepresented minorities were more likely to be interested in mentoring undergraduate students.

Both the Eagan et al. (2011) and Morales et al. (2017) studies rely on McManus and Russell's (1997) conceptualization of OCB, "exerting more effort on the job than is required or expected by formal role prescriptions" (p. 148). This presents a limited understanding of OCB, as it does not explicitly engage either the contribution to organizational effectiveness or the unlikely to be rewarded component. Furthermore, Morales et al. (2017) offered Likert-scale measures (strongly disagree to strongly agree) of OCB that are more representative of a faculty members' values and abilities than their actual behavior (e.g., I enjoy teaching students about research; I am able to help students be better prepared for graduate studies). On the other hand, Eagan et al. (2011) utilized a dichotomous measure that asked, "During the past two years, have you engaged undergraduates on your research project?". This measure is a more appropriate representation of OCB as it explicitly captures faculty behavior. Eagan et al. (2011) also included multiple variables in their study that captured institutional climate and how faculty allocate their time, both of which will play a key role in this examination of faculty teaching practices.

Lawrence, et al. (2012) examined whether faculty's commitment to the university influenced their OCB, which they equated to service to the university. Organizational commitment was a faculty members response to the Likert-scale item, "If I had to do it all over again, I would still accept a faculty position at this institution" (1=strongly disagree through 7=strongly agree). While organizational commitment was not a significant predictor, time spent on both research and teaching was found to inversely affect university service. However, defining service to the university as attending governance activities, meetings, and committee work may be inconsistent with traditional definitions of OCB which place restrictions on whether such behavior can be required, expected, or generally rewarded by the organization, in this case the faculty member's department. Nonetheless, the general finding that faculty's time is quite limited and primarily devoted to research and teaching is an important consideration in our examination of STEM faculty's use of student-centered teaching practices.

Empirical studies that have applied an OCB framework to study college and university faculty behavior have several important limitations. First, OCB has struggled to evolve beyond the field of management and human resources, leaving studies of higher education few and far between, particularly those concerning faculty. Second, those studies that have integrated OCB concepts have done so in a limited manner, failing to problematize or even consider each of the three key principles of the framework: behavior that contributes to organizational functioning, is generally not required, and is usually not tied to specific rewards. Third, in some instances, measures that have been attributed to OCB are inconsistent with the conceptualization offered by Organ and colleagues over the years. Finally, in management, human resources, and education scholarship, authors have investigated OCB almost exclusively through quantitative methods. This study seeks to improve upon these limitations by examining faculty's pedagogical practices through a mixed-method approach and embedding in its research design a more complete conceptualization and operationalization of OCB and its three tenets.

Organizational Citizenship Behavior and this Study

While teaching remains one of the core responsibilities of faculty, *how* and *what* material is taught remains, for the most part, up to the individual faculty members discretion. As we have previously noted, lecturing remains the primary method of content delivery in STEM classrooms despite overwhelming evidence that demonstrates the superior effectiveness of alternative pedagogical practices. This underscores faculty members' ability to choose how they teach – albeit under some constraints – and the fact that some faculty and their departments may be unaware of, unconvinced by, or even opposed to student-centered teaching. Even if STEM departments are committed to more effective teaching practices, faculty autonomy within the classroom – a direct extension of academic freedom – makes it difficult to expect or enforce specific teaching practices (Gutmann, 1999; O'Neill, 2016). This leeway extends not only to what gets taught (e.g. assignments, readings) and how it gets taught (e.g. extensive lecture, case studies, group exercises), but to how learning is evaluated (e.g. multiple-choice exams, essays).

This makes it generally unlikely that faculty would be reprimanded for teaching in a particular fashion, even if the department has embraced more effective pedagogical techniques. Thus, while teaching is a core tenet of faculty life and its basic execution remains fundamental, instructors generally have broad license to exercise this duty how they best see fit. Academic freedom is a staple of faculty life and this study does not intend to ignore or restrict faculty autonomy within the classroom, rather, it is intended to understand the factors that shape how faculty approach their teaching. Within the context of academic freedom, faculty who embrace student-centered pedagogical practices at institutions where active learning is not the norm exemplify Organizational Citizenship Behavior. At institutions where active learning is the expectation and faculty are regularly evaluated for how active their classrooms are, there remains an imperative to explain variation in the use of active learning between faculty members, the evolution of a faculty member's approach to teaching, and the extent to which institutional context plays a role in the degree to which active learning is integrated into the classroom.

Faculty's use of student-centered teaching can be viewed through the lens of OCB for two additional reasons. First, it enhances the organization (department) by delivering improved student outcomes (Freeman et al., 2014; Haak et al., 2011; Prince, 2004). Improved teaching, especially in the aggregate, decreases the likelihood that students will repeat courses, leave a STEM major, or leave the university entirely (Handelsman et al, 2004; Seymour & Hewitt, 1997). This bodes well for the department particularly as higher education continues to move towards outcomes-based funding models and limited public support. Second, even though most departments would likely encourage excellent teaching, how excellence is judged and rewarded is expected to vary. Therefore, the use of student-centered teaching practices is generally not believed to lead to guaranteed compensation or rewards of any kind from the department.

Faculty who embrace SCP of their own volition do so knowing that how they teach may not impact their performance reviews, promotion process, tenure or even short-term benefits such as bonus pay, awards, or recognition. While some institutions may expect and even reward faculty for integrating active learning teaching practices into their teaching, it is important to remember that these institutions are outside the norm, especially at research universities, where the literature has consistently found a predominance of lecturing. This is consistent with Organ's (2018) conceptualization of OCB, which specifies that such behavior is generally not rewarded by the organization.

OCB provides the theoretical tools to examine faculty use of student-centered teaching and answer the following question. What motivates faculty to choose to invest substantially more time and energy to transition their pedagogical style to one that caters to the needs of learners? In some cases, faculty may perceive that student-centered teaching is part of their job responsibilities. In these instances, it is important to understand how and why these individuals perceive enhanced teaching as part of their obligations, how they arrived at this conclusion, and how we can learn from them as we seek to improve teaching across STEM. For other faculty, prosocial values, organizational commitment, and impression management may play an important role in the extent to which they display OCB through their teaching (Rioux & Penner, 2001). Why and how faculty are motivated to push beyond traditional expectations of teaching and focus on the needs of learners remains to seen. Organizational Citizenship Behavior provides us with a framework to examine these issues and answer these questions.

Resource Dependence Theory

Although an OCB framework can illuminate the personal and professional motivations behind faculty who go above and beyond teaching expectations, it does not consider the structural challenges faculty face when trying to integrate more effective teaching practices into the classroom. This study will draw from aspects of resource dependence theory (Pfeffer & Salancik, 1978) to further complicate our understanding of the environmental factors that inhibit or support faculty within the teaching enterprise. While RDT has a broad range of theoretical and practical applications, this study will draw from its contributions to understanding how organizations and their sub-units' decision-making processes are impacted by limited resources. Specifically, I will utilize RDT to understand the organizational- and individual-level decision-making processes that contribute to a faculty member's use of specific teaching practices. Because it can help understand the extent to which faculty are influenced by the availability or scarcity of resources (e.g., time, funding) within the context of an academic department, RDT is an appropriate framework for this study. The following sections review the key principles of resource dependence theory, highlight relevant empirical literature in higher education, and connect RDT to this study.

Theoretical Foundations

Resource dependence theory seeks to explain how organizational and interorganizational behavior can be described in terms of the resources that are essential for organizational functioning. Pfeffer and Salancik (1978) argue that organizations become dependent on external entities that control access to resources essential for the organization. In the case of higher education, academic departments within a university may vie for institutional resources (e.g., funding, facilities). This dependence results in uneven power relations between the organization and entities within its external environment (Emerson, 1962). As a result, an organization is subject to the pressures placed by external entities. Moreover, the extent to which such dependence takes place is directly tied to the importance of the resources that are controlled by the external entity (Pfeffer and Salancik, 1978). Resource dependence theory can thus be summarized by three core ideas: the importance of an organization's social context, how organizations attempt to maximize autonomy and pursue interests, and the role of power in understanding internal and external decisions (Davis & Cobb, 2010).

Pfeffer and Salancik (1978) note that, "…the underlying premise of the external perspective on organizations, is that organizational activities and outcomes are accounted for by the context in which the organization is embedded" (p. 39). In some cases, organizational functioning is directly influenced by the availability of resources in the external environment. For example, the availability of institutional funding was found to be a powerful incentive for biology departments seeking to transform the way science was taught (Wieman, 2017). In the absence of such funding, in-depth transformations of the teaching enterprise could hardly have been realized (Wieman, 2017). Such behavior highlights the importance of resources for organizational behavior and organizational change. The next section will explore how scarcity of resources impacts organizations at the sub-unit level.

Impact at the Sub-unit Level

Organizations must not only work to improve their relationship with external elements, but they must also consider the influence of the environment on intra-organizational behavior. When resources are scarce, sub-units must decide on they can best maximize existing resources to achieve individual and organizational objectives. For example, faculty must negotiate how they dedicate their time within the context of potentially competing individual and departmental priorities. Considering time as a resource, the extent to which faculty devote sufficient time to teaching can be understood as a function of how much time they are provided by their department. Therefore, faculty behavior (teaching) would be expected to fluctuate based on the availability or scarcity of this resource.

In the context of environmental pressures, power relations play an important role in organizational decision-making. Power is unequally distributed within most organizations because of – among other factors – experience, skillset, positionality, and ability to solve critical problems for the organization. Power is also dynamic, as actors who are most able to cope with critical problems acquire power within the organization (Nienhuser, 2008). Facing critical problems within the organization, powerful actors exert their influence through decision-making, selection of leaders, and control over resources and other sub-units (Nienhuser, 2008). For example, in his efforts spread innovative teaching practices across STEM departments, Wieman (2017) notes the importance of having faculty members within a department who are supportive of student-centered teaching. Influential faculty members play a critical role in encouraging or convincing their peers to change their teaching; in some cases, these individuals are more important than empirical research highlighting the benefits of SCP (Wieman, 2017).

Resource Dependence in Studies of Higher Education

Unlike Organizational Citizenship Behavior, Resource Dependence Theory has a firm foothold in higher education research. RDT is utilized as a principal framework in studies that examine the impact of external uncertainty on institutions of higher education broadly, internal sub-units specifically, and especially pertinent to this study, faculty's decision-making processes. On a broad institutional level, RDT has frequently been used to study the impact of declining public support for higher education and institutional responses to minimize or relieve such financial constraints (Fowles, 2004; Jacquette & Curs, 2015; Jacquette, Curs, Posselt, 2016; Ortagus & Yang, 2018; Weerts, 2014). This literature has especially focused on the impact such financial pressure has on tuition and fees at public institutions. However, faculty behavior can best be explained by understanding how the availability of resources influences decision-making at the sub-unit level. Therefore, this review focuses on examining studies that highlight how external resources influence internal sub-units either directly or vis-à-vis organizations. Although RDT is not used as a guiding framework in all of these studies, it is clear that its principles and applications can be useful in examining how external resources shape intra-organizational behavior.

Studies have utilized RDT to examine internal decisions aimed at coping with external dependencies. For example, the development or closure of academic programs has been shown to be directly associated with the availability or scarcity of external funding (Eckel 2002; Huisman, 1997). This aligns with RDT's view of organizations that "alter their purposes and domains to accommodate new interests, sloughing off part of themselves to avoid some interests, and when necessary, becoming involved in activities far afield from their stated central purposes" (Pfeffer & Salancik, 1978, p. 24). In this case, institutions remove programs no longer viewed as worthwhile while investing in those that are viewed as more promising. Resource dependence theory also postures that organizations and their sub-units will seek to expand or diversify their revenue sources. Evidence for this position has been found in studies examining athletic conference realignment (Kramer, 2016) and course offerings aimed at attracting specific groups of students (Cole, 2011). Similarly, extramural support for improving courses, curriculum, or teaching may catalyze STEM departments to support faculty in transitioning to new teaching paradigms. If funding can be secured, departments may incentivize faculty to transform their teaching practices.

One example of departments using external funding to support faculty teaching practices comes from the use of learning assistants (LA) into a large-enrollment introductory biology course (Sellami, Shaked, Laski, Eagan, Sanders, 2017). Undergraduate learning assistants are unique in that they are required to participate in training for pedagogies that foster greater student involvement and critical thinking. In this case, learning assistants were utilized to support a broader curricular reform and reduce the student to faculty ratio (Sellami et al., 2017). Results indicate that while the inclusion of LA's was not found to have a significant impact on student learning gains as measured on a pre- and post-concept test compared to students in classrooms without LA's, significant differences in student learning were observed when exclusively analyzing non-CT exam questions (Sellami et al., 2017). The use of LA's may not only contribute to improved student learning, but it may also help important implications for faculty. For example, integrating learning assistants into classrooms, in addition to traditional teaching assistants, send a visible message to faculty that improved learning is valued at the department. The use of external funding to include LA's can also elicit greater investment from faculty in student learning as they now have additional partners with whom to collaborate on content delivery. From the perspective of RDT, the availability of grant funding is critical for the initiation of pedagogical change and improved student learning observed in this study.

Chasteen et al. (2015) highlight how coupling institutional and federal funding can bring about pedagogical change in upper division courses at a Physics department at a four-year research university. Funding was used to hire recent physics Ph.D.'s interested in education research as science teaching fellows (STF) that would partner with faculty on course redesign, development of instructional materials, and improved pedagogical practices and evaluation methods. Over the course of several years of funding, the authors expected that these partnerships would lead to increased discussions about effective teaching within the department and that shifts in individual faculty members' pedagogy would lead to a broader shift in departmental norms for instruction (Chasteen et al., 2015). The impact of these transformation process on faculty was measured using interviews of STF's, departmental leadership, and faculty members who were involved in course redesigns. Although only 14 percent of upper division faculty were directly involved in course transformation, results from an online survey of faculty show that slightly over half of respondents indicated their instruction was "significantly" impacted by redesigned course materials. Furthermore, 62 percent of faculty surveyed indicated that they plan to repeat or have repeated instructional changes in additional courses. Despite low figures of faculty participation, this study sheds light on how external grant funding can directly impact the way some faculty teach their courses. Understanding the additional barriers that prevent faculty from participating in these course transformation programs can significantly impact the spread of more effective teaching practices.

Additional evidence shows that grant funding for teaching reform is a catalyst for improving pedagogical change. Wieman's (2017) Science Education Initiative (SEI) at the University of Colorado, Boulder and the University of British Columbia demonstrated that external funding is a crucial factor in transforming and sustaining pedagogical change in undergraduate courses. In both of these institutions and across STEM departments, funding was utilized to catalyze pedagogical transformation through the hiring of science education specialists that would support the development of course content and instructional materials. Similarly, grant funding can also be utilized to incentivize faculty participation in professional development programs as in the case of the New Faculty Workshop for junior physics and astronomy faculty (Henderson, 2008). Without the availability of government funding to cover most of the participation costs, it may not have been possible to gather nearly a quarter of the new physics and astronomy faculty each year (Henderson, 2008). Faculty are also incentivized to participate in Faculty Learning Communities (FLC) (Addis et al., 2013). These incentives provide a small stipend for STEM faculty who engaged with their peers on discussions about teaching and improving pedagogy. This would suggest that providing faculty with incentives (e.g., stipends) can be an important factor in introducing faculty to student-centered teaching and/or generating discussions about improving pedagogy.

Although RDT has clear applications to the study of colleges and universities, its use in the reviewed literature has several limitations. Most studies that draw on RDT as a principal framework conceptualize institutions as organizations seeking to maximize autonomy and diversify funding sources. This coincides with a near total focus on public institutions. This is perhaps not surprising given the also frequent analysis of decreasing state revenues since this can especially be troubling for publicly funded institutions. Nonetheless, studies have not examined the specific behaviors of organizations or their constituents with samples that included private institutions. It would be worthwhile to examine the different strategies used by institutions, their departments, and particularly their faculty to manage these external constraints and consider whether institutional control factored into the various approaches. Additional limitations of RDT's application to studies of higher education institutions include a near-total focus on tuition as an outcome and singular reliance upon quantitative methodologies. Subsequent research should utilize RDT to analyze additional outcomes such as research productivity, tenure, or teaching.

This section also reviewed studies that could have integrated principles of RDT. Funding at the organizational level (institution or department) and the faculty level shows promise as an important tool for influencing pedagogical change. Yet, these studies have not addressed the extent to which faculty are motivated by incentives to improve their pedagogy, especially while considering additional barriers to course transformation (e.g., department culture, lack of training, rewards systems). It is important to consider how additional factors and characteristics may mediate the relationship between incentives and improved teaching practices.

RDT and this Study

At research universities, STEM departments are typically organized into sub-units within colleges (e.g. College of Engineering), whose governance structure may directly or indirectly influence priorities, student success outcomes, and resource allocations. For the purposes of this study, STEM departments will be considered both a subunit and an organization with their own sub-units. While previous organizational thinkers (Parsons 1956; Perrow 1970) identified organizations by a shared purpose or goal-oriented nature, Pfeffer and Salancik (1978) took a different approach. They proposed an organization as a coalition of groups and interested parties that can shift its purpose and domains to accommodate evolving interests at an organizational and sub-unit level (Pfeffer & Salancik, 1978). In this more fluid conception of organizations, internal and external participants may or may not share the same goals, yet they make contributions to the organization and are rewarded for their participation.

Applying this conceptualization to STEM departments, a biology department, for example, has a wider range of goals (e.g., teaching, research, service, survival, independence) than a for-profit organization. These goals may frequently shift in importance according to both external (e.g., state funding) and internal pressures (e.g., fluctuating enrollment, faculty turnover) that are placed on the department. Faculty can be considered internal participants who contribute to the department through their research, teaching, and service, and are rewarded for their participation through salary, awards, tenure, etc. External participants in the organization (e.g., state or federal agencies, professional associations, dean, provost) can also influence the department by contributing resources and/or making demands of the organization. In these instances, decision-making is influenced by the availability or scarcity of resources at both the organizational and individual level (Pfeffer & Salancik, 1978).

At the organizational level, external grant funding for teaching can help persuade STEM departments to transform pedagogical practices. Increased resources may help support the hiring of additional teaching assistants, discipline-based educational researchers, postdoctoral fellows or grant faculty additional release time, technological equipment, or stipends (Major & Palmer, 2006; Pelletreau et al., 2018). Such rewards may be a powerful incentive for departments and their faculty members to consider participating in pedagogical transformation efforts. External funding can also be used to fund faculty participation in professional development or learning communities (Addis et al., 2013; Daly, 2011). Through either direct compensation for pedagogical transformation or nudging faculty to participate in SCP professional development, incentives can provide a powerful tool for motivating faculty to utilize SCP. Resource dependence theory provides the conceptual tools to examine the impact of incentives on faculty behavior.

At the individual level, faculty must weigh the costs and benefits of the availability (or lack) of resources and the time and effort needed to effectively transform their pedagogical practice. In this case, resources are not just funding, but also the time that is available to faculty. For example, if departments could provide additional course release time for improving teaching (albeit rare) or decrease a faculty member’s service responsibilities, faculty may be more willing and able to dedicate enough time to improve their teaching. Institutional funds may also help departmental leadership and fellow faculty convince skeptical peers to transform their educational practices. In some cases, faculty may be unconvinced by research highlighting extensive learning gains, increased engagement, and improve retention figures (Freeman et al., 2014; Gasiewski et al., 2012; Haak et al., 2011; Jensen et al., 2015). In these scenarios, additional funding may provide faculty the needed incentive to evolve current teaching practices. Thus, the availability of external funding has a complex relationship with faculty teaching practices in undergraduate STEM courses. Such a relationship is mediated by additional factors that impact faculty responsibilities and time commitments. These additional factors and characteristics that influence teaching practices are reviewed in the following section.

This study proceeds from the basic assumption that all faculty want to teach well, yet they are constrained by the nature of their position and immediate responsibilities. For some, these constraints impede them from improving their teaching despite a willingness to do so. For many others, funding may tip the scales in favor of improved teaching practices. From this perspective, Resource Dependence Theory presents a suitable framework for understanding the changing relationships between STEM departments, STEM faculty, external funding sources, and teaching practices.

STEM Teaching Practices

While OCB and RDT provide a conceptual framework for understanding STEM faculty's decision-making processes regarding the use of student-centered pedagogy, they have not been previously utilized to examine how and why faculty ultimately decide to utilize such approaches in their courses. This necessitates a review of literature that examines factors and characteristics which may facilitate or inhibit pedagogical change in STEM. As part of a national conversation to improve teaching practices, research within science education primarily, and to a lesser extent higher education, has considered the influence of these factors in a variety of academic disciplines (e.g., biology, engineering, mathematics, geological sciences, etc.). This research contributes to our understanding of why antiquated teaching techniques remain commonplace in STEM despite extensive evidence that links pedagogical strategies designed to encourage active learning among students and improved learning outcomes. To gain a broader understanding of this phenomenon, a detailed review of the factors and characteristics that may promote or discourage faculty's adoption of specific teaching practices is merited.

Professional Development

To improve teaching in mathematics, Hayward, Kogan, and Laursen (2016) examined the impact of annual professional development workshops on math instructors' use of inquiry-based learning (IBL). This intervention involved three weeklong summer workshops in which faculty received pedagogical training and support in designing courses utilizing inquiry-based learning. Analyses of data in the form of pre- and post-workshop surveys, one-year follow-up surveys, and semi-structured interviews suggested that participants gained in their understanding of IBL after attending the workshop and implemented IBL approaches at a high rate (92%). Equally important, rates of lecturing were down while faculty's incorporation of student-led discussions and presentations increased relative to what respondents had reported on the survey conducted prior to the workshop. These results are encouraging because they suggest that professional development workshops are one way to support faculty in making the transition to student-centered teaching. While encouraging, concerns about an unrepresentative sample of faculty (overrepresentation of younger faculty) and high non-respondent rates restrict generalizability.

In a broader study of professional development, Henderson (2007) evaluated the effectiveness of a workshop specifically designed to introduce relatively new physics and astronomy faculty to educational research and interactive instructional strategies and materials. This effort is noteworthy because of its scope, as it draws roughly a quarter of the about 300 new physics and astronomy faculty each year nationwide. Like Hayward et al. (2016), this several-day workshop covered physics and astronomy educational research, pedagogy and assessment, and strategies to active learning strategies (e.g., problem-based learning, peer instruction, collaborative learning) into their curriculum. In 2007, an online survey was administered to faculty who participated in the workshop during the previous decade, resulting in over 500 responses. Results show that roughly 40 percent of faculty would describe their current teaching style as either mostly alternative with some traditional features or highly alternative while less than 20 percent of faculty would describe their pre-workshop teaching style as such. Similarly, the number of faculty who described their teaching as highly traditional pre-workshop was almost 30 percent, while this number decreased significantly to about one percent (Henderson, 2007). Across 11 years of workshop participants, 96 percent of faculty who reported making a change in their teaching attributed at least some of this change to their participation in this workshop (Henderson, 2008). Considering second- and third-year physics and astronomy faculty were invited to participate in the workshop, this would appear to suggest that the insights gained at the faculty workshop have remained with faculty several years later, or at the very least, have planted a seed for future interest in additional pedagogical training. Of the survey respondents, 82 percent indicated they discussed workshop ideas with colleagues upon returning to their departments, with 39 percent reporting their colleagues had made changes to their teaching as well. Although, this would suggest that professional development benefits extend beyond the workshop and its participants, additional evidence is needed to corroborate the extent to STEM departmental culture and faculty colleagues may be positively influenced.

Although the previous two studies report encouraging results in improved teaching practices, these are notably based on self-reported practices and beliefs, which have been shown to be unreliable (Derting et al., 2016; Ebert-May et al., 2015). Nonetheless, professional development opportunities instill in faculty a foundational knowledge of innovative teaching strategies and inspire them to continue to improve their teaching (Manduca et al., 2017; Owens et al., 2018). Perhaps this is its greatest impact, especially considering the focus on relatively new faculty members.

Although training current faculty to use more learner-centered approaches in their teaching offers some promise toward transitioning toward more engaging pedagogy used by STEM college faculty, a slightly different approach is to focus on professional development for postdoctoral scholars before they join the faculty ranks. Taking this approach, Ebert-May et al. (2015) sought to determine the extent to which future faculty members believed in and implemented evidence-based pedagogies after completing a two-year professional development program. The Faculty Institutes for Reforming Science Teaching IV (FIRST IV) program involved summer workshops, mentoring, and an opportunity to implement student-centered teaching during a course. Pre- and post-surveys demonstrated gains in understanding of student-centered teaching practices. Importantly, the authors also evaluated videos of live teaching using the Reformed Teaching Observation Protocol (Sawada, 2003), which describes five categories of progressively student-centered teaching approaches. The first category documents straight lecturing while the fifth category documents teaching that utilizes active student involvement in open-ended inquiry and engages students in alternative hypotheses, numerous explanations, and critical reflection (Ebert-May et al., 2015). Results indicate that 86 percent of those who taught an entire course exhibited significant student engagement and some minds-on and hands-on student involvement (Ebert-May et al., 2015). This visual analysis would appear to support survey findings. Yet, it remains to be seen whether such findings would hold long-term or if they were a byproduct of the current participation in this professional development.

To help address this question, Derting et al. (2016) matched alumni of the FIRST IV program with other faculty at their institutions and compared their use of learner-centered teaching practices. They found that although FIRST IV alumni and their peers reported similar perceptions of their teaching strategies and environment, significant differences were found between FIRST IV faculty and their peers on actual teaching practices (e.g. use of clickers). FIRST IV faculty's teaching videos were also rated by external reviewers using the RTOP described above. FIRST IV faculty were rated as exhibiting teaching in RTOP category III, which is characterized by significant engagement and some minds-on and hands-on student involvement while their peers reflected teaching in category II, described as primarily lecture with some minor participation (Derting et al., 2016). This would appear to suggest that the professional development program has an impact on how faculty are teaching. These studies demonstrate that pedagogical change can be influenced by faculty professional development programs.

While the previous professional development programs included STEM faculty or postdoctoral scholars across multiple institutions, Owens et al. (2018) focused on a single department. The Biology Faculty Explorations in Scientific Teaching (Biology FEST) program included a weeklong scientific teaching institute and additional follow-up programs. Extensive incorporation of active learning strategies in these classrooms was demonstrated through audio recordings and reported in both faculty and student surveys. Moreover, most faculty who participated in Biology FEST reported increased interactions with their departmental colleagues around teaching (80 percent) and a positive effect on sense of belonging (76 percent) and relationships with departmental colleagues (84 percent). These findings provide evidence suggesting the effectiveness of week-long professional development workshops as a tool to catalyze faculty's decision to incorporate more active learning strategies into their teaching. The findings also speak to the potential to begin to shift departmental cultures around teaching, and the issue of culture is further addressed in a later section in this chapter.

Faculty Learning Communities

Learning communities represent a specific kind of professional development that also incorporates networking with colleagues. Faculty Learning Communities (FLC) are development programs where small groups of faculty engage in collaborative discussions about teaching, learning, and community-building on campus (Cox, 2004). For STEM faculty, these spaces can be quite beneficial. Not only can they provide increased support and collaboration on campus, but they also function as a hub for the exchange of pedagogical information. FLC's can serve as intellectually engaging forums for discussing discipline-based educational research, assessment tools, and what is or is not working in the classroom (Addis et al., 2013; Daly, 2011). Comparing the experiences of STEM faculty by participation in FLC's, reflective surveys find that after participating in FLC's for two years, participants report significantly higher rates of experimenting with how they teach and working to clarify the learning goals of their courses (Addis et al., 2013). These results suggest that FLC's represent one way that faculty can collaborate to support a dialogue about teaching and make incremental improvements in their pedagogy.

Organizational Citizenship Behavior would predict that some faculty engage in student-centered pedagogy given their desires to contribute to organizational functioning (e.g. enhanced student learning) and their personal values about teaching. From this perspective, it is worthwhile to question whether faculty who engage in faculty learning communities are already willing to or have engaged in some form of student-centered pedagogy? Put differently, are FLC's failing to reach the faculty who would most benefit from participating in conversations about enhanced teaching practices and SCP implementation? Sirum, Madigan, and Klionsky (2009) evaluated an FLC which attempted to adjust for this by recruiting life science faculty members with no prior experience in active learning pedagogy. This year-long program was aimed at facilitating pedagogical change by engaging faculty in discussions about how students learn, active learning principles, integrating active learning into the curriculum, and barriers to enhanced teaching practices (Sirum, Madigan, Klionsky, 2009). Interviews with participants at the end of the program suggested that faculty made strides in their thinking about teaching and integrating active learning into their classrooms. Some faculty indicated that participating in the FLC provided them the tools to revamp their classes with active learning principles and techniques, reduce the amount of time spent lecturing, and gave them the courage to seek out additional information, resources, and suggestions from colleagues about teaching practices (Sirum, Madigan, Klionsky, 2009).

While most FLC's focus on enhancing the teaching and learning environment at a single institution, other programs span across several campuses. In a study of faculty learning communities at seven higher education institutions, Daly (2011) considered the impact of FLC's on faculty growth and development. During semi-structured interviews, faculty shared that participating in the FLC enhanced their motivation and desire to improve their teaching and student learning. Additional benefits included: identifying new areas of competence in their teaching, feeling valued as instructors, enhanced pedagogical knowledge, and developing connections with fellow faculty. Thus, it appears that participation in FLC's benefits faculty's teaching practices and pedagogical knowledge. However, a question remains on the influence of incentives for participation, as both Addis et al. (2013) and Daly (2011) provided incentives for faculty's participation in the FLC, yet do not explore this issue in depth. Resource Dependence Theory would suggest that faculty participation is enhanced when incentives are provided. Is it possible that faculty would have participated in the FLC were they not incentivized monetarily to do so? The influence of rewards and benefits on improved teaching is further explored below.

(Dis)Incentive System

The formal incentive system of higher education institutions stands as a significant barrier for efforts to transform undergraduate STEM teaching (Austin, 2011; Fairweather, 2008; Wieman, 2017). At departmental, institutional, and external levels, incentive structures overwhelmingly reward faculty for their productivity and status as researchers, not as teachers, especially at research intensive universities. For example, evidence shows that regardless of institutional type, there is an association between increased time dedicated to classroom teaching and a lower faculty salary (Fairweather, 2008). Intentional or not, this sends the message that classroom teaching is not as valued by the institution as much as other scholarly activities, namely research. Faculty hear this message quite clearly. In promoting the Science Education Initiative (SEI) to STEM departments at the University of Colorado and the University of British Columbia, Wieman (2017) shares that a universal concern for faculty was how adopting new teaching practices would impact their research productivity. Concerns about the amount of time that improving their teaching would require and how this might take away from time they could be dedicating to research might discourage efforts to reform the teaching enterprise (Dancy & Henderson, 2008; Michael, 2007). Until higher education leaders recognize, value, and reward the significant time commitment that is required to transform lecture-centered courses and prepare for student-centered teaching on a regular basis, faculty may continue to resist transitioning toward more student-centered approaches (Brownell & Tanner, 2012).

Institutional incentive structures impact STEM faculty's pedagogy in additional ways. In thinking about the effective use of faculty time, faculty must consider how their institution makes promotion and tenure decisions. In interviews of STEM faculty, considerations of tenure and evaluation are cited as key barriers to implementing student-centered pedagogy (Hayward, Kogan, and Laursen, 2016). This is further manifested in concerns over whether enacting pedagogical reform will negatively impact a faculty member's course evaluations (Henderson, 2008). The gravity of promotion and tenure decisions for a faculty member's career makes faculty uneasy about participating in STEM reform initiatives. For instance, Wieman (2017) cites how some faculty put off participating in the Science Education Initiative until after they had earned tenure. These concerns are not limited to current faculty, as both faculty and doctoral students can easily perceive the difference in value that is assigned to research awards relative to teaching awards (Austin, 2011). Thus, embedded within the structure of higher education are reward systems that prioritize scholarly activities associated with research and tenure. Given this fact, it is entirely reasonable that faculty prioritize their time conducting research rather than focusing extensively on their teaching.

Resource Dependence Theory would suggest that the availability of incentives to either directly transform classroom pedagogy or facilitate participation in professional development is a powerful tool for drawing faculty towards the use of student-centered pedagogy. Wieman (2017) wrote of the impact of incentives:

> More faculty participated in the SEI transformation efforts and with greater enthusiasm when departments provided explicit incentives to them. Such incentives took many forms, and were most effective when they were tailored to the specific needs of the faculty member, often in a way that could benefit their research or free up their time.

Faculty incentives may take additional forms, including but not limited to support for a research assistant, postdoctoral scholar, or teaching assistant, reduction in teaching loads, stipends, release time, summer salary, opportunities to publish, or an expanded budget for research equipment (Major & Palmer, 2006; Pelletreau et al., 2018; Wieman, 2017). Incentives can also be used to encourage faculty to participate in faculty learning communities (Addis et al., 2013; Daly, 2011). For some faculty, these rewards may be enough encouragement to encourage further learning about innovative teaching practices. Once they have spent time learning and using these techniques effectively, faculty may continue using student-centered teaching given the greater personal satisfaction derived from it (Wieman, 2017). Unfortunately, there are few incentives within higher education even for faculty who want to transform their teaching. Yet, when faculty have access to such rewards, evidence shows that they play an important role in eliciting engagement with professional development or curricular development.

Departmental Culture

The choices faculty make with respect to their teaching style and the amount of time they invest in teaching are often shaped in part by the culture of their department and their discipline (Austin, 2011; Ebert-May et al., 2015; Henderson & Dancy, 2011). Faculty may take cues from department chairs and the priorities they set or the extent to which they perceive their colleagues focusing on or valuing teaching. Students' expectations for faculty and the structure of the curriculum also may shape how faculty ultimately adapt and adjust their teaching styles (Austin, 2011). Additionally, whether other faculty have already implemented student-centered pedagogy within the department can be key, providing confidence and support for further faculty members (Dancy & Henderson, 2008). As faculty consider pedagogical innovation, they must consider how they may balance departmental expectations, directives, and values with improved teaching.

Evidence showing how far a departmental culture can be influenced has delivered mixed results. After participating in professional development programs, faculty were known to have engaged in an increased number of conversations about teaching with their STEM colleagues (Manduca et al., 2017). Furthermore, in a study that included nearly 90 percent of a biology department, Owens et al., (2018) report that participation in a professional development program increased STEM faculty's self-confidence regarding teaching, sense of belonging, and relationships with colleagues in the department. On the other hand, in interviews of faculty who participated in the SEI, Wieman (2017) reports that the majority of faculty believe their departments do not embrace new approaches to teaching and their benefits. This falls in line with findings by Dancy and Henderson (2010) who conclude that departments may state they are "supportive" of teaching, but usually fail to follow through with any substantive actions on the subject. In the end, faculty take cues from the department with regards to their teaching practices. An unsupportive environment may make it much more difficult for faculty to embrace evidence-based teaching practices even if they desire to do so.

Colbeck (2002) considers the impact of institutionalization processes on the persistence of curricular and pedagogical reform and sensitivity to the needs of minority students at seven engineering schools across the country. She hypothesized that deans' and chairpersons' commitment to teaching contributes to diffusion and durability of reforms. Likewise, support for teaching from fellow faculty was also expected to positively impact pedagogical reform. Results indicate that there is a significant relationship between faculty perceptions of the supportiveness of their faculty peers and their use of design projects within undergraduate courses (Colbeck, 2002). This would suggest fellow faculty have some influence on the use of student-centered teaching. Although significant effects were not found between departmental or institutional support for teaching and the use of design projects or group projects in courses, departmental and institutional support for teaching was significantly related to increased sensitivity to the needs of both women and minority students in engineering. This may suggest that administrators' and faculty leaders' efforts to promote effective teaching are noticed by faculty and that these are especially beneficial for underrepresented students in engineering. In summary, faculty may take their cues from values set forth by their administrators.

There is also evidence that shows faculty engage in student-centered pedagogical practices when they perceive their departments and fellow faculty are supportive and involved in these practices. After implementing the Science Education Initiative (described above), Chasteen et al. (2015) report that faculty's use of interactive techniques (e.g., clickers) has increased, even with faculty not involved in the course transformation program. The authors attribute this development to two factors. First, as more students experience transformed courses, they have become more resistant to traditional teaching, resulting in some student-led pressure to innovate teaching practices. Second, the development of course materials that significantly lessen the amount of time required to implement instructional change facilitates the spread of interactive techniques. In these ways, the use of student-centered teaching by some faculty serves as a catalyst for change across the academic department. Further evidence of this process is the fact that some faculty who were not involved in course transformation processes took it upon themselves to redesign their own courses (Chasteen et al., 2015). These findings may suggest that some faculty take cues from their peers' use of student-centered practices and adjust their own teaching accordingly.

Professional Science Identity

In addition to departmental culture, disciplinary norms, and the extent to which faculty value those particular norms factor into decisions faculty make about their pedagogical approaches. Brownell and Tanner (2012) propose that how faculty view themselves and how they are viewed by their colleagues within the context of their professional discipline can be an impediment to science teaching reform. This professional identity is strongly influenced by their scientific training, lab experience, research publications, and grant funding (Brownell & Tanner, 2012). These factors shape professional identities through the culture and rewards system of academic departments which reinforce notions of the dominant position of research and funding and are strengthened by peer acceptance in the science community (Brownell & Tanner, 2012). Notably, these professional identities are not strongly influenced by teaching and many faculty and graduate students are afraid to "come out" as teachers given the strict disciplinary focus on research (Brownell & Tanner, 2012).

Shifts in faculty professional identities may contribute to subsequent decisions to adopt new teaching strategies. Manduca et al. (2017) evaluated changes in pedagogical practices and faculty behavior related to teaching because of participation in a national geosciences professional development program (Cutting Edge). The program aimed to, "foster learning from peers, introduce ideas from cognitive science and education research, and engage participants in reflecting on applications to their own work" (Manduca et al., 2017, p. 4). During follow-up interviews, faculty reported a shift in attitude about teaching, with nearly half of interviewees now realizing teaching is a learned skill. In addition, 73 percent of interviewees (n=52) stated that discussions with fellow participants helped them leave the workshop with increased motivation to incorporate changes into their teaching practices. Furthermore, more than half of interviewees (n=39) stating that they use Cutting Edge web resources to continue developing their understanding of teaching and learning (Manduca et al., 2017). While Manduca et al. (2017) conducted classroom observations as part of this study, these observations were disconnected from interview data. Therefore, it is difficult to ascertain whether the changes in professional identity match observed changes in pedagogical practice. Nonetheless, it appears that faculty did leave the Cutting Edge program with a deeper commitment to learning and a motivation to continue improving their teaching.

Professional development has the potential to shape how faculty view their role in the classroom. Major and Palmer (2006) sought to understand how faculty pedagogical content knowledge changed because of a major teaching intervention – the implementation of problem-based learning across the undergraduate curriculum at a private university. Semi-structured interviews indicated some faculty came to view themselves more as “facilitators” or “guides” as opposed to more authoritative positions within the classroom (Major & Palmer, 2006). Moreover, faculty noted changes in their views about teaching. Some faculty noted that they became more aware of teaching literature and began to think about teaching and assessment differently while other faculty shared that they began to see the consequences of the way they teach and that these are closely linked to student learning. These remarks suggest that faculty who participated in this pedagogical transformation demonstrated subtle yet important changes in their views of teaching, their professional identity, and students. Ultimately, the extent to which faculty centralize excellence in teaching as a part of their scientific identity has substantial influence on their openness to shifting their instructional approach from instructor-centered to learner-centered.

Conclusion

The previous sections have reviewed the theoretical foundations of, and pertinent studies related to three streams of literature: Organizational Citizenship Behavior, Resource Dependence Theory, and teaching practices in STEM. These three bodies of research come together in important ways to form the basis of this study. This section briefly reviews how these bodies of research integrate to inform the present study and highlights important limitations this study intends to address.

To briefly summarize OCB, it represents behavior that contributes to organizational functioning yet is rarely (if ever) rewarded by the organization. Although OCB has most frequently been utilized to examine individual behavior within corporate settings, its applicability to faculty members' decisions to use student-centered teaching practices lends this study a powerful tool for examining the levers that facilitate more effective teaching practices. Considering the powerful role of current reward systems in higher education, the culture of STEM departments and academic disciplines, and faculty members' professional identities, faculty who go above and beyond standard expectations of teaching by employing student-centered teaching practices are considered a display of OCB. Examining faculty teaching practices through an OCB framework may yield crucial insights into the personal motives (e.g., organizational commitment, prosocial values) that may influence faculty's pedagogical decisions. While an OCB framework can shed light on what motivates faculty to invest substantially more time and energy to incorporate student-centered teaching practices into their courses, it does not explicitly address the influence of contextual factors in facilitating or inhibiting the use of SCP. Because it can specifically account for the impact of some of the existing environmental structures (e.g., reward systems) embedded within academic departments, Resource Dependence Theory complements OCB and extends this study's capability examine a broader range of institutional, professional, and cultural factors that influence teaching. RDT provides the conceptual tools to specifically analyze resources that may restrict (e.g., limited time, scarce funding) and promote (e.g., incentives for professional development) the use of SCP. Together, OCB and RDT can contribute to our understanding of the personal and resource considerations that shape how STEM faculty teach.

Much of the OCB literature presents a limited understanding of behavior that goes above and beyond organizational expectations. With some exceptions, most studies have conceptualized OCB as relatively trivial intra-organizational behavior (e.g., consistent attendance, punctuality). Considering the positive impact of student-centered teaching on student outcomes, this study brings a more complicated and consequential measure of OCB. Additionally, most studies examining OCB have relied on descriptive statistics and single-level quantitative approaches. This study enhances our understanding of OCB using hierarchical models and semi-structured interviews. To my knowledge, neither OCB nor RDT have been used to examine faculty members' teaching practices.

Similarly, RDT has limitations in its application to higher education research. While most of the literature has conceptualized a college or university as the organization, this study considers both the institution and the department as an organization. This approach may help uncover the unique ways in which faculty are influenced by both their department and their institution directly or vis-à-vis their department. Specifically, this study will draw from RDT to understand how institutions and departments utilize resources to promote pedagogical change and how scarcity of resources may shape faculty's decisions to incorporate student-centered teaching into their courses. Additionally, most RDT research in higher education has centered on public institutions and conceptualized resources as the amount of funding an organization receives. This study not only considers resources as such, but also includes time as a resource. In this respect, faculty behavior can be partially explained not just by financial resources, but by the extent to which they free up faculty time to engage in additional scholarly activities, including enhancing their teaching approach.

Although much research has sought to evaluate the effectiveness of specific teaching practices and understand how student learning can be improved, less attention has been paid to how faculty make decisions about that pedagogy they implement and how these decisions are constrained or encouraged by their academic environment. Many of the studies that have looked at what influences STEM teaching practices have centered on key variables such as professional development, lack of time and resources, and departmental culture. Yet, most of these studies have employed descriptive statistics and/or faculty interviews as their principal analytical methods. In part, this is a result of small sample sizes (n<100) that are frequent in much of the reviewed literature. This study will not only utilize a larger sample size, but also include both hierarchical analyses and semi-structured interviews, faculty across STEM disciplines, and faculty at both public and private institutions. The following chapter expands upon the methodological approach of this study.

CHAPTER 3: METHODOLOGY

Introduction

The previous chapter reviewed theoretical frameworks and literature that shed light on the teaching experiences of STEM faculty in higher education. Several factors and characteristics that influence pedagogical practice were reviewed and underlying reasons for how faculty make decisions about teaching were explored. Extensive literature also explored best practices for improving how STEM faculty teach undergraduate courses. Yet, while we know much about the effectiveness of active learning strategies on a host of student outcomes, we know less about the barriers and opportunities that factor into faculty members' utilization of more student-centered practices. More specifically, research has largely ignored how faculty arrive at their preferred pedagogical approach, the role of peers in motivating instructional change, and faculty members' personal views on teaching and learning.

Given the dearth of research examining the individual and institutional factors related to faculty's decision to incorporate more student-centered strategies in teaching, this study sought to explore a wide range of personal, pedagogical, structural, and contextual arguments that may explain variability in teaching practices among STEM university faculty. By identifying the contexts, policies, and experiences that contribute to or detract from STEM faculty's use of student-centered pedagogy, this study aimed to provide the field with strategies to optimize opportunities and overcome barriers related to faculty's adoption of active learning. Expanding faculty's utilization of more effective teaching strategies has the potential to not only retain greater numbers of students in STEM but also recruit more students to these disciplines. Additionally, this in-depth examination of departmental and institutional contexts has shed light on structural barriers within academia that impede one of the fundamental components of the mission of higher education: teaching students.

The present study used an explanatory mixed methods approach to explore the factors related to the extent to which STEM faculty use student-centered teaching practices in their courses and how they have developed their particular approach to instruction. The first phase of the study featured secondary analysis of quantitative survey data and aimed to shed light on the contextual and individual factors related to STEM faculty's teaching practices. Importantly, these analyses highlight the extent to which faculty's perceptions about teaching and the degree to which they believe their institution values it, competing time demands related to research, service, and other personal and professional activities, and contexts at both the department and institutional levels collectively explain differences in the extent to which faculty draw from active learning strategies in their teaching. Subsequently, the qualitative component of the study sought to understand how and why these perceptions, activities, and contexts have shaped STEM faculty's current pedagogical styles. Specifically, interviews provided the opportunity to dig deeper into faculty's values and beliefs regarding teaching and learning, pedagogical training and development, the evolution of their instruction, and the influence of their surrounding environmental contexts.

This chapter begins with a delineation of the study's research questions and then provides a detailed description of the mixed-methods research design. The research design description begins with an overview of the quantitative phase of the study, including details related to the data source and analytic sample. A discussion of the proposed variables to be considered for the analyses follows the discussion of the data, and the section on the quantitative phase concludes with an overview of the proposed analyses. The second section discusses the methodology for the qualitative phase of this study. This section begins with a brief discussion of the approach to the qualitative phase before examining the participant selection and data collection processes. Subsequently, a review of the analytical strategy is discussed. This chapter concludes with a summary of the key limitations of this study.

Research Questions

1. What are the competing time demands, perceptions, contexts, and personal and professional characteristics that explain variation in STEM faculty's utilization of student-centered pedagogies at research universities?
2. How do STEM faculty describe the evolution of their pedagogical approach– what individuals, resources, or contexts have informed their current approach and thinking about their teaching strategies?
3. To what extent do institutional and departmental contexts shape faculty's approach to teaching?

Research Design

A central premise of this study was that teaching practices are significantly influenced by a faculty member's views on teaching and learning, the competing demands placed on their time, and their surrounding institutional and departmental contexts. To adequately understand the complexities involved within and between these two notions, this study employed a sequential explanatory design. This mixed-method approach is preferable to a singular methodology as it allows a researcher to explain and interpret quantitative results by collecting and analyzing follow-up qualitative data (Creswell, 2009). This study aimed to both identify the factors that explain variation in STEM faculty's teaching practices and better understand how and why these factors have shaped faculty's pedagogical styles. Accordingly, the research questions lend themselves to the use of mixed methods; quantitative methods primarily addressed the first research question while the qualitative inquiry primarily answers the second and third questions.

While the quantitative data can yield substantial information about the relationships between variables and the outcomes of interest, survey items cannot adequately answer questions about the evolution of a faculty member's pedagogical approach nor the influence of departmental and institutional contexts. Surveys provide data on a snapshot in time, and most available survey data on college faculty do not longitudinally follow faculty throughout their careers. These limitations of analyzing secondary data necessitate the use of alternative data collection and analytic strategies. Additionally, a qualitative approach on its own is insufficient as it would lack generalizability and the capacity to estimate the magnitude of relationships between phenomena. Not only are the limitations of using one methodology offset by the strengths of the other but utilizing a mixed-method approach provides a more complete understanding of how STEM faculty make decisions about their teaching practices (Bryman, 2006; Creswell & Plano Clark, 2011).

The first phase of this study involves quantitative analyses of secondary data collected via a national survey of faculty that includes self-reported measures related to faculty's teaching practices, views on teaching and learning, professional activities, and characteristics of their institutions and departments. Quantitative results helped revise the interview protocol by highlighting key areas of inquiry for the interview participants. Phase two included analysis of qualitative data collected via semi-structured individual interviews with faculty that examined in greater detail how and why faculty have adopted their current pedagogical styles. This analysis focused on how the qualitative data could both help explain the quantitative results and provide a more complete understanding of factors that may influence student-centered teaching (Creswell

& Plano Clark, 2011). Subsequently, meta-inferences and divergent findings between the two phases are highlighted in the discussion section of this study. Figure 3.1 provides a graphical representation of the research design.

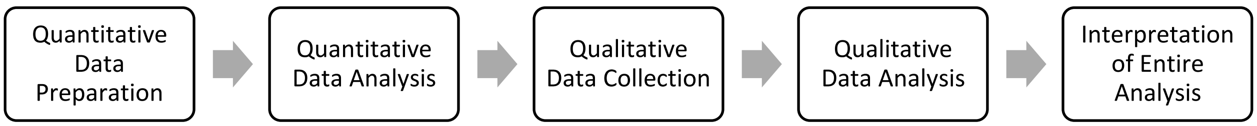

Figure 3.1. Sequential Explanatory Research Design. Adapted from Creswell et al. (2003).

Quantitative Data Collection and Analysis: Hierarchical Linear Modeling of HERI Faculty Survey Data

Data Source

Quantitative data come from the 2016-2017 administration of the Higher Education Research Institute's (HERI) Faculty Survey. This web-based instrument provides a comprehensive view of key aspects of the faculty experience. More specifically, the instrument collects information from faculty related to their pedagogical practices, research and service activities, beliefs about students and learning, and interactions with students, colleagues, and the local community (Higher Education Research Institute, 2018). The HERI Faculty Survey is conducted on a triennial basis, with the 2016-2017 administration being the most recently available data. Participating institutions vary by Carnegie classification, size, urbanicity, selectivity, and geographical region.

Data related to institutional characteristics were also drawn from the National Center for Education Statistics' Integrated Post-Secondary Education Data System (IPEDS). Colleges and universities that participate in federal financial aid programs are mandated to report data to

IPEDS, which makes it the premier source of data on colleges and universities in the United States. A dozen interrelated survey components provide information on institutional characteristics, admissions, enrollment, human resources, and student outcomes, among other measures. Selected IPEDS variables from the 2016-2017 academic year were merged to the dataset containing faculty survey respondents to provide a more complete understanding of the extent to which individual and institutional characteristics collectively explain differences among STEM faculty's pedagogical practices.

Sample

To explain variation in STEM faculty's teaching practices, the 2016-2017 Faculty Survey data was restricted in several ways. First, I used an item that captures the department of the faculty member's current appointment to identify those faculty who are currently employed in STEM (See Appendix A for a full list of STEM departments). Department of employment was utilized instead of the discipline in which the faculty member's degree was awarded given this study's emphasis on the role of the STEM department in influencing teaching practices. This process also filtered out STEM graduates who are teaching outside STEM departments. However, some of the faculty identified in this study may be teaching in a STEM discipline outside their academic major (e.g., Mathematics graduate teaching in Statistics). Second, given the differential treatment of part-time faculty by institutions with regards to access to resources and professional development, this study was limited to ladder faculty who indicated they are full-time employees during the current academic year. Third, the sample was limited to ladder faculty who were employed at either public or private research universities, in line with the crucial role these institutions play in STEM degree production and research productivity (National Science Board, 2018). Further, Carnegie Classification was used to differentiate

Research 1 and Research 2 universities. Fourth, cases that were missing for the outcome or either of the demographic variables (race, sex) were excluded from the sample. The final sample included a total of 1063 cases across 15 public and six private universities nationwide. Of these 21 campuses, 8 are considered Research 1 universities and 13 are Research 2 universities.

Variables

This section reviews the variables from both the HERI Faculty Survey and IPEDS that were included within the quantitative model. First, the dependent variable is discussed in detail. Next, four sub-sections describe individual-level blocks of variables: Background characteristics, professional characteristics, faculty activities and time commitments, and perceptions of the profession and institution. The final block of variables comprises institutional characteristics. These blocks are important both conceptually and methodologically, as is discussed below. Appendix B provides a full accounting of the variables included in the quantitative analysis.

Dependent Variable. The quantitative portion of this study was centered around the variable *Student-centered pedagogy* (SCP), a factor composed of nine individual items. These items include class discussions, cooperative learning, experiential learning, group projects performances/demonstrations, using real-life problems, using student inquiry to drive learning, student presentations, and student evaluations of each other's work. Appendix C lists each of these items' factor loadings and the overall Cronbach's alpha. These nine items are subcategories of the same question bank and thus share the same response options. The survey question asks, "In how many of the courses that you teach do you use each of the following?". Faculty can indicate that "None", "Some", "Most", or "All" of their courses utilize each of these nine specific pedagogical strategies.

Background characteristics. This study tested several demographic characteristics to determine whether particular groups of faculty have greater inclinations toward student-centered teaching compared to others. There is limited evidence that women may approach science teaching differently than their male counterparts. For example, Wieman (2017) noted several examples of influential female faculty who take initiative in transforming undergraduate pedagogy within their departments. Examining whether sex plays a role in teaching practices for this sample of faculty is worthwhile.

In addition to female faculty members, racial and ethnic minorities are vastly underrepresented in STEM fields, especially when filtering for four-year universities. In the sample, 3.5 percent of the faculty identified as Black or African American, 1.8 percent identified as Latinx, and 0.3 percent identified as Native American. Given the very small number of racial and ethnic minorities in the sample, a measure of Underrepresented Racial Minorities (URM, African American/Black, Latinx, and Native American/Alaska Native) was included in the model as opposed to individual binary variables for each racial/ethnic group.

Professional Characteristics. These variables encompass the attributes of faculty members' position within their institution. Rank was included in the models as the literature has conflicting opinions about the extent to which less experienced faculty members may embrace student-centered pedagogy (Henderson, 2008; Wieman, 2017). Rank is encompassed by two binary variables representing assistant professor and full professor. For both dichotomous variables, the rank of associate served as the comparison group. Creating these binary variables helps tease out individual differences in the way faculty at distinct points in their careers approach their teaching. Since rank is heavily correlated with tenure, indicators for being a tenured or tenure-track faculty are not included in the quantitative analysis. However, the model does include an item that indicates whether a faculty member is not on the tenure track but is employed at a university that has a tenure system. This is because the theoretical foundations of this study highlight the importance of incentives (i.e., tenure) and prosocial behavior, and literature has shown that faculty who are detached from the tenure process and its potent influence may utilize student-centered teaching to a different extent compared to their tenure-track peers. Subsequent references to faculty not on the tenure-track are a refence to this group of instructors, which are not to be confused with faculty who are employed at institutions that lack a tenure system. The latter are also included in the HERI Faculty Survey sample but are not included as a predictor in the model.

The number of years that have passed since a faculty member received their first academic appointment may also be related to faculty's pedagogical style. Several professional development initiatives specifically target junior faculty members (Ebert-May et al., 2015; Henderson, 2008), an intentional investment in potential long-term pedagogical change. For faculty who have been teaching for many years in one style, it can be quite difficult to accept change (Wieman, 2017). Furthermore, how faculty were taught while they were students has been discussed as a crucial influence on teaching practices (Addis et al., 2013; Major & Palmer, 2006; Michael, 2007). This would suggest that as teaching practices continue to change, newly-trained faculty would have been exposed to and theoretically, more willing to embrace student-centered teaching in their classrooms.

Finally, binary variables indicating which STEM department a faculty member is currently employed at were included, with the largest department, Life Science, serving as the reference group. Specific departments are grouped into larger scientific areas: Physical Science, Engineering, Mathematics and Statistics, and Computer Science and Technologies (See

Appendix A). These variables provide insight into differences between faculty teaching practices across departments.

Faculty's Activities and Time Commitments. The conceptual framework and literature guiding this study suggest several likely relationships connecting faculty's teaching practices with their job responsibilities, daily activities, and motivations. According to RDT, faculty would be expected to be prioritize their work based upon the availability of scarce resources (e.g., time, funding, incentives). In a department where promotion and tenure heavily favor research productivity, faculty would be expected to invest substantially more time in their research rather than in their teaching or service responsibilities. Several variables attempted to capture the strong impact of research activities on teaching cited in the literature (Austin, 2011; Brownell & Tanner, 2012; Wieman, 2017). To account for this relationship, I include variables that capture: the number of research grants the faculty member has written in the past three years, the hours per week a faculty member does research or scholarly activities, and the number of publications in the last three years. Individually and collectively, these items are expected to capture the perception that faculty prioritize research over teaching. Additionally, a measure of whether faculty have received external funding from a state or federal government source is included in the model with the aim of accounting for whether faculty have invested time pursuing and managing extramural funding.

The model includes a factor capturing extensive and in-depth faculty engagement with undergraduate students. Factor loadings for each of the four items used to create this factor and the Cronbach's alpha all exceeded recommended minimum thresholds (Appendix C). Some of these items include engaging undergraduates on a research project and presenting with undergraduates at a conference. This latent variable is significant as it highlights a willingness to take on extra-role responsibilities for which a faculty member may not be rewarded. Related variables include the extent to which a faculty member mentors undergraduate and graduate students respectively. This behavior aligns with the altruistic dimension of Organizational Citizenship Behavior (Organ, 1988).

Additional variables capture items related to the practice of teaching, including professional development and how much time is spent preparing for teaching each week. Items relating to professional development include participation in organized activities around enhancing pedagogy, curriculum development, or funded teaching workshops. Items also account for faculty members' additional time demands within and outside the university. These include the number of hours per week a faculty member devotes to committee work and meetings and community or public service. Faculty who may be engaged in higher levels of service within and outside the university may display lower use of student-centered pedagogy given a lack of available preparation time. The following group of variables examine faculty perceptions of their teaching and institutions context.

Faculty Perceptions of Profession and Institution. This block of variables includes items related to a faculty member's perceptions of their profession, how their perception impacts them personally, and their professional and personal priorities. In line with Resource Dependence Theory, incentives would be expected to make a change in how faculty approach teaching. Therefore, a variable capturing whether faculty have been recognized for outstanding teaching is considered. A key item in this group is the extent to which a faculty member feels there is close alignment between their work and their personal values, as predicted by OCB (Bateman & Organ, 1983; Organ, 1988). Additional items include the extent to which a faculty member believes they have to work harder than their colleagues to be considered a legitimate scholar and whether they consider they were adequately prepared for their faculty role by their graduate department. The latter captures the importance of professional development and the fact that many faculty members receive little to no training on teaching during graduate school (Kane, 2002; Manduca et al., 2017; Owens et al., 2018). Finally, measures of career-related stress, satisfaction in the workplace, and satisfaction with compensation provide greater clarity on how job responsibilities personally impact faculty and the extent to which these responsibilities may influence teaching practices.

Institutional Characteristics. Both original and derived variables are drawn from IPEDS and the HERI Faculty Survey. IPEDS variables include measures of student-faculty ratio, institutional control, and whether the campus is a minority-serving institution (MSI). Given faculty concerns with classroom size as they relate to innovations in pedagogy (Addis et al., 2013; Austin, 2011; Dancy & Henderson, 2008; Henderson & Dancy, 2008; Michael, 2007), student-faculty ratios are included from IPEDS. Although this is not a direct measure of the size of STEM undergraduate classrooms, it serves as the nearest proxy and may shed light on whether larger STEM classrooms curb the implementation of student-centered pedagogy. The derived variables include a binary MSI measure indicating whether the institution is classified as an MSI. The five MSI universities in the sample include one Historically Black College or University (HBCU) and four Hispanic-Serving Institution (HSI). Additionally, a measure of selectivity is created from first-time full-time students' median SAT Verbal and Mathematics scores (or ACT composite scores). Whether an institution is classified as a Research 1 or Research 2 campus is derived from the publicly available Carnegie classification system for the 2016-2017 academic year.

Missing Data

Missing data is a common problem when working with survey data. As previously mentioned, cases with missing data for the outcome and demographic variables were excluded from the analytic sample, therefore, no cases were imputed for these variables. The remaining variables from the HERI Faculty Survey ranged between less than one percent and less than five percent of cases missing. For variables with missing cases, I relied on the Expectation-Maximization algorithm to impute missing values for items with a small proportion of missing data (Dempster, Laird, Rubin, 1977). The EM algorithm has been found to be more reliable than traditional methods for handling missing data, such as listwise deletion or mean imputation (Cox, McIntosh, Reason, Terenzini, 2014). Variables merged from the IPEDS data collection system did not include missing data.

Centering

Before proceeding to a discussion of the analytical process, it is important to consider how variables were centered in the model. Centering involves rescaling a variable by subtracting a constant and makes for an easier interpretation of coefficients by designating either the group or grand mean for each centered variable equal to zero (Raudenbush & Bryk, 2002). Continuous variables at both level-one and level-two were centered around the grand mean, which involved subtracting the mean value of all faculty in the sample from an individual's value for a given variable. Continuous variables that were tested for interaction effects at level-one were group centered, which involved subtracting the school mean from each faculty's value on that variable. Non-continuous variables were not centered.

Analyses

Initial analyses included descriptive statistics for all variables in the sample. These statistics describe the sample generally and include the item's mean, standard deviation, and minimum and maximum values. Additionally, cross-tabulations and correlations provide a glimpse into relationships between variables. Primary analysis involved a hierarchical linear model on the student-centered pedagogy outcome (Raudenbush and Bryk, 2002). The SCP outcome employed a multilevel linear model with a slopes-as-outcomes approach given the continuous nature of the outcome. The first step in this process was to specify a fully unconditional model with no covariates to determine the extent to which schools vary in their mean student-centered pedagogy scores (Raudenbush and Bryk, 2002). Having a continuous outcome allows us to estimate the variance components at both the faculty- and school-level. With these parameters, a measure of the Intra-class correlation (ICC) was derived, which is the proportion of the variance in the outcome (SCP) that is found between schools (Raudenbush and Bryk, 2002). Generally, ICC values above 10 percent would necessitate a hierarchical analytical strategy, yet given the nested nature of the data and the proposed research questions, this study proceeded with a hierarchical approach even with a substantially lower ICC value (Thomas & Heck, 2001).

Once I calculated the percentage of variance in student-centered pedagogy scores that existed between schools, I proceeded to an explanatory model to examine what variables were associated with these differences. The conditional model at level-1 included faculty-level predictors entered in the order specified above, beginning with demographic characteristics, and proceeding through faculty perceptions of their profession and institution. Entering variables in a blocked sequential manner provided the opportunity to see how the explanatory power of predictor variables changed as additional variables enter the model. While the level-one model included faculty-level variables, the level-two model included institution-level variables. Results from the level-one model determined the extent to which each of the variables was associated with student-centered pedagogy. Level-two results helped determine if differences in the variation of SCP scores between schools can be attributed to the variables included in the model.

Qualitative Data Collection and Analysis: An Inquiry into STEM Faculty's Student-Centered Pedagogy

Approach to Inquiry

This study followed a pragmatic worldview in its approach to the study of teaching practices in STEM. Pragmatism is focused on applications and solutions to problems, rejects traditional dualisms (e.g., facts vs. values), and applies philosophical and methodological approaches based on how well they work in solving a problem (Johnson, & Onwuegbuzie, 2004). Following results from the quantitative phase, the qualitative inquiry involved a detailed exploration of STEM faculty's teaching practices. This second phase explored in-depth the factors and characteristics that shape teaching, how faculty's pedagogical approach has changed over time, and specifically, the role of the environmental context in shaping teaching. Qualitative results served to not only test the theoretical propositions of OCB and RDT, but also confirm or fail to confirm quantitative findings.

Participant Selection

Interview participants were selected from the pool of STEM faculty respondents to the 2016-2017 HERI Faculty Survey. When completing this survey, faculty were asked if they would be willing to participate in future research. Those who answered affirmatively provided their contact information to HERI for potential follow-up. This mechanism provided the avenue for identifying individual faculty members who were invited to participate in this study and provide a deeper analysis of the quantitative findings. Participants contributed to a broader understanding of how faculty select their teaching practices and what factors promote or inhibit the use of student-centered pedagogy. The potential interview pool included the same individuals represented in the analytic sample in the quantitative phase of the study, with the caveat that some of the respondents in the quantitative analytic sample may not have indicated an interest in participating in future studies.

Data Collection

Recruitment e-mails were sent to faculty identified using the selection method outlined above. Faculty who expressed interest received a follow-up email to coordinate an interview date and time and provide consent to participate in the study. The consent form addressed confidentiality, anonymity, potential risks and benefits of participating in this study, and provided contact information for the researcher. It also stressed how faculty could have withdrawn from this study at any time. Faculty who provided their informed consent were invited to participate in a phone interview or a virtual face-to-face interview via an online platform (e.g., zoom). These interviews were digitally recorded by the researcher and subsequently transcribed verbatim either by the researcher or through a confidential third-party. Interviews lasted between 30 and 75 minutes, with an average of 50 minutes.

A semi-structured interview protocol was utilized with the goal of covering a wide range of factors that may impact teaching practices in STEM (Appendix D). This protocol was developed in multiple stages. First, interview questions were formed based on the research questions, conceptual framework, and literature review that guided this study. This protocol was subsequently revised to reflect the findings from the quantitative phase of this study. While the essence of the protocol remained the same, the wording of some questions was modified, and additional questions were added and/or removed to reflect the quantitative results.

The interview protocol started off by building rapport with the faculty member by inquiring about their trajectory to their current position and what they most enjoy about their position. The bulk of the interview questions focused on pedagogical training, the evolution of their approach to teaching, factors that impact their teaching, areas of potential improvement, and views about student learning. Several questions also teased out the influence of departmental support for teaching (or lack of) and the reward structure embedded within higher education. The protocol consisted of eight core questions and numerous probing questions for more detailed responses. Faculty responses also prompted additional substantive or explanatory questions throughout the course of the interview.

Data Analysis

Data analysis commenced as soon as the first interview was completed and proceeded throughout the data collection phase. To facilitate analytical insights and capture the ways I think about the data in real-time, I wrote analytical memos after each interview, while listening to the recordings, while reviewing transcripts, and throughout the coding process (Maxwell, 2013). These memos provided greater familiarity with the data, and as I completed more interviews, the ability to make connections across cases and themes. Moreover, analysis of interview data began as soon as the first transcription was available, rather than waiting to complete all interviews. Thus, data collection and analysis happened simultaneously.

Analysis of interview transcripts proceeded through numerous steps. First, data for each participant was organized, including transcripts and memos written after completing the interview and while listening to the data. Second, transcripts were read multiple times to ensure familiarity with the data and highlight passages of interest to the researcher (Seidman, 2013).

During these initial readings, I used analytical memos to reflect on what was being said, the tone of the ideas, and the meaning that was being conveyed by the participant (Creswell, 2009).

Step three involved a detailed analysis through a coding process. I utilized Dedoose, a web-based qualitative software program, to move through two stages of coding: initial and axial coding. Initial coding (also known as Open Coding) breaks up the data into specific sub-units that can be compared for similarities and differences, allowing the researcher to reflect on the contents and nuances of the data (Saldaña, 2016). During this first round of coding, interview transcripts were re-read multiple times to ensure initial codes are accurately capturing the data. Axial coding extends the analytical work accomplished during initial coding by reassembling data into revised coding categories (Saldaña, 2016). This second state of coding revised codes, explored how categories and subcategories related to each other, and selected the most representative codes (Maxwell, 2013; Saldaña, 2016). As was the case with the first cycle of coding, axial coding proceeded through multiple rounds through each of the interview transcripts.

The final step in the analytical process was to understand relationships between analytical categories and structure the qualitative data in such a way that facilitated the writing of results (Saldaña, 2016). This was accomplished using a data analysis matrix that visually displayed the most important themes and their accompanying data (Maxwell, 2013). Creating this matrix through a qualitative software program allowed the researcher to see patterns in the data, make comparisons, and develop new strategies for sharing the study’s findings. It must be noted that these analytical steps were not linear in nature, but rather were cyclical within and amongst participants, especially during the early stages of data analysis when data collection was ongoing.

Limitations

This study has several important limitations. As with all survey research – especially secondary data analysis – the researcher was limited to the items available on the survey instrument. While the HERI Faculty Survey captures a wide range of pedagogical measures and factors that may impact them, this instrument was not designed for this purpose. For example, the dependent variable in this study comes from the question, *In how many of the courses that you teach do you use each of the following?* While many of the often-cited barriers to pedagogical transformation (e.g., class size) are in relation to undergraduate courses, faculty undoubtedly include perceptions of their graduate courses in their response to this item. In an ideal scenario, this question would have solely referred to undergraduate courses. Unfortunately, developing a survey instrument specific to this study was not a feasible option.

This study is not immune to limitations faced elsewhere in the research literature. Several studies have noted that faculty perceptions of their teaching practices may not accurately reflect how they teach their courses (Derting et al., 2016; Ebert-May et al., 2015). This presents a challenge for this study considering the inability to observe real-time teaching practices. However, unlike studies that have cited this discrepancy, the HERI Faculty Survey was not solely created to examine teaching practices nor was it pitched to faculty in this way. While we cannot rule out some degree of response bias in the sample, it is plausible that this design aspect curtailed such discrepancies between reported and actual teaching practices.

This study is also limited by a homogenous sample. While STEM faculty departments often-time are lacking in demographic diversity (Carrigan, Quinn, & Riskin, 2011), several decisions made during the design of this study exacerbate this lack of diversity. Selecting four-year public and private institutions and ladder faculty further limits the number of women and underrepresented racial minorities who could be included in this study. The inability to include their teaching practices and experiences to a greater extent may potentially mask differences in pedagogical approaches between men and women and white and non-white faculty members in STEM.

In addition to limitations stemming from the use of the HERI Faculty Survey, additional considerations must be laid out regarding the study design. Most importantly, the HERI Faculty Survey was administered in the 2016 academic year while semi-structured interviews took place a full three years later in the fall of 2019. It must be noted that faculty interviews are being used to attempt to explain, contextualize, and expand upon findings based on data from several years prior. Thus, it is certainly possible that interviewees' use of SCP may have changed during the intervening time and thus their narrative responses may or may not align with their frame of thinking at the time of the HERI Faculty Survey. This limitation is noted especially because SCP scores are directly used as an analytical lens in Chapter 5 to help situate findings from individual faculty.

CHAPTER 4: RESULTS FOR VARIATION IN STUDENT-CENTERED TEACHING

Introduction

This study sought to understand the factors that explain variation in STEM faculty's use of student-centered teaching at research universities. Investigating the opportunity structures, faculty activities, time commitments, and institutional contexts that shape instructors' decisions to incorporate pedagogies may contribute to efforts aimed at enhancing student learning and student outcomes at public and private institutions across the country. As described in Chapter 3, this study used Hierarchical Linear Modeling (HLM) to investigate the individual and institutional-level factors which explain differences in faculty members' instructional practices. This technique will thus address two of the research questions posed by this study. First, understanding what individual and institutional characteristics, activities, perceptions, and commitments explain variation in faculty's use of student-centered pedagogy. Second, measuring the extent to which institutional and departmental characteristics shape faculty's use of student-centered teaching. The latter question will also be addressed in the subsequent chapter discussing qualitative results.

This chapter begins with a frequency analysis of key sample characteristics and proceeds to examine descriptive statistics of all independent and dependent variables included in the final Hierarchical Linear Model (HLM) analysis. Subsequently, HLM is introduced and the final analysis is derived through a sequential process beginning with an unconditional model and progressing through four blocks of variables. Model disparities are discussed throughout the building process and final results are presented. Afterwards, interaction effects present in the model are discussed and tested. The chapter concludes with a summary of the quantitative results.

Descriptive Statistics

Sample

The final sample was composed of ladder faculty from STEM disciplines at both public and private research institutions. Table 4.1 presents a breakdown of key institutional and faculty characteristics by academic discipline. While the sample is reasonably varied across STEM departments, it is less representative of underrepresented faculty and women. Although women make up only a quarter (25.7%) of the faculty in this study, they represent a larger share of Life Science faculty (34.8%) than other STEM disciplines. This is consistent with research that has found women to be more numerous in Life Science fields (e.g., biology) than other STEM departments (Carrigan, Quinn, & Riskin, 2011). Notably, African American/Black, Latinx, and Native American/Alaska Native faculty represent less than five percent (4.1%) of surveyed faculty. The majority of faculty in the sample are tenured faculty members (71.3%) and the sample is nearly even split between research one (47.3%) and research two institutions (52.7%).

Table 4.1
Percentage of STEM Faculty by Classification, Control, Sex, URM Status, and Tenure (n=1,063)

Department	Faculty	Research One	Private Institution	Female	URM*	Tenured
Life Science	336	49.4	34.5	34.8	4.2	70.2
Engineering	225	57.3	41.3	20.0	4.0	65.8
Mathematics and Statistics	138	37.7	43.5	20.3	3.6	70.3
Physical Sciences	272	45.2	35.3	23.5	4.0	76.1
Computer Science and Technologies	92	35.9	43.5	20.7	5.4	76.1
Total	1063	47.3	38.1	25.7	4.1	71.3

Note: Underrepresented Racial Minority (URM) refers to African American/Black, Latinx, and Native American/Alaska Native.

Faculty-level Independent Variables

Table 4.2 presents descriptive statistics for student-centered pedagogy and all of the independent variables included in the final HLM analysis. While the binary nature of some of the items in the final model renders their descriptive statistics inconsequential, several items in each of the major blocks of variables are worth a closer look. As far as professional characteristics, faculty in the sample are quite experienced instructors with a mean of 18 years since their first academic appointment. This is perhaps not surprising considering the high rate of tenured faculty members in the sample, yet it is important to note the wide range of responses (SD = 11.38, Min. = 1, Max= 61). Although some faculty may be relatively new to the profession, many have clearly been teaching for quite a long time. Similarly, faculty reported significant variation in institutional salary, while the mean salary stood at $90,000 to $99,999, some faculty members earned considerably more or less than this amount per year.

With respect to activities and time commitments, Table 4.2 shows that faculty members were moderately prolific in their number of manuscripts published or accepted for publication during the last three years. Considering that all these faculty members are employed at research institutions and roughly half are working at research one campuses, the rate of publication is not surprising. In addition, the widespread range of responses for this item (SD = 6.38, Min. = 1, Max. = 22) speaks to the variation in faculty members' position within academia (i.e., tenured vs. not tenured, assistant professor or professor) and to the pressures that institutions and professional characteristics may place on a faculty member.

How faculty spend their time and how much of it is allotted to teaching-related activities is especially important to this study. The average Likert-scale scores and corresponding hours per week doing research and scholarly writing (4.32, 9-12 hours per week), preparing for teaching and grading (3.36 or 5-8 hours per week), committee work and meetings (2.86 or 1-4 hours per week), community or public service (1.80 or None) demonstrate the importance of these activities to faculty members and the job responsibilities and expectations of ladder faculty at research institutions. With respect to the time allotted in preparing for teaching (including reading papers and grading), some faculty said they spend no time during the week on these activities while others spend more than 21 hours per week. Given that time allocations may vary by institutional type, Figure 4.1 displays hours per week preparing for teaching by Research 1 or 2 status. Faculty at Research 1 institutions outnumber their peers at Research 2 campuses in allocating no hours per week, one through four hours per week, and five through 8 hours per week. On the other hand, Research 2 faculty are more numerous at higher levels of hours spent on preparing for teaching. The average Likert-scale scores for hours spent preparing for teaching were 3.16 (Research 1, n=503) and 3.56 (Research 2, n=560). This demonstrates that although faculty at Research 2 institutions are more likely to spend a higher number of hours than their Research 1 peers, the difference in the actual number of average hours is minimal, with both groups of instructors scoring in the 5-8 hours per week range.

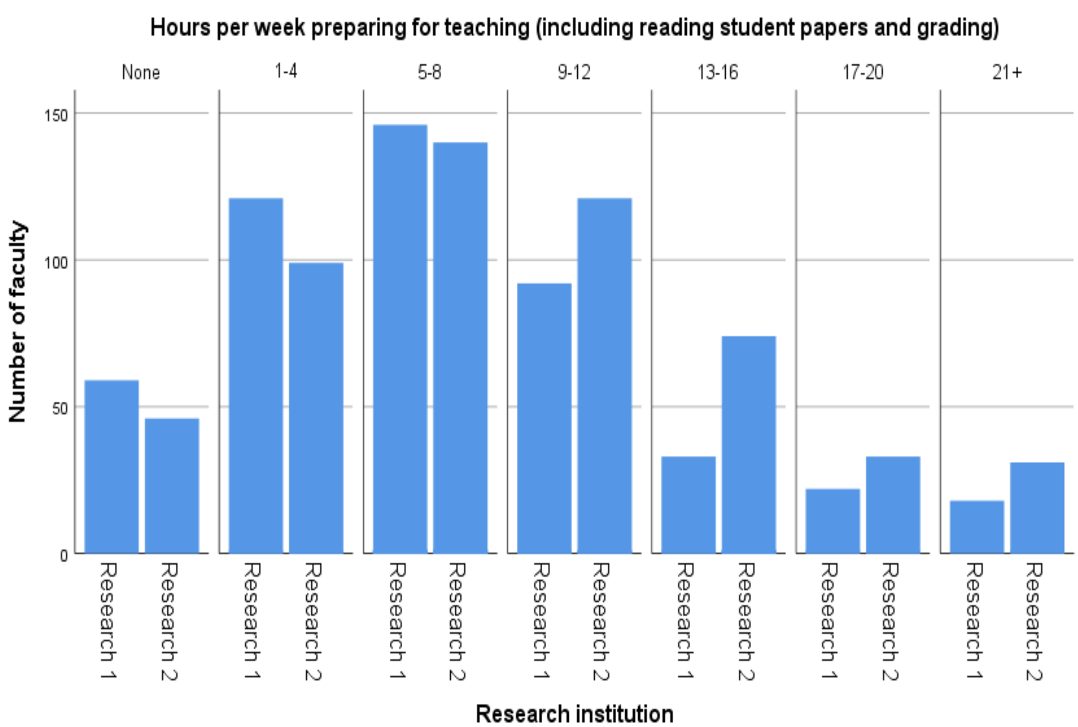

Figure 4.1. Hours Per Week Preparing for Teaching by Research Institution

Faculty perceptions of their profession and institution provide a glimpse into how instructors view their current role and how they position themselves within their working environment. On average, faculty members felt that to some extent the graduate training they received prepared them well for their role in academia. Given this result, it will be worthwhile to explore further during the semi-structured interviews whether this level of preparation was in relation to research, teaching, service duties, or a combination of the three. Faculty felt that to a large extent, their work and personal values were closely aligned, which is perhaps a reflection of the fact that on average, instructors have been in academic for nearly twenty years. Additional items included questions where faculty were asked whether they (1) Try to dispel perceptions of competition, (2) Achieved a healthy balance between their personal and professional lives, and (3) Had to work harder than their colleagues to be perceived as a legitimate scholar. Respondents were found to somewhat disagree with each of these views.

Institutional-level Independent Variables

The continuous variables included in the model at the institutional level include student-faculty ratio and selectivity (SAT score). The mean ratio of students to faculty across all institutions was 17.34, with public institutions averaging 18.36 and private institutions averaging 15.69 students per instructor. Overall, the difference in student-faculty ratio between public and private research institutions does not appear to be substantive. As far as selectivity goes, the mean SAT score for all the institutions in the sample was 1203.47 (out of 1600), with Research 1 institutions scoring a mean of 1239.76 and their Research 2 peers scoring 1170.87. The remaining items in this block of variables and dichotomous and thus their descriptive statistics lack a meaningful interpretation.

Table 4.2
Descriptive Statistics for Outcome and Independent Variables Included in the Final Model

	Mean	S.D.	Min.	Max.
Outcome				
Student-centered pedagogy	-0.01	0.93	-2.07	2.14
Background Characteristics				
Female	1.26	0.44	1.00	2.00
URM	1.04	0.20	1.00	2.00
Professional Characteristics				
Years since first academic appointment	18.51	11.38	1.00	61.00
Salary	10.39	2.01	1.00	15.00
Assistant Professor (Associate)	0.23	0.42	0.00	1.00
Professor (Associate)	0.48	0.50	0.00	1.00
Not on tenure track	0.07	0.26	0.00	1.00
Physical Science (Life Science)	0.26	0.44	0.00	1.00
Engineering (Life Science)	0.21	0.41	0.00	1.00
Mathematics/Statistics (Life Science)	0.13	0.34	0.00	1.00
Computer Science (Life Science)	0.09	0.28	0.00	1.00
Faculty Activities and Time Commitments				
Past three years: Engaged in academic research that spans multiple disciplines	1.77	0.42	1.00	2.00
Past three years: Written research grants	1.86	0.34	1.00	2.00
Past three years: Received state or federal government funding	1.68	0.46	1.00	2.00
Past three years: Number of accepted or published writings	9.27	6.38	1.00	22.00
Hours per week: Preparing for teaching	3.36	1.53	1.00	7.00
Hours per week: Committee work and meetings	2.86	1.30	0.40	7.00
Hours per week: Research and scholarly writing	4.32	1.89	1.00	7.00
Hours per week: Community or public service	1.80	0.95	0.90	7.00
Participated in organized activities around enhancing pedagogy or student learning	1.61	0.49	1.00	2.00
Participated in the development of curriculum	1.84	0.36	1.00	2.00

Past year: Attended funded workshop focused on teaching	0.40	0.49	0.00	1.00
Undergraduate engagement	0.03	0.92	-1.54	1.82
Perceptions of Profession and Institution				
Formally recognized for outstanding teaching	1.34	0.48	1.00	2.00
Graduate training prepared you well for faculty role	3.74	0.96	1.00	5.00
Close alignment between work and personal values	4.14	0.83	1.00	5.00
I try to dispel perceptions of competition	2.53	0.83	1.00	4.00
Achieve a healthy balance between personal and professional life	2.73	0.94	1.00	4.00
I have to work harder than my colleagues to be perceived as a legitimate scholar	2.54	0.99	1.00	4.00
Career stress	0.01	0.86	-3.30	2.01
Job satisfaction: Workplace	0.02	0.95	-2.53	1.58
Job satisfaction: Compensation	0.06	0.92	-2.70	1.62
Institutional Characteristics				
Student-faculty ratio	17.34	4.44	8.00	29.00
Selectivity (SAT score)	1203.47	117.23	900.00	1427.00
Institutional control (private)	1.38	0.49	1.00	2.00
Minority-serving institution	0.12	0.33	0.00	1.00
Research one	0.47	0.50	0.00	1.00

Outcome: Student-centered Pedagogy

Student-centered pedagogy (SCP) is a construct of nine related items that capture the extent to which faculty utilize active learning teaching techniques in their courses. These items include whether instructors rely on class discussions, cooperative learning (small groups), group projects, or performance/demonstrations for their teaching. See Appendix C for a full list of all items in the construct, factor loadings, and Cronbach's Alpha statistics. Higher SCP scores indicate that faculty draw upon these teaching techniques on a consistent basis while lower scores on SCP would suggest that faculty are not frequently relying upon these teaching practices in their classrooms. Figure 4.2 displays the distribution of SCP scores for all faculty members in the sample (n=1,063). The distribution is roughly normal with an approximate mean of zero and standard deviation of .93. The minimum and maximum values for SCP (-2.07 and 2.14, respectively) demonstrate the wide variation that exists in faculty's individual SCP scores.

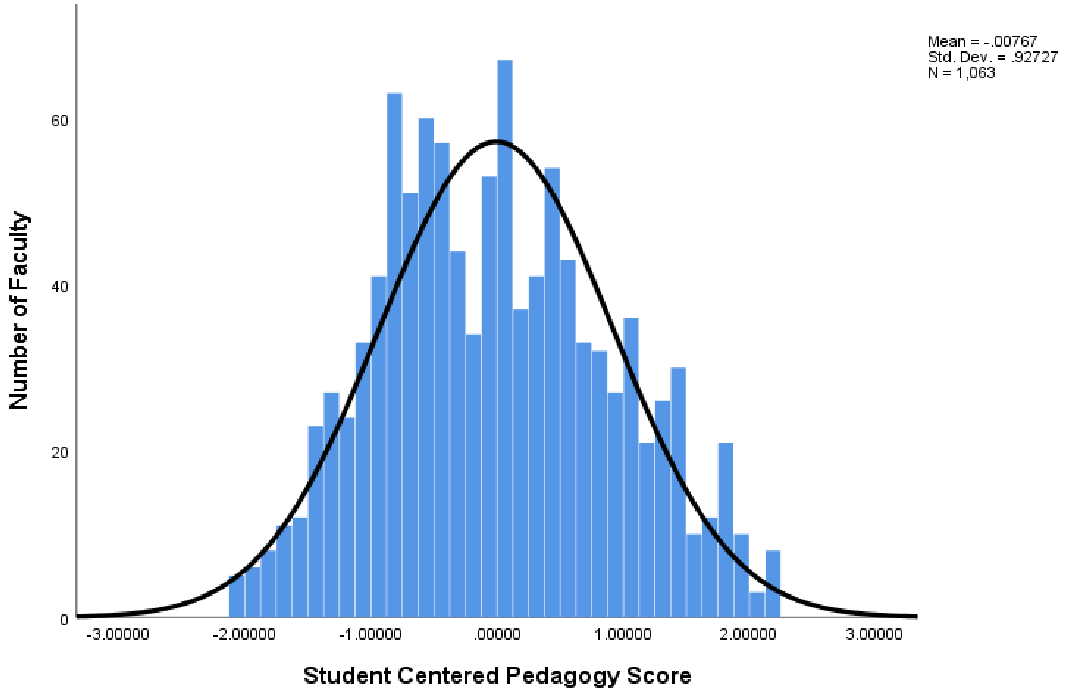

Figure 4.2. Distribution of Student-centered Pedagogy Scores

Since this study is additionally concerned with the variation in faculty SCP scores that is influenced by the individual's institutional environment, is was worthwhile to examine the mean SCP scores across institutions. Figure 4.3 displays the average SCP score for each of the 21 institutions surveyed (institutions are displayed in no particular order). The number of faculty surveyed at each institution ranged from a low of six to a high of 177 and averaged 51 respondents. A total of 8 institutions had a combined positive score on SCP while 13 institutions scored negatively. While the highest score was .28 and the lowest came in at -.35, it is important to highlight that the average scores by institution are fairly close to the mean of -0.01 for all individual faculty members seen in Figure 4.2. Additionally, the mean SCP scores at each institution are well within the standard deviation of .93 for SCP scores across all faculty. This would suggest that there is more variation in SCP scores between faculty than between institutions.

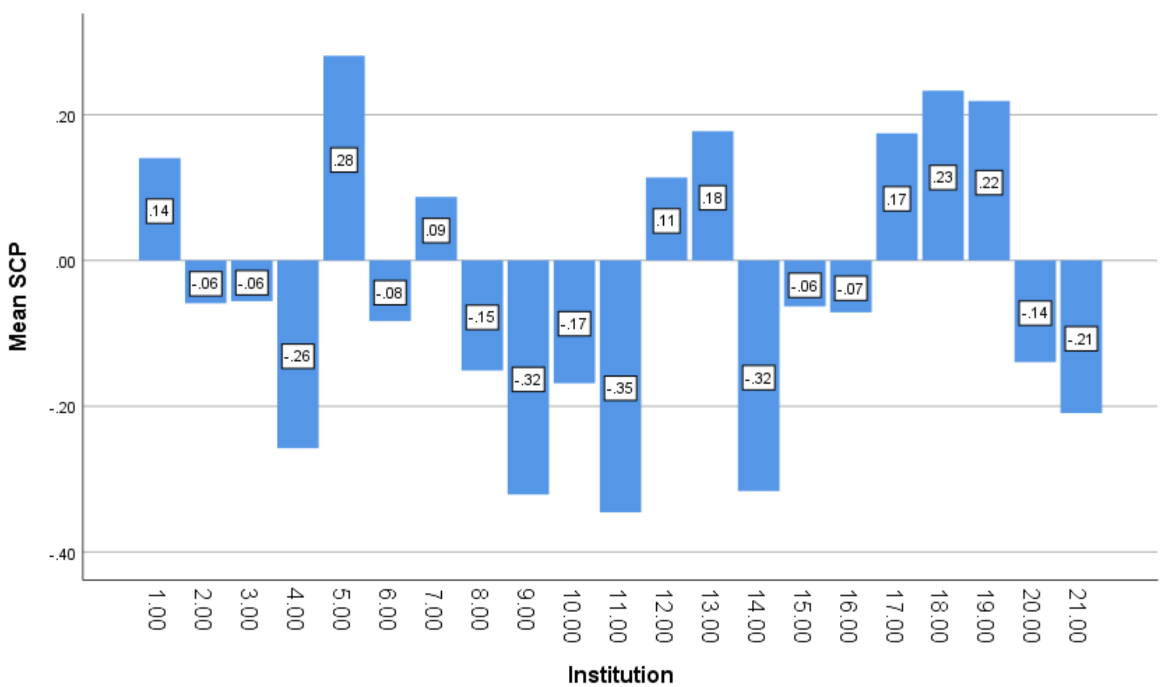

Figure 4.3. Mean Student-centered Pedagogy Scores by Institution

Table 4.3 displays the number of institutions by positive or negative mean SCP scores and select institutional characteristics. Of the eight institutions with positive scores, six of them were public institutions and five of them were Research 2 universities. Curiously, for each of the institutional characteristics, with the exception of Minority-serving Institutions (MSI; Hispanic Serving Institutions, Historically Black Colleges and Universities), more institutions were observed with a negative mean SCP score than a positive one. While the ratio of positive to negative scores is nearly identical between research one and two institutions, it is different between public and private schools, albeit with a limited sample size.

Table 4.3
Number of Institutions by Characteristics and Mean SCP Scores (n=21)

	Research 1	Research 2	MSI	Non-MSI	Public	Private
Positive SCP	3	5	3	5	6	2
Negative SCP	5	8	2	11	9	4
Total	8	13	5	16	15	6

A descriptive analysis of the sample, independent variables, and outcome of interest demonstrated that extensive variation exists at the individual level. Faculty are diverse in many ways and report a range of scores on views regarding their profession, institution, and their personal lives. Similarly, faculty present a healthy variety of scores on student-centered pedagogy. While the institutions where faculty are employed are similar and divergent in various ways, the potential influence of environmental characteristics on an individual faculty member's use of student-centered pedagogy merits additional attention. The next section will explore this relationship in further detail and take a deep dive into what influences the extent to which faculty incorporate student-centered teaching in their classrooms.

Hierarchical Linear Modeling

Unconditional Model

As discussed at the outset of this chapter, the Hierarchical Linear Model (HLM) is built sequentially, and the evolution of the model is discussed throughout this process. The first step in building the HLM is the unconditional or null model. Running the model with no predictors at either level one or level 2 yielded the variance components at the faculty (0.836) and institutional level (.021). Respectively, these represent the level of within-group variability (faculty) and between-group (institutions) variability that exists in the sample. These components were then used to calculate the intraclass correlation coefficient (ICC), with a result of 2.4%. This means that 2.4% of the variability in the outcome (student-centered pedagogy) is between the institutions in the sample.

While we would usually want higher levels of ICC when using HLM, several reasons necessitate the use of this analytical method despite the low ICC. First, HLM is a more robust analytical strategy than alternatives such as ordinary least squares regression given that Type 1 errors can still take place when not accounting for the nested structure of data (Thomas & Heck, 2001; Musca et. al., 2011). Second, the research questions posed by this study and the mixed-method research design center the influence of the institution on a faculty member. Third, utilizing HLM allows for cross-level interaction effects, unlike OLS regression. Lastly, the lack of a more significant ICC may be partially explained by the construction of the sample (ladder faculty at research institutions) yet these institutions may still have an influence on faculty members' teaching.

Model 1

The first model predicts student-centered pedagogy scores from individual faculty members' sex and whether they are an underrepresented racial minority (URM). Table 4.4

presents the results of each of the models as the HLM is successively built. In the first model, female faculty were found to be a statistically significant predictor ($\gamma = 0.18$) of student-centered pedagogy. The fact that women's scores on SCP were found to be 0.18 points higher than their male peers supports evidence of female faculty members who have taken the initiative to transform undergraduate teaching within their departments (Wieman, 2017). While sex was found to be associated with SCP, URM status did not demonstrate a statistically significant relationship with the outcome. This is not surprising considering that less than five percent (4.1%) of the faculty in the sample are underrepresented racial minorities (African American/Black, Latinx, Native American/Alaska Native). A more diverse faculty and/or sample is required to examine whether racial and ethnic minorities teach appreciably different than their non-URM peers in STEM fields.

Model 2

In the second model, *Professional Characteristics* such as the number of years since the faculty members' first academic appointment, salary, rank, and academic department enter the analysis in addition to background characteristics. Controlling for the inclusion of sex and whether the faculty member is an underrepresented racial minority, several items were found to significantly predict student-centered pedagogy. While the number of years that have passed since a faculty member's first academic appointment was found to be a significant predictor of SCP, its coefficient was quite small ($\gamma = -0.01$) and plays a very minor part in predicting student-centered pedagogy. A stronger predictor of the outcome is faculty salary, which is positively associated with the dependent variable ($\gamma = 0.07$). As a faculty member's salary increases, so too does their use of SCP. This makes sense when viewed through the lens of Resource Dependence Theory (RDT) since faculty are dependent on external resources (e.g., time, salary) provided by their academic department. As these resources are expanded, faculty can devote increasing amounts of time to their teaching. The nature of promotion and tenure systems at research universities makes this relationship even more likely. Faculty who have higher salaries may already have received tenure, potentially reducing the pressure to invest considerable amounts of time into their research and freeing up opportunities to enhance their teaching. Additionally, faculty with higher salaries might feel a greater responsibility to teach in ways that are conducive to effective learning. Higher salaries may prompt a deeper commitment to student learning and provide the impetus for altering one's teaching approach.

In addition to salary, faculty who are not on the tenure-track were found to be positively associated with the use of student-centered pedagogy ($\gamma = 0.24$). Of both the background and professional characteristics, this item represented the strongest positive predictor of SCP. This group of faculty may be associated with higher levels of SCP for several reasons. First, faculty outside the tenure-track will likely face less pressure – either formally via their job description or informally via their professional environment – to produce a sizable body of research and thus may find it much easier to focus on developing their teaching. Second, it is not uncommon for STEM disciplines to hire non-tenure track positions solely or primarily focused on teaching. In some cases, these positions may not only involve a certain course load but may also be specifically geared towards helping faculty peers improve or fully redesign their courses (Wieman, 2017). The rise of non-tenure track Discipline-Based Education Researchers (DBER) or similar positions in STEM fields is evidence of the growing use of faculty who are not only trained in their discipline but in innovative teaching methods and research on student learning (National Research Council, 2012). This expertise would help explain higher levels of SCP. Third, applicants attracted to such positions may possess an intrinsic desire to prioritize teaching and student learning, resulting in a greater use of student-centered teaching practices compared to their tenure-track peers.

Academic discipline also appears to have a significant influence on faculty's use of student-centered pedagogy. While no statistically significant relationship was found for faculty in Engineering and Computer Science, those in Physical Science ($\gamma = -0.29$) and Mathematics/Statistics ($\gamma = -0.71$) were found to have a negative relationship with student-centered pedagogy relative to their peers in the Life Sciences. Furthermore, the negative relationships between faculty in these departments and SCP exceeded the impact of all other variables in the model by a wide margin. While faculty in Physical Science departments exhibited SCP scores that were 0.29 points less than their peers in the Life Sciences, Mathematics and Statistics faculty were much lower, at a rate of 0.71 points less than their peers in Life Sciences. These differences align with previous research highlighting disparities in the extent to which STEM faculty in various departments employ SCP (Lund & Stains, 2015; Wieman, 2017). While some variation in use of SCP may be explained by course content, the culture of an academic department and the professional identity of academic disciplines have also been found to contribute to these differences (Austin, 2011; Brownell & Tanner, 2012; Chasteen et al., 2015; Dancy & Henderson, 2010; Manduca et al., 2017). Figure 4.4 highlights the substantial variation in mean faculty SCP score by each of the disciplinary areas within STEM.

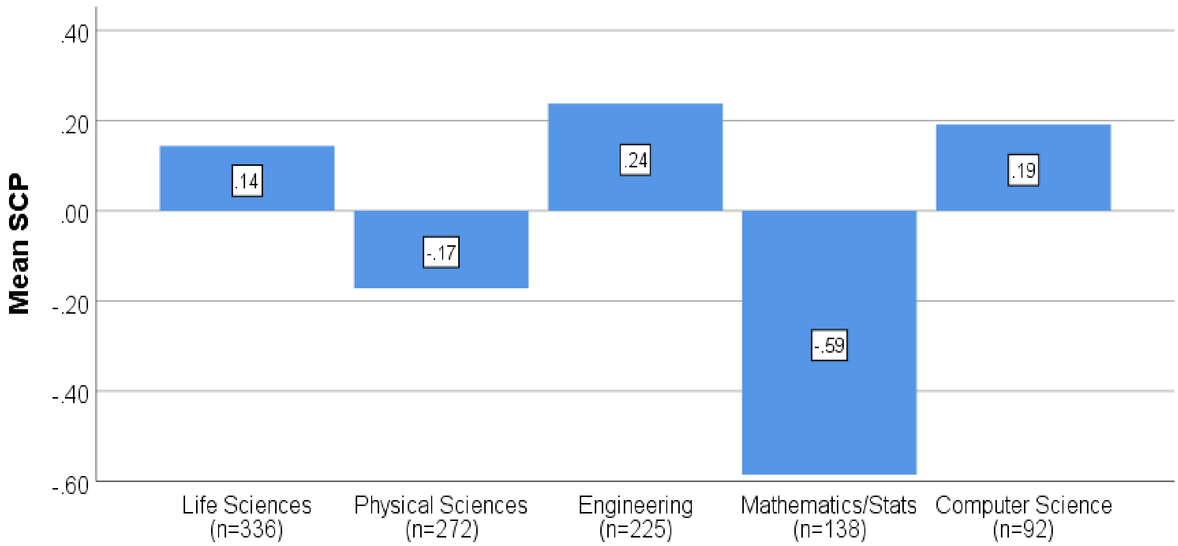

Figure 4.4. Mean SCP Score by STEM Academic Area

Variation in SCP use by academic discipline may help explain the non-significance of sex once professional characteristics were included in the model. Given that female faculty members represent a comparable segment of each of the non-Life Sciences areas of STEM (20% - 23%, see Table 4.1), it appears that academic discipline has accounted for some of the variation in SCP attributed to sex in Model 1. In addition, while female faculty represent only 25.7% (n=273) of the overall sample, they account for 42.7% (n=32) of the faculty who are not on the tenure track. The overrepresentation of women among this group of faculty also helps account for the non-significance of sex. In summary, it appears that female faculty members' higher scores on SCP can be partially explained by the culture of the department in which they are employed and the nature of their academic position.

Table 4.4

Hierarchical Linear Modeling (HLM) Results Predicting Student-centered Pedagogy (n=1063 faculty, 21 institutions)

	Model 1			Model 2			Model 3			Final Model		
	Coef.	S.E.	Sig.	Coef.	S.E.	Sig.	Coef.	S.E.	Sig.	Coef.	S.E.	Sig.
Background Characteristics												
Female	0.18	0.06	**	0.12	0.06		0.07	0.06		0.05	0.06	
URM	0.11	0.15		0.05	0.14		0.09	0.13		0.13	0.13	
Professional Characteristics												
Years since first academic appointment				-0.01	0.00	**	0.00	0.00		0.00	0.00	
Salary				0.07	0.02	**	0.05	0.02	*	0.06	0.02	*
Assistant Professor (Associate)				-0.04	0.09		-0.01	0.08		-0.04	0.08	
Professor (Associate)				-0.11	0.08		-0.12	0.07		-0.12	0.07	
Not tenure-track faculty				0.24	0.11	*	0.43	0.11	***	0.47	0.11	***
Physical Science (Life Science)				-0.29	0.07	***	-0.30	0.07	***	-0.28	0.07	***
Engineering (Life Science)				0.01	0.08		-0.02	0.08		-0.01	0.08	
Mathematics/Statistics (Life Science)				-0.71	0.09	***	-0.39	0.09	***	-0.43	0.09	***
Computer Science (Life Science)				-0.04	0.11		-0.04	0.10		-0.04	0.10	
Faculty Activities and Time Commitments												
Past three years: Engaged in academic research that spans multiple disciplines							0.29	0.06	***	0.28	0.06	***
Past three years: Written research grants							0.07	0.09		0.06	0.09	
Past three years: Received state or federal government funding							-0.07	0.07		-0.06	0.06	
Past three years: Number of accepted or published writings							0.01	0.00	*	0.01	0.00	*
Hrs./Wk.: Preparing for teaching							0.03	0.02		0.02	0.02	
Hrs./Wk.: Committee work and meetings							0.02	0.02		0.01	0.02	
Hrs./Wk.: Research and scholarly writing							-0.03	0.02		-0.02	0.02	
Hrs./Wk.: Community or public service							0.15	0.03	***	0.14	0.03	***
Participated in organized activities around							0.16	0.06	**	0.14	0.06	*

enhancing pedagogy or student learning												
Participated in curriculum development							0.32	0.07	***	0.31	0.07	***
Past year: Attended funded workshop focused on teaching							0.15	0.06	**	0.13	0.06	*
Undergraduate engagement							0.19	0.03	***	0.15	0.03	***
Perceptions of Profession and Institution												
Recognized for outstanding teaching										0.09	0.06	
Graduate training prepared you well for faculty role										0.07	0.03	*
Close alignment between work and personal values										0.08	0.03	*
I try to dispel perceptions of competition										0.08	0.03	*
Achieve a healthy balance between personal and professional life										0.07	0.03	*
I have to work harder than my colleagues to be perceived as a legitimate scholar										0.06	0.03	*
Career stress										0.07	0.04	*
Job satisfaction: Workplace										0.05	0.04	
Job satisfaction: Compensation										-0.09	0.04	*
Institutional Characteristics												
Intercept	-0.52	0.30		-0.07	0.30		-1.33	0.36	***	-1.37	0.36	***
Student-faculty ratio										0.00	0.01	
Selectivity										0.00	0.00	
Institutional control (private)										-0.09	0.12	
Minority-serving institution										0.07	0.14	
Research one										-0.08	0.09	
Model Statistics												
Level-1 variance	0.83	0.04	***	0.75	0.03	***	0.63	0.03	***	0.61	0.03	***
Level-1 explained variance	0.01			0.10			0.24			0.27		
Level-2 variance	0.03	0.02		0.03	0.02		0.02	0.01		0.01	0.01	
Level-2 explained variance	-0.50			-0.44			0.28			0.31		

Model 3

The third model introduces *Faculty Activities and Time Commitments* while controlling for both background and professional characteristics (Table 4.4). This block of items includes research-related activities such as writing research grants, receiving funding, and publishing manuscripts, measures of how faculty spend their time, and whether they have participated in professional development opportunities related to teaching. An important predictor of higher SCP scores was whether faculty had engaged in academic research that spanned multiple disciplines during the previous three years ($\gamma = 0.29$). Conducting research across disciplines may be fruitful for SCP implementation since it may help foster relationship-building across departments and expose faculty to novel ideas and teaching strategies utilized by colleagues in other fields. Considering the impact of departmental culture on SCP, faculty employed within academic departments where student-centered pedagogy is largely absent may especially benefit from cross-disciplinary collaborations.

A less influential predictor of SCP was the number of hours per week that a faculty member devotes to community or public service ($\gamma = 0.15$). While references to this item are essentially absent from the research literature, the statistical significance of this variable can be partially explained through the lens of Organizational Citizenship Behavior. Faculty who reserve a greater number of hours to community or public service would exhibit OCB since these activities are only minimally required as part of their employment obligations. Given that OCB is intrinsically motivated, faculty who commit additional hours of community or public service might also be intrinsically motivated to go above and beyond teaching expectations. These faculty members might care more deeply about student learning than their average peer just as they spend more hours of their week performing public service.

While engaging in research across academic disciplines and spending time on community or public service was found to be statistically significant, several key variables the research literature and Resource Dependence Theory would predict might be important in explaining SCP variation were found to be statistically insignificant. Research on teaching strategies in STEM has continuously found that a lack of time coupled with the pressing demands of research obligations are an impediment to the improvement of teaching strategies (Brownell & Tanner, 2012; Dancy & Henderson, 2008; Michael, 2007). Considering time as a resource, RDT would predict that faculty's embrace of SCP can be understood as a function of their perceptions of the amount of time available to them and institutional rewards system that may encourage them to spend time elsewhere. Yet, items such as writing research grants or receiving state or federal funding during the past three years, along with the hours per week a faculty member devotes to preparing for teaching, committee work and meetings, and research and scholarly activities were all found to lack statistical significance. Furthermore, even though the number of accepted or published writings during the past three years is associated with SCP, it plays a very minor part in explaining variation in teaching pedagogies and as a positive predictor of SCP, would seemingly contradict the research literature ($\gamma = 0.01$).

One of the most common suggestions for improving undergraduate STEM teaching at research universities is providing faculty with professional development opportunities. Activities, workshops, learning communities, and more have been found to shape faculty's perceptions regarding their teaching and student learning while introducing them to more effective methods of content delivery (Ebert-May et al., 2015; Henderson, 2008; Owens et al., 2018). This study supports previous research by finding a positive association between participation in organized activities around enhancing pedagogy or student learning and SCP (γ =

0.16). Similarly, faculty who attended a funded workshop focused on teaching during the past year were also found to have higher SCP scores than their peers who did not attend such a workshop ($\gamma = 0.15$).

In addition to professional development specific to pedagogy, faculty who participate in the development of curriculum also appear to be associated with higher student-centered pedagogy scores. In fact, this item is the strongest predictor of all the faculty activities and time commitments ($\gamma = 0.32$). This means that faculty who participate in curriculum development have SCP scores that are 0.32 points higher than their peers who do not participate in this activity. While we do not know whether such participation is voluntary or mandatory, it is important to recall that faculty tend to repeatedly teach the same or similar courses on a yearly basis. Participating in curriculum development might indicate that faculty are taking a closer look at the courses they teach either informally on their own or in a formal professional development setting. On the other hand, faculty may also play a role in shaping curriculum at a departmental level, which might provide them with a grander vision for student learning that could shape the way they approach their own teaching and the extent to which they incorporate student-centered pedagogy in the classroom.

The construct underlying undergraduate engagement was also found to be statistically significant with SCP ($\gamma = 0.19$). The 0.19 increase in SCP score for every increase in student engagement demonstrates a strong relationship between the two variables. While all faculty care about student learning, those who engage more frequently and closely with students might be more inclined to invest additional time incorporating active learning techniques in the classroom. Faculty with higher levels of student engagement could receive more feedback about their teaching, which may prompt them to incorporate student-centered teaching practices.

While the inclusion of faculty activities and time commitments yielded several important predictors of student-centered pedagogy and some noteworthy non-significant findings, the model also delivered a few important deviations from the previous model. For example, the item capturing the number of years since a faculty member's first academic appointment was no longer significant once we accounted for activities and time commitments. Similarly, faculty salary lost predictive power. These changes may be because *Model 3* is controlling for faculty members' research demands and productivity, which tend to vary throughout the course of a faculty member's career trajectory. Lastly, the association between Mathematics/Statistics faculty and student-centered pedagogy was nearly cut in half from *Model 2* to *Model 3* once we controlled for professional development opportunities, undergraduate engagement, and time commitments.

Model 3 also demonstrated a suppressor effect as the predictive power of faculty who are not tenured increased once activities and time commitments were introduced. Investigating this phenomenon more closely revealed significant negative correlations between not being on the tenure-track and both engaging in academic research that spans multiple disciplines and participating in the development of curriculum. At the same time, the latter two variables displayed significant positive relationships with the outcome, student-centered pedagogy. This means that faculty who are not on the tenure track are less likely to engage in academic research across multiple disciplines and curriculum development. Therefore, the predictive power of being a non-tenure track faculty would be even greater would it not be for their lower scores on both activities. Controlling for these two variables by introducing them into the model at step 3 reveals the true impact of being a faculty member at a research university while not on the tenure track.

Final Model

In the final model, perceptions of the profession and institution enter the HLM along with background and professional characteristics and faculty activities and time commitments (Table 4.4). Except for being recognized for outstanding teaching, all the items in this block of variables were found to be statistically significant. Despite this significance, these items lack the predictive strength of some of the items seen in the professional characteristics or faculty activities blocks (e.g., Physical Science, Participating in curriculum development). This section also demonstrates key changes in variable strength for items in Models 1-3 and provides a statistical summary of variables in level two of the HLM.

Survey data shows that faculty's perception of whether graduate training prepared them well for their role was associated with SCP ($\gamma = 0.07$). Unfortunately, this item does not identify whether such graduate training refers specifically to teaching-related training, preparation to conduct research, or both. Regardless, those who feel to a greater extent that their graduate programs prepared them well are associated with higher levels of SCP. Those who feel they were not prepared well enough for their role as a faculty member might be associated with lower levels of SCP due to the increased pressure of being underprepared for their research demands and teaching responsibilities. These faculty might be more overwhelmed than their better prepared peers and have less time to integrate active learning activities into their curriculum.

Several variables in this final block consider what might be personally important to faculty as they carry out their job responsibilities. For example, faculty who feel to a greater extent that there is close alignment between their work and personal values are associated with higher levels of SCP ($\gamma = 0.08$). Additionally, those who agree more strongly that they try to dispel perceptions of competition were also associated with higher levels of SCP ($\gamma = 0.08$). This may be because student-centered teaching and dispelling perceptions of competition can both be thought of as prosocial behaviors. This position is consistent with Organizational Citizenship Behavior and may detail key personality traits of faculty who are exceeding teaching expectations by integrating more time-consuming content-delivery methods into their classrooms. These faculty members may be more concerned with equity, fairness, and being helpful both within and outside the classroom. This concern with fairness is supported by the finding that faculty who agree more strongly that they try to achieve a healthy balance between their personal and professional lives are associated with higher levels of SCP ($\gamma = 0.07$).

How the profession makes faculty feel and the potential impact of these feelings on SCP is a focus of this study. Those who feel more strongly that they must work harder than their colleagues to be perceived as a legitimate scholar were associated with higher SCP scores ($\gamma = 0.06$). Similarly, those who felt more career stress ($\gamma = 0.07$) and less satisfaction with their compensation ($\gamma = -0.09$) were also associated with greater use of student-centered teaching techniques. These findings somewhat contradict Resource Dependence Theory since faculty with more time, resources, and funding might be predicted to utilize SCP to a greater extent. Yet, it appears the opposite may be true. Faculty who are under greater levels of stress and less satisfied with their compensation package are bringing more active learning techniques into the classroom. While it is possible that investing more time in their teaching may be causing additional stress, it is also possible that this stress may be caused by peers and administrators not recognizing and rewarding more effective teaching practices.

The inclusion of faculty's perceptions of their profession and institution modifies the predictive power of a handful of variables previously in the HLM. Two variables related to professional development lost a minor amount of explanatory power – participating in organized activities around enhancing pedagogy and student learning ($\gamma = 0.16$ to $\gamma = 0.14$) and attending a funded workshop focused on teaching ($\gamma = 0.15$ to $\gamma = 0.13$). Undergraduate engagement lost a larger share of its predictive strength ($\gamma = 0.19$ to $\gamma = 0.15$). On the other hand, a pair of predictors gained strength after the inclusion of the final block of variables. Faculty who are not on the tenure-track went from $\gamma = 0.43$ to $\gamma = 0.47$, continuing their upward trend with each successive block of variables. Similarly, faculty employed in Mathematics/Statistics departments also appear to be a stronger predictor in the final model ($\gamma = -0.39$ to $\gamma = -0.43$).

Although numerous individual-level predictors were significantly associated with the student-centered pedagogy outcome, this was not the case at the institution level. Consistent with an ICC of 2.4%, most of the variation in SCP was contained within institutions (i.e., between faculty). Each successive block of variables contributed to a growing aggregate of explained variation in the HLM, with the third block (*Faculty Activities and Time Commitments)* representing the largest share ($r^2 = 0.14$). The final model accounted for 27% of the variation in level 1, representing a substantial amount of the variation in student-centered teaching practices of STEM faculty at research universities.

Interaction Effects

Testing for interaction effects allows researchers to probe whether a third variable can moderate the impact of a predictor variable on an outcome. While the *Final Model* presents a snapshot of key characteristics, activities, and perceptions that influence student-centered teaching, there are potential nuances within these findings that are worth exploring. Following from the third research question – understanding how departmental and institutional contexts influence SCP – it is important to know if differences exist between academic areas (Physical Sciences, Engineering, Computer Science, Mathematics/Statistics) and faculty who are tenured compared to those not on the tenure-track and key variables in this study. These key variables were chosen based on their prevalence in the research literature as possible explanations for variation in student-centered teaching, including the amount of time a faculty member devoted to research and scholarly writing, participation in organized activities around enhancing pedagogy or student learning, student-faculty ratio, and Research one status.

At the faculty-level, two out of 10 possible interaction effects were found to be statistically significant and both improved the level of variation that was explained by the model. Both of these same-level interaction effects involved faculty employed in Mathematics/Statistics departments. In the first case, the effect of being employed in Mathematics/Statistics departments on SCP was moderated by the number of hours that faculty spent on research and scholarly writing. Faculty who devoted more hours to this activity were associated with higher SCP scores than their peers who dedicated less time to these activities ($\gamma = 0.10$, $p = .02$). Similarly, participation in organized activities around enhancing pedagogy or student learning also enhanced the association between being a faculty member in Mathematics/Statistics and SCP ($\gamma = 0.32$, $p = .03$). This effect was noticeably larger than that of time spent on research and scholarly writing. Figure 4.5 graphically displays the gap in SCP scores for Mathematics/Statistics faculty who participate or not in these pedagogically-related activities.

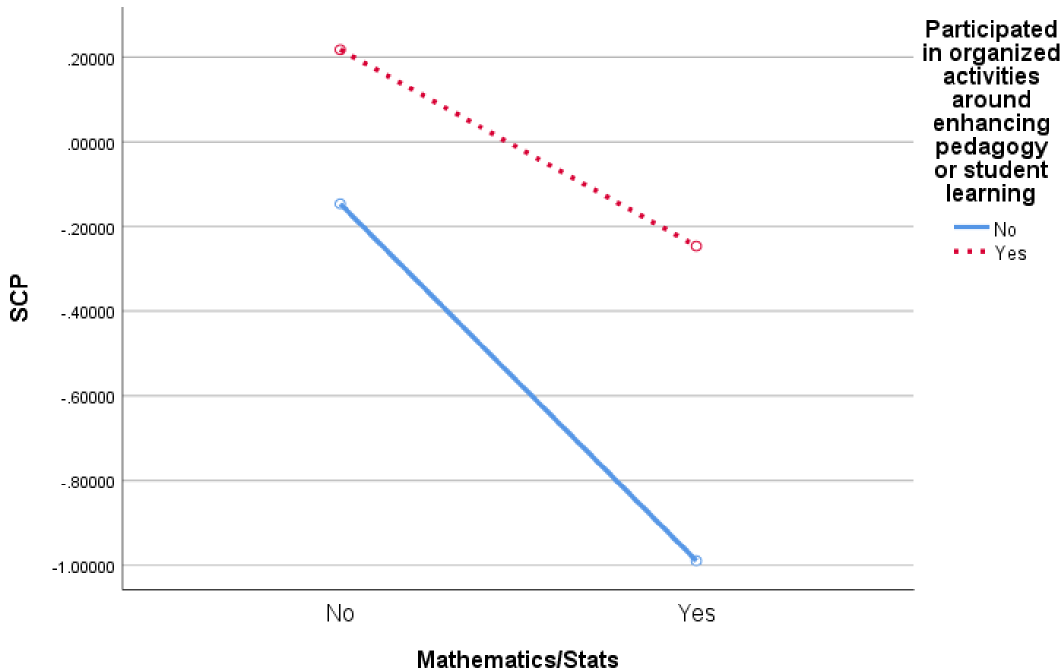

Figure 4.5. Mathematics/Stats Faculty SCP Scores by Participation in Pedagogical Activities

In addition to these same-level interaction effects, one out of a possible 10 cross-level interaction effects was found to be statistically significant and improve the model. Faculty who are employed in positions that are not on the tenure track are differentially impacted by whether their institution is a Research 1 or Research 2 university ($\gamma = -0.41$, $p = .04$). Faculty in these positions who are employed at Research 1 universities have a much lower SCP score than their peers employed at Research 2 universities. This disparity speaks to the institutional culture present at these campuses. Figure 4.6 graphically displays this relationship.

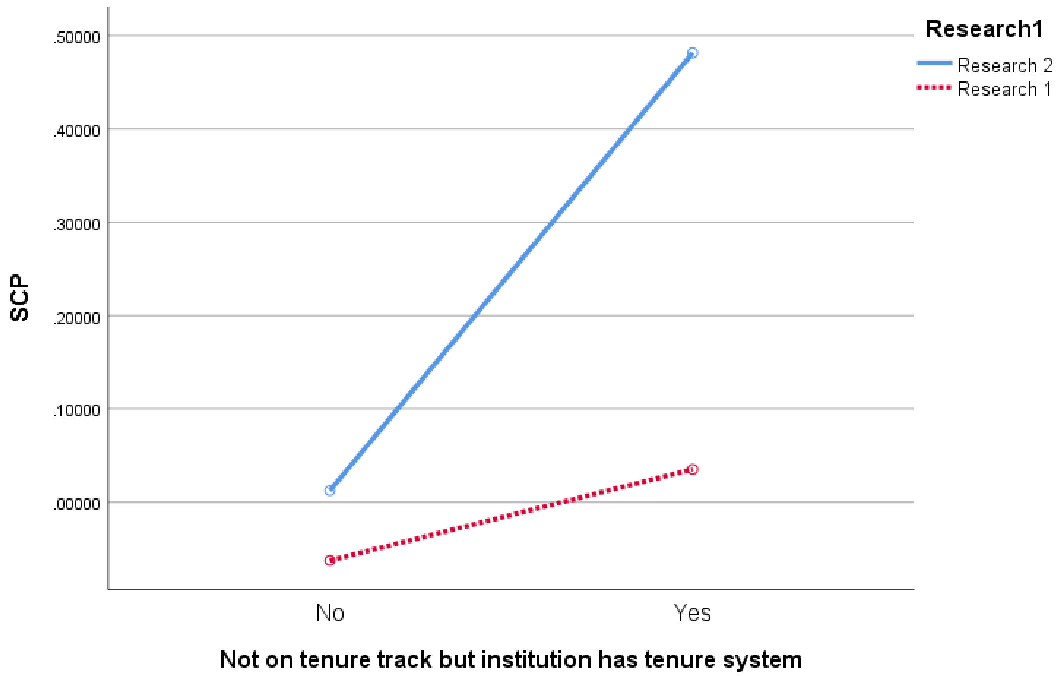

Figure 4.6. Student-centered Pedagogy Scores of Faculty not on Tenure-track by Research 1 Status

CHAPTER 5: RESULTS FOR STEM FACULTY INTERVIEWS

Introduction

This study relies on a sequential mixed-method design given the need to both uncover the factors and characteristics that explain variation in STEM faculty's use of SCP and better understand how the individual trajectories and contextual experiences shape the extent to which faculty integrate these teaching approaches in their classrooms. Chapter 4 took a deep dive into whether and to what extent background, professional, and institutional characteristics, time commitments, activities, and perspectives influence the use of student-centered teaching. Drawing from semi-structured interviews with 17 STEM faculty across the country, this chapter will seek to understand how and why faculty have adopted their current pedagogical style. Two specific aims guide this chapter. First, these results will contextualize, explain, and expand upon the findings of the previous chapter, with specific attention paid to particularly salient findings. Secondly, this chapter will seek to answer the latter two research questions guiding this study – how faculty describe the evolution of their teaching and the extent to which institutional and departmental contexts shape their pedagogical approach.

This chapter begins with a descriptive discussion of the faculty interviewed in this study. Special attention is given to examining variation in SCP scores within this subgroup and how these interviewees compare to both their faculty peers at their respective institutions and all Faculty Survey respondents. Next, interview data is presented that enriches our understanding of the Hierarchical Linear Model (HLM) findings in the previous chapter. Additionally, data will illuminate further factors absent from the HLM that faculty cite as being influential in how they approach their teaching. The following section is concerned with understanding how faculty describe the evolution of their teaching and the factors that have helped shape their pedagogical style or – in the case of a few faculty – why they believe their pedagogy has remained consistent throughout their career. The remaining pages of this chapter are dedicated to understanding the contextual influences at the departmental and institutional level that contour faculty's approach to teaching.

Faculty Sample

A total of 17 semi-structured interviews were conducted with STEM faculty across the country over a period of several months during fall of 2019. Table 5.2 presents a snapshot of the participants who were interviewed and the institutions where they are employed. The sample is overwhelmingly White (94%), which reflects not just the population of faculty who completed the Faculty Survey but also the lack of faculty diversity within STEM departments at public and private research universities (Carrigan, Quinn, & Riskin, 2011). About 35 percent of the faculty interviewed were women (n=6), which is a larger proportion than are present on the Faculty Survey (25%). The sample is representative of faculty at various points in their academic careers, with four Assistant Professors (24%), six Associate Professors (35%), and seven Professors (41%). With respect to academic department, 24 percent of interviewees are employed in the Life Sciences (n=4), an additional 24 percent in Engineering fields (n=4), and the remaining 53% hail from Physical Sciences departments (n=9). Faculty are spread out across six public and two private institutions, with five out of eight being R1 universities.

Table 5.1

Demographic and Professional Characteristics of Interviewed STEM Faculty

Name	Gender	Race/ Ethnicity	Academic Rank	Tenure Status	Department	Institution	R1 or R2
Dr. Ashford	Male	White	Asst. Professor	Not on tenure track	Life Sciences	Rocks University	R1
Dr. Avasarala	Female	White	Assoc. Professor	Tenured	Life Sciences	Mountain University	R1
Dr. Burton	Male	White	Professor	Tenured	Engineering	Tree University	R1
Dr. Cortazar	Male	White	Asst. Professor	Tenure track	Engineering	Univ. of the Hills	R2
Dr. Dawes	Female	White	Assoc. Professor	Tenured	Physical Sciences	Univ. of the Desert	R1
Dr. Draper	Female	White	Assoc. Professor	Tenured	Physical Sciences	Univ. of the Hills	R2
Dr. Drummer	Male	White	Professor	Tenured	Physical Sciences	Ocean University	R2
Dr. Duarte	Female	Hispanic	Assoc. Professor	Tenured	Engineering	River University	R1
Dr. Holden	Male	White	Assoc. Professor	Tenured	Physical Sciences	Univ. of the Desert	R1
Dr. Inaros	Male	White	Professor	Tenured	Life Sciences	Rocks University	R1
Dr. Johnson	Male	White	Professor	Tenured	Engineering	Ocean University	R2
Dr. Kamal	Female	White	Asst. Professor	Tenure track	Life Sciences	Univ. of the Desert	R1
Dr. Mao	Male	White	Assoc. Professor	Tenured	Physical Sciences	Canyon University	R2
Dr. Miller	Male	White	Professor	Tenured	Physical Sciences	Mountain University	R1
Dr. Nagata	Male	White	Professor	Tenured	Physical Sciences	Ocean University	R2
Dr. Okoye	Male	White	Professor	Tenured	Physical Sciences	Univ. of the Desert	R1
Dr. Roci	Female	White	Asst. Professor	Tenure track	Physical Sciences	Ocean University	R2

Note: Names of individuals and institutions are pseudonyms.

In addition to reviewing demographic and professional characteristics, it is important to recognize the individual SCP scores of faculty who were interviewed. Doing so will provide a greater understanding of the extent to which these 17 STEM faculty are employing active learning practices in their classrooms. More importantly, SCP scores will provide an additional lens for analyzing the qualitative responses of individual faculty. In addition, individual student-centered pedagogy scores will allow us to consider how these faculty compare to their peers both within and outside their home institution. Appreciating these differences will provide greater ability to situate qualitative findings within the greater context of diverse teaching practices in STEM.

Figure 5.1 displays the distribution of SCP scores for the 17 faculty who were interviewed. This distribution is normal, with a mean of .13 and standard deviation of .76. As the graphic shows, while most faculty who were interviewed had SCP scores near the mean, some were more than one standard deviation above or below the average score. Comparing the interviewee group to all faculty who completed the Faculty Survey offers valuable insights. Recalling that the mean score of all Faculty Survey participants was -.01 and the standard deviation was .93, it is evident that interview participants had a slightly higher average SCP score and a slightly smaller spread around the mean than the full sample of faculty. Importantly however, interviewed faculty were not concentrated on either side of the full sample mean, with representation both above and below -.01. This lends greater confidence that qualitative results are reflective of not just faculty who have implemented SCP to a large or minimal extent in their classroom, but a healthy balance of both teaching styles.

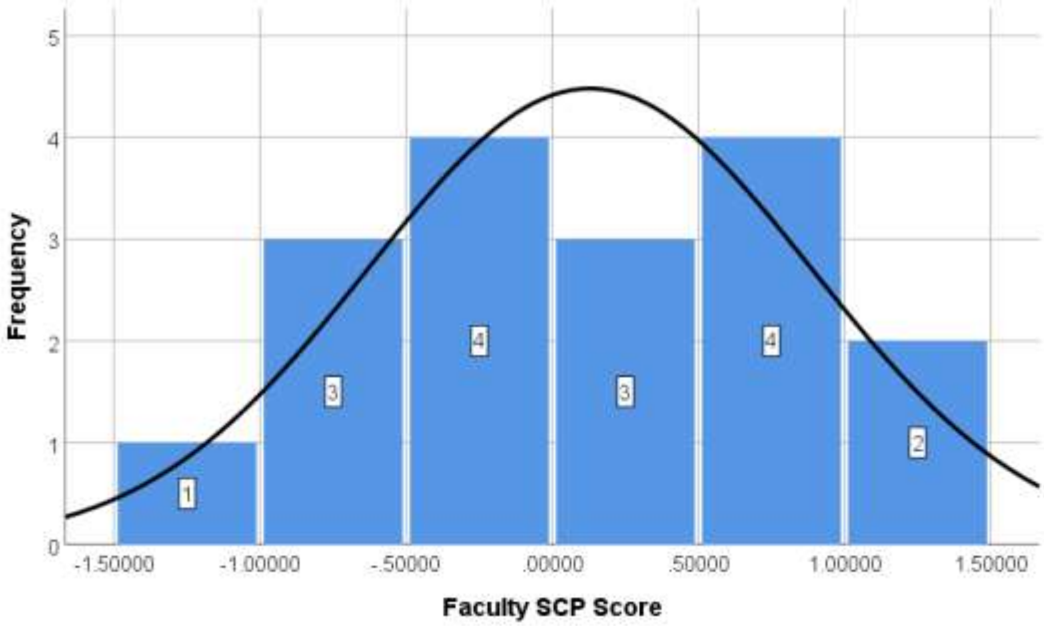

Figure 5.1. Distribution of Student-centered Pedagogy Scores for the 17 Faculty Interviewed

It is also worthwhile to situate individual SCP scores within the institutional context in which these faculty are instructing students. Table 5.1 displays faculty and mean institutional SCP scores. While some faculty's scores closely mirror the average of survey respondents at their campus (i.e., Dr. Dawes, Dr. Duarte), others exhibit scores that are markedly different (i.e., Dr. Burton, Dr. Inaros). Notably, interviewed faculty do not exhibit values exclusively higher or lower than the average on their respective campuses – some of the faculty incorporate student-centered teaching to a greater extent than their colleagues on campus while others do so at a lower rate than their institutional peers. In seven out of 17 cases, the university mean score is higher than that of the faculty member (Table 5.1). Recognizing the gap between individual and institutional mean SCP scores and the directionality of the contrast provides an additional lens for contextualizing qualitative responses.

Table 5.2

Faculty Interviewee and their Institution's Mean Student-centered Pedagogy (SCP) Scores

Name	Institution	Faculty SCP	Institution Mean SCP	Institution SD	Institution Total *	Higher SCP Score
Dr. Ashford	Rocks University	0.64	-.26	.96	93	Faculty
Dr. Avasarala	Mountain University	0.58	-.08	.95	81	Faculty
Dr. Burton	Tree University	1.09	-.07	1.06	61	Faculty
Dr. Cortazar	University of the Hills	-0.82	-.06	.92	48	University
Dr. Dawes	University of the Desert	0.32	.18	1.01	115	Faculty
Dr. Draper	University of the Hills	-0.52	-.06	.92	48	University
Dr. Drummer	Ocean University	-0.09	.23	.87	177	University
Dr. Duarte	River University	-0.31	-.32	.89	61	Faculty
Dr. Holden	University of the Desert	0.48	.18	1.01	115	Faculty
Dr. Inaros	Rocks University	1.24	-.26	.96	93	Faculty
Dr. Johnson	Ocean University	0.94	.23	.87	177	Faculty
Dr. Kamal	University of the Desert	-0.42	.18	1.01	115	University
Dr. Mao	Canyon University	-1.26	-.06	.92	58	University
Dr. Miller	Mountain University	-0.96	-.08	.95	81	University
Dr. Nagata	Ocean University	0.44	.23	.87	177	Faculty
Dr. Okoye	University of the Desert	0.90	.18	1.01	115	Faculty
Dr. Roci	Ocean University	-0.08	.23	.87	177	University

*Total number of Faculty Survey respondents

Note: All Faculty Survey (n=1063), mean = -0.01 , standard deviation = 0.93

Factors Influencing Teaching

Faculty expressed a variety of factors and characteristics that influenced how they approached their teaching. These factors provide greater context and a deeper understanding of the HLM results. Interviews also provided the chance to fill in the gaps in our understanding of what else influences teaching, as faculty highlighted additional reasons that explain their teaching approach which were not available as possible variables on the HERI Faculty Survey.

Professional Development

Results from the Hierarchical Linear Model (HLM) in Chapter 4 demonstrate the positive relationship between professional development opportunities and increased student-centered pedagogy scores (Table 4.4). While attending a funded workshop focused on teaching was significantly associated with a higher SCP score, participating in curriculum development was not only statistically significant, but it was also one of the strongest predictors of SCP in the final HLM model. As such, it is not surprising that during interviews faculty would cite professional development opportunities both on and off their home campus as influential factors shaping their approach to teaching. While most faculty acknowledged professional development opportunities related to teaching were available on their campus, the breadth, type, and impact of such programs varied between institutions and faculty.

Dr. Dawes, a faculty member in the Physical Sciences at University of the Desert, spoke about the varied types of professional development programs related to teaching she participated in:

> And so then when I came to University of the Desert, I took advantage of lots of those kind of professional development opportunities as well to try to become a better teacher. Yeah, so there were faculty learning groups. While I was an assistant professor, these were pretty prevalent on campus, where it was kind of like a book club where we'd all sign up, we'd get a copy of the book, we'd work through the book throughout the

> semester, and we'd meet once a week to discuss the book and talk about how we might implement the things that we were reading about in our classrooms. So I think I did two of those as an assistant professor. And then I also participated in inclusive teaching workshops, both as a participant and then later as a workshop leader. – Dr. Dawes, Physical Sciences, University of the Desert

Given the institutional variation in availability of professional development opportunities on campus, Dr. Dawes was fortunate to have access to multiple such opportunities. She goes on to discuss the impact these programs had on her teaching:

> So the active learning has definitely been from kind of these professional development workshops and basically the evidence-based research that shows that active learning is more effective and more engaging and can be more inclusive than kind of the traditional lecture-based teaching. I also find it a lot more interesting as a professor to do that than to just make PowerPoint slides and present them. So that's been a pretty good change from my perspective. – Dr. Dawes, Physical Sciences, University of the Desert

Understanding the impact that distinct teaching styles can have on student learning is perhaps one of the most important contributions of teaching-focused faculty professional development.

For some faculty, these lessons were imparted early in their careers and through participation in National Science Foundation (NSF) professional development programs.

> So that was at the beginning now I do have to say that I think it was two years ago at Ocean University I participated in a longer one semester program that was focused on teaching in STEM. And that was a project at Ocean University that was funded by the NSF primarily to improve STEM teaching. And so I was again a student in this and it was run by a group of other professors here from different colleges like Engineering, Technology, Life Sciences and so on…I have tried to do even in these classes I find now activities that are more active learning based and anyway, I've found ways to adapt some of these things and delete something, that works for the classes that I teach – Dr. Drummer, Physical Sciences, Ocean University

Similarly, Dr. Okoye at the University of the Desert also spoke about participating in an NSF-sponsored program:

> So, of course, most of the professional development has been as a researcher. But, I'd say two things have helped my teaching. One is I went to a conference in Washington D.C. for new faculty members. When I was second year at University of the Desert or

> something. And, I think it was NSF sponsored. And, they did a whole weekend or a few days on teaching. – Dr. Okoye, Physical Sciences, University of the Desert

In these instances, faculty participated in structurally distinct NSF programs intended to improve teaching in STEM. While the location, duration, and structure of programs can significantly vary, professional development early in the careers of STEM faculty can have a powerful impact.

Professional development opportunities were also found to be localized in specific departments:

> I mean, University of the Desert actually, we have had something called PISOT. The Physics Informal Seminar on Teaching or something. And, we have actually done this on and off in my 20 some years here. Where we bring in interested faculty, to talk about some of the better techniques of teaching what's been done in physics education research. And, things like that. And so, there has been an effort, kind of a grassroots effort by some of the better teachers in the department to bring together particularly young faculty. But, anybody interested and talk about what we know as good teaching pedagogy, from what's going on in physics education research. – Dr. Okoye, Physical Sciences, University of the Desert

In this case, the availability and scope of this professional development speaks to the culture of this department. The willingness to embrace these efforts throughout several decades highlights the ongoing support from leadership within the department and the establishment of a culture focused on improving teaching.

In addition to department-led initiatives, many campuses have also established professional development programs within faculty development centers. Dr. Ashford spoke to his broad off and on relationship with the center on his campus, he said:

> Off and on, I've been active with [Campus Center]. I'm taking ... I did one of the summer institutes, I did one up in [State] up at [College] and then when they started, the first year they did one of the summer institutes here, I was one of the facilitators for it because I had been and then I've taken other classes with [Campus Center], other seminars. I did the faculty learning program, the FLP program through [Campus Center]. In the past I've attended their journal club and stuff like that and I'm friends with a lot of those people so I kind of like go in and out of that group from time to time and sometimes get frustrated

> with them and then leave and then come back and go back and forth. – Dr. Ashford, Life Sciences, Rocks University

Dr. Ashford is especially well-suited to facilitate a summer institute and additional programs as his individual SCP score (0.64) is significantly higher than the mean for Rocks University's surveyed faculty (-0.29). In this way, Dr. Ashford has not only been a beneficiary of professional development but has also been able to share his expertise with fellow faculty, likely having a positive impact on the development of their teaching.

Many faculty were quite clear in expressing the positive impact that professional development had on their teaching style and their views on student learning. Dr. Holden spoke to this when discussing the fact that he joined a faculty reading group:

> But we became friends and liked talking about teaching and how especially what got us started was the transfer, math going between physics and engineering and then physics going between physics and engineering, and these topics and how students learn and how students transfer that information. Anyway, and so we've been going for years now, reading books on how people learn, how students learn, how the brain functions, and those things…so that's revolutionized my thinking about how learning works and that part of what we learned in reading these books is that there has to be some action after the fact, that it comes in, information rattles around the brain for a while, it synthesizes, it connects to something that you already know. But then there has to be an action associated with it. And so then that action creates more input and it cycles and does that. And so this idea that they can't just listen to something, they can't just read something, these students have to do something about that right away. –Dr. Holden, Physical Sciences, University of the Desert

Similarly, other faculty spoke to the positive impact of participating in professional development:

> I definitely do because it's things I had not thought about, but they really made a lot of sense when someone pointed that out, but I don't think I would have come up with it. It would have taken me a lot of years to come to that information. –Dr. Kamal, Life Sciences, University of the Desert

The idea that faculty would have a difficult if not impossible time learning some of these things was supported by Dr. Dawes:

> Yeah, I think it definitely exposed me to the idea that graduate students and faculty need to have professional development opportunities to learn about pedagogy and teaching, that it's not just something that happens automatically. –Dr Dawes, Physical Sciences, University of the Desert

While Dr. Dawes and other faculty had access to professional development programs early in their careers as assistant professors, other faculty were not as fortunate. Dr. Draper recalls:

> Not a bit, not when I started my first faculty position. By the time I got to University of the Hills, there was some faculty professional development opportunities, there, but I'd been teaching in college classroom for five plus years, at that point, if you don't count my time as an undergrad TA, which, also, there was no training for. So, I didn't feel like I needed to do any of that but, these days, our Faculty Professional Development Program, here, at University of the Hills is really robust, and we do encourage a lot of our young faculty to be attending those sessions to help them as they're learning their way through teaching, but it did not exist for me, when I started. – Dr. Draper, Physical Sciences, University of the Hills

Notably, Dr. Dawes also brings attention to the importance of personal and professional satisfaction with teaching. The positive association between satisfaction and SCP was found in both the quantitative and qualitative sections of this study and is explored further below.

Personal Satisfaction with Teaching

Although the HLM did not include a measure examining personal satisfaction with respect to teaching, faculty expressed a broad range of attitudes that in most cases reflected their individual SCP scores. While most faculty expressed a sense of joy or satisfaction regarding teaching, others described a stronger favorable sentiment while a select few conveyed a more indifferent attitude towards instruction. Undoubtedly, personal satisfaction may play an important role in how faculty develop their teaching style and what strategies they employ in the classroom. Some faculty directly linked their satisfaction with teaching and specific teaching methods.

At the R1 institution Mountain University, Dr. Avasarala expressed enjoyment with classroom teaching:

> I think it's the captive audience. It's really fun. I mean, I really enjoy the courses that I teach… Almost everything about it is fun, and I team teach it with other faculty members that I really like, and who are on the same wavelength about having project-based learning and active learning exercises, so that makes it fun for me too, so I don't just stand up there and talk the whole time. It's been a really good experience. I also just really like students. I really like students that age. It's just really a good age. – Dr. Avasarala, Life Sciences, Mountain University

She also draws a connection between classroom teaching, students, and her fellow faculty. All of these contribute to the joy she has in teaching. Notably, she also implies a disdain for lecturing and a preference for incorporating active learning activities in the classroom. Dr. Inaros also expressed similar sentiments regarding how he approached his teaching:

> I mean, no, just sort of personal satisfaction, that the students are learning, and engaged, and enjoying the class. Well, I mean it's always a challenge to keep people interested and engaged. I know a lot of students take the classes because they have to, and they may not be passionate about it, and they may have other things they're dealing with at the time. So the traditional classroom environment is always challenging in that respect. That you don't always get the sense that everybody is motivated and wants to be there. So trying to make that as positive an environment, and as engaging, as interactive is a challenge. But I think you're never happy when you lecture for an hour and you just get the sense you lost most of the students halfway through… –Dr. Inaros, Life Sciences, Rocks University

Both Dr. Avasarala and Dr. Inaros express a preference for teaching methods that lead them away from lecturing the entire class period and towards more engaging teaching strategies.

While the previous two faculty members specifically cited teaching methods that make their instruction responsibilities more enjoyable, other faculty noted a deeply-rooted passion for the broader act of teaching. This interest in teaching shaped their career path, leading them to choose a life in academia over other career routes. Dr. Burton shares how teaching at a community college during his graduate program shaped his career path:

> So, I was still a graduate student and teaching night classes at a technical college, community college… But that was I think where I kind of got the teaching bug, right? So, especially with my background, the presumption was you went to grad school, you got your PhD, you went to work for recording or build apps or a company in that fiber, laser space. You didn't go off with that type of background to university. But I remember distinctly sitting there and saying, "Well, I love to do research. But I like to teach…But it was back in grad school because I was teaching these night courses at the earliest days of the internet that that kind of set me on that path. – Dr. Burton, Engineering, Tree University

Another engineering faculty member at a different research university expressed a similar career trajectory:

> I love teaching. I really love teaching. And that's why I came to academia because research and engineering consulting, which is what I was [Inaudible], they're kind of similar. They're very technical, they're kind of similar. So what's different about being at a university is the teaching part. And so I really truly enjoy teaching and working on one-on-one with students on projects, I really enjoy.– Dr. Duarte, Engineering, River University

In the physical sciences, Dr. Mao expressed a similar view:

> …I TA'ed pretty much every semester that I was a graduate student and got heavily involved in it. Really found that I enjoyed it and I think that led to my desire ultimately to try and follow the academic path rather than going into industry. I'm an analytical chemist and there's obviously tons, there are plenty of opportunities for that in industry and in academia as well but more in industry definitely. – Dr. Mao, Physical Sciences, Canyon University

Each of these faculty members joined academia in part because of their interest in pursuing teaching. This interest in teaching might be expected to influence how they approach their respective classes. Specifically, it would be expected that faculty who choose to pursue a career path specifically because it involves teaching might invest more time and effort into strengthening their teaching and involving a higher degree of student-centered activities.

Examining the association between the SCP scores of these faculty members and their personal satisfaction with teaching reveals a lack of a distinct pattern. Of the five faculty cited above, Dr. Avasarala (.58), Dr. Inaros (1.24), and Dr. Burton (1.09) scored above the mean SCP score of all faculty survey respondents (-.01). On the other hand, both Dr. Duarte (-.31) and Dr.

Mao (-1.26) scored below and well below the average score, respectively. Three of these faculty scored beyond one standard deviation (.93), with two achieving positive scores (Dr. Inaros, Dr. Burton) and one displaying a negative score (Dr. Mao). Taken together, it appears that expressing a personal satisfaction with teaching – and in some cases, joining academia partly due to a desire to teach – does not necessarily make faculty much more inclined to include student-centered teaching practices in the classroom. While a three-year gap exists between the time SCP scores and interview data were collected, the impetus to join academia partially due to teaching would have also been true at the time of completing the faculty survey and it is unlikely that faculty would have enjoyed teaching to a vastly different degree three years before participating in these interviews. It is possible that some faculty who express great enjoyment with teaching but scored particularly low in SCP may be unaware of pedagogical techniques or lack sufficient experience in implementing a teaching strategy that incorporates student involvement to a greater degree.

The (Dis)Incentive System

While faculty shared a wide variety of factors that influence their teaching practice, the most common responses described the influence of structural and position-related characteristics that pull faculty away from dedicating time to their pedagogy and its refinement. These interconnected factors include academic rank, tenure, and the importance of research in their career trajectory. Together, these contribute to steering faculty towards investing time away from teaching and into their academic research. This section will review key examples that demonstrate the challenges faculty face as they are incentivized to disinvest time in their teaching and in some cases, are dissuaded from attempting to improve their teaching whatsoever.

Several interviewees spoke to the fact that faculty early in their careers are consistently sent the message that they should disinvest from their teaching in favor of their research. These messages encourage faculty to invest any available time in their research program, at times going above the agreed upon time breakdown for their position (e.g., 40%). These messages early in careers can have a powerful impact in shaping how faculty approach their teaching for years to come. Dr. Roci spoke to how newer faculty were denied the opportunity to participate in a professional development program:

> …there were faculty who were new faculty who wanted to participate in the program, and the department chair said no. They can't participate because they need to focus on their research. I know that that exists, and that's a message that people get pretty strongly as young faculty. You should wait to focus on your teaching, unless your teaching is really bad. You've got to get it up to like the bar. Once you hit the bar, you shouldn't spend any extra time focusing on your teaching, you should be focusing on research. – Dr. Roci, Physical Sciences, Ocean University

Dr. Holden also spoke about the challenges faced by new faculty in academia:

> As a beginning faculty member at a research institution, you can't... you have to really be careful about... You're learning how to teach, of course, so you have no training. It's really easy to spend all of your time doing that, and then you'll fail. And so you have to like, "Okay, I can only spend this amount of time teaching," because I have to do all of this research to get grants and to get tenure write papers and all that. – Dr. Holden, Physical Sciences, University of the Desert

The message that faculty should invest their allotted and available time in their teaching can be reinforced even before faculty join an institution. Dr. Holden succinctly summarized how hiring processes valued teaching:

> I mean, it's not. I mean, when we hire we only care about research. When people go up for a tenure promotion, it's only about the research. – Dr. Holden, Physical Sciences, University of the Desert

This messaging to current and new faculty makes it quite clear that the focus should be on a research program.

While it may seem evident that faculty at research institutions would be asked to invest more time in their research and that this would constitute the primary criteria for promotion and tenure decisions, many faculty pointed to the fact that such rewards did not always stay faithful to their official job descriptions. Some faculty stated that campuses – at both the institution and departmental level – played lip service to teaching and teaching well. Dr. Kamal spoke to the disconnect between official expectations at a research one university and the off-the-record message:

> So officially I am 65% research, 30% teaching, 5% service. So that's a [inaudible]. So the emphasis is supposed to be on research and teaching... Off the record we're told you don't have to be the outstanding super instructors, just don't mess it up, do a good enough job. I think me and my colleagues all struggle though because we all want to do a good job and teaching is really fun and it becomes really hard to not fully engage as much as you may wish sometimes. – Dr. Kamal, Life Sciences, University of the Desert

This disconnect is especially evident in consideration of how faculty are granted or denied tenure. At the same institution but in a different academic department, Dr. Okoye shared a similar opinion:

> If, if research is 50% of my job and teaching is 33%, and service is 17%. Then in theory I should be able to get tenure by being a great teacher and a great person doing service, and in actuality nobody will get tenure based on that. There's the real issue from my perspective is that; if we're going to call those other things 50%, then shouldn't we expect people to be good 50% on those things? And, the answer is no, not for tenure. – Dr. Okoye, Physical Sciences, University of the Desert

He goes on to add:

> Yeah, you're not going to get tenure for being a good teacher. If, you're borderline research, it might push you over the edge one way or another. But, other than that, it isn't. So, I've even said to the chair of the department, we say that tenure's based on these things, but it's not. Well, even formally, I guess in our formal book that describes tenure, it all discusses research. – Dr. Okoye, Physical Sciences, University of the Desert

These examples highlight the challenges of facing contradictory messages on the value of teaching and how it is rewarded.

While the previous faculty spoke to the challenges at one research institution, these views were by no means limited to this campus. At other institutions, faculty also spoke to these concerns and how mixed messages should be not only clarified but how teaching should be valued to a greater extent. At Rocks University, Dr. Ashford called for teaching to play a bigger and more influential part of the review process:

> I just think that they need to make it a bigger part in a more explicit part of the review process. I think that's the biggest thing that they could do and they need to, instead of just playing lip service to it, they need to actually say that…I think they actually need to put some weight behind that. – Dr. Ashford, Life Sciences, Rocks University

Dr. Avasarala echoed this sentiment at Mountain University:

> They could weigh it more strongly in tenure decisions and promotion decisions. I think they really could weigh it more strongly. I think it's sort of at the, "Well, that wasn't terrible," bar. There's plenty of lip service to it, but there could be better reality. – Dr. Avasarala, Life Science, Mountain University

Although both Dr. Ashford and Dr. Avasarala achieved higher SCP scores than the average of their respective institution and thus might seemingly benefit from increased weight being applied to effective teaching, neither of the two currently stands to benefit from any potential changes to how tenure decisions are made. The former is currently in a non-tenure-track position while the latter has already been granted tenure. The fact that Dr. Avasarala has achieved tenure and likely has witnessed additional tenure decisions lends further strength to her opinion that changes can be made to how teaching is valued and rewarded throughout the tenure process.

While teaching was commonly viewed as being undervalued in tenure and promotion decisions, some faculty expressed that being perceived as spending too much time on teaching can have a negative impact on their career trajectory. Despite that fact that he had excelled in his research and considered himself a “natural teacher”, Dr. Okoye was surprised during his tenure process:

> When I went up for tenure, there were a few negative votes. And, I talked within the faculty, I talked to the chair of the department and I said, "Why am I getting negative votes? My research is great." And he said, "The reason is because your teaching is so good. People have the perception that you're spending too much time teaching." Which is, so there's the problem. Even if you're not spending too much time teaching, if you're really good at it, then people say, "oh he must not be spending as much time in research as he needs to." So, it really is a pressure, to minimize time spent and being a good teacher, or a good service member until you get tenure. – Dr. Okoye, Physical Sciences, University of the Desert

Like Dr. Okoye, Dr. Dawes also found that being perceived as investing too much time in teaching can be negatively judged, particularly early in an academic career:

> I think that there is a complicated dynamic that happens whereas an assistant professor we're told that it's really the research that matters, and even if you're doing a really good job on research, if you're seen spending a lot of time on teaching, you can be negatively judged for spending time on teaching when you're an assistant professor, when everyone's telling you that you should really be going all-in on your research. So even if the research is going well, there can still be a negative consequence to devoting a whole lot of time to teaching beyond just what's kind of required. – Dr. Dawes, Physical Sciences, University of the Desert

Even though research may still be a priority for faculty and may be progressing quite well, spending too much time on teaching – or being perceived as such – can have a negative impact. Considering the teaching function required of most faculty, it is disturbing to know that faculty are discouraged from going beyond simply what is required of them and further troubling to recognize that some may be penalized for spending extra time on their pedagogical craft. This would explain why, when asked whether additional time would help her improve or change her teaching, Dr. Kamal provided the following response:

> Probably not. Honestly, it would probably get used up in research. So the teaching really is designated to its little niche in the [inaudible] hours a week that's it. – Dr. Kamal, Life Sciences, University of the Desert

Given the powerful influence of this incentive system, it is not surprising that additional available time might not make much of a difference in how much time is spent on teaching. This is an important consideration for those seeking to transform STEM teaching at research universities.

Any effort to transform teaching in STEM would have to take into consideration the academic rank and tenure status of faculty. Interviewees spoke to how investing time in their teaching is viewed differently depending on where they were in their academic careers. Dr. Dawes spoke about a “safe time” to devote to improving her teaching:

> I would say that I participated in workshops and tried to gather information as an assistant professor, but didn't really spend a whole lot of time revamping things as an assistant professor. It wasn't until I became an associate professor that I really kind of went all in on the activity-driven teaching, because I felt like it was a safe time to devote time to that. – Dr. Dawes, Physical Sciences, University of the Desert

For Dr. Nagata, faculty have to reach the rank of Professor in order to truly invest time in their teaching:

> The transition to full professor though is more difficult. That is an area where most people have done the teaching well enough but the research level the university expects in terms of national and international recognition and funding proves to be the barrier. At that point, it’s trying to get people over that last hurdle to be full professor that teaching becomes… well they almost have to put teaching innovation on the back burner while they can keep research going. – Dr. Nagata, Physical Sciences, Ocean University

For both Dr. Dawes and Dr. Nagata, climbing through the academic ranks provides the protection faculty need to invest time in their teaching. As associate professors, faculty are more beholden to the research demands of their department and institution, with far less wiggle room to innovate in the classroom. Like rank, Dr. Mao highlights how his department discourages faculty from investing in their teaching:

> I think the department, it likely comes down to where you are in your career once again. I think there's a real divide between tenured and non-tenured faculty…I think because of some of our department's history and some of the successes and failures prior faculty have had in terms of obtaining tenure we do to an extent discourage our faculty who are pre-tenure from investing too much time in their teaching. – Dr. Mao, Physical Sciences, Canyon University

It is evident that faculty members take into consideration their rank and tenure as they consider how much time to invest in their teaching. As Dr. Mao mentioned above, some may even be directly instructed not to invest too much time into their pedagogy. These messages are powerful warnings for newer faculty and help establish a departmental culture with respect to teaching.

In addition to subtle and not-so-subtle messages about how time is dedicated to teaching and research responsibilities, faculty also cited structural challenges that limited their exploration of active-learning pedagogy. Dr. Dawes shared how her department's evaluation system contributed to her use of a more traditional teaching approach earlier in her career:

> I think our student-teaching evaluation system might lead faculty to be risk-averse. Like not wanting to go too far out of the range of what students expect to happen in the classroom. I mean that's one of the reasons that I didn't switch from lecture-based to activity-based until after I'd gotten tenure, was because before tenure, I guess at some level I cared what the teaching evaluation scores were because that was going to go into my tenure file. – Dr. Dawes, Physical Sciences, University of the Desert

The consideration that faculty may be both not rewarded for enhancing their teaching and perhaps even face negative consequences for doing so can be a formidable factor that depresses the use of SCP. This finding supports the general trend that faculty feel much more comfortable making changes to their teaching after they have received tenure.

Financial Incentives

Following from Resource Dependence Theory (RDT), it was expected that the availability of incentives to improve pedagogical practice would serve as an important catalyst for the adoption of student-centered teaching practices. In fact, extensive literature has documented the impact of the availability of resources for stimulating further learning and implementation of active learning pedagogy (Major & Palmer, 2006; Pelletreau et al., 2018, Wieman, 2017). Despite this, some faculty were concerned about the worth of such incentives relative to the time and effort required to secure these resources and others simply felt these incentives had no impact on their teaching. Several examples highlight the inability of this type of incentive to influence faculty teaching:

> As far as awards and monetary things they don't influence the way I teach at all. –Dr. Drummer, Physical Sciences , Ocean University

> No, well I am quite sure they don't. I'd say more of that comes out of individual commitment. – Dr. Nagata, Physical Sciences, Ocean University

> When I have the time to but I mean, applying for that stuff often becomes another thing to do...The kind of monetary and grants and stuff like that, it's nice when you can get it, when you can apply for them but it's just hard to find the time to do that sort of stuff. – Dr. Ashford, Life Sciences, Rocks University

Dr. Ashford's concern about the time required to apply for monetary support highlights the cost/benefit analyses faculty engage in when considering whether to modify their teaching. These analyses are a direct result of the pressure placed on faculty by the (dis)incentive system at research institutions. On another front, Dr. Nagata's admission that individual commitment as opposed to financial incentives could more accurately account for faculty's adoption of student-centered teaching aligns well with our understanding of Organizational Citizenship Behavior (OCB). Faculty adoption of student-centered pedagogy can be seen as contributing to organizational efficiency and production via the improvement of student learning, even when such actions are not usually or consistently rewarded by the organization (i.e., department).

The influence of the (dis)incentive system is likely to be more potent at research one institutions compared to research two universities given the heightened research demands. Just like Dr. Ashford at Rocks University, Dr. Duarte at River University felt that the monetary incentive available to her was not worth it:

> I just feel like most of them aren't worth it. For example, if you want to redesign a course and so that it's active learning, there's $1,000 grant for a course or something like that. You have to apply for the grant and you have to use the $1,000 on your course. In the

> way I've thought about it is it wouldn't cost $1,000 to do active learning in my course. It wouldn't cost any money. I just needed the time to figure out how to do it…So, I don't need to write a proposal to get $1,000 to spend on a course. I just need some time to figure it out or a person to talk to who's an expert who can help me with it…And that, no, it was not enough of an incentive, for me. – Dr. Duarte, Engineering, River University

Importantly, she offers key insights into what type of incentives or resources may be more beneficial for her teaching. She shares that having an expert guide her through the process of redesigning a course would be helpful. Dr. Duarte also offers the option of additional time to transform teaching. It is possible that grants in the form of release time may be more appealing to faculty members than a one-time payment. This view is shared by Dr. Mao at Canyon University:

> Yeah, I think the grants definitely help. It either buys us some time or some resources to get involved in doing it. I think without it, it's not something most of them would have jumped down that rabbit hole, doing this additional work to get it together. – Dr. Mao, Physical Sciences, Canyon University

However, unlike Dr. Ashford and Dr. Duarte, that Dr. Mao and his peers are employed at a research two institution where the research demands are likely less pressing than at either Rocks University or River University. Nonetheless, it is important to consider the current workload of faculty when providing incentives for teaching support and how workload may shape the type of incentives that should be provided. This aligns with previous findings that recommend incentives be tailored to faculty, often in ways that specifically support their research programs (Wieman, 2017).

The Evolution of Teaching

Just as faculty cited a broad range of factors and characteristics that influenced their teaching, they also shared diverging perspectives on whether and to what extent their pedagogical approach had changed throughout their careers in academia. While some individuals expressed their approach has remained consistent throughout the years, others articulated an evolving methodology based on various influences and the benefits gleaned from years of experience. This section will review the pedagogical evolution (or lack of) of STEM faculty at research universities before highlighting potential modifications instructors would like to make to their teaching but are unable to do so under their current working environment.

A Consistent Approach

While most faculty noted changes in their teaching approach, a few faculty members shared how their teaching practice and philosophy have remained consistent throughout their careers. At the University of the Desert, Dr. Kamal expressed how content-wise, not much has changed in his teaching:

> I feel like because I've been teaching the same sort of courses I have the material more prepared. So certainly the time that I spend preparing for teaching now is less than when I first started. My first couple of semesters I remember that's pretty much all I did for the whole semester was prepare to teach. Now it's nothing close to that. But the content hasn't really... I've added in a few extra things to try to pull student interest in. But the content really hasn't changed lots or its delivery, I don't think. – Dr. Kamal, Life Sciences, University of the Desert

In a different field and at a different institution, Dr. Burton expressed a similar sentiment:

> I think that it has remained fairly consistent. Obviously, I have taught different classes at different levels so I'm not comparing the same class. But I think my philosophy, I guess for lack of a better word, is probably more or less the same. – Dr. Burton, Engineering, Tree University

Although these faculty shared similar perspectives on their teaching, their professional characteristics and SCP scores differed significantly. Dr. Kamal is an Assistant Professor on the tenure track whose SCP score (-0.42) was below her institution's average (0.17) while Dr. Burton is a tenured Professor who scores (1.09) well above the mean for his university (-0.10). The fact that the latter has maintained a consistent approach throughout his career and significantly engaged his students in student-centered teaching supports the idea that some faculty may engage their students in active learning practices at a higher rate from the outset of their careers.

One faculty member who shared that he had employed active learning practices since early in his career was Dr. Okoye. He described a learning activity he utilized when he arrived at the University of the Desert:

> So, when I came there was no technology like clickers that we use now. And, I actually bought colored three by five cards. And, handed them to my students, and would ask qualitative questions and have them hold up, a colored card based on their answer… and, this was way back in like 1996. So, I was probably the first person at the University of the Desert, to take these big lecture classes and try to use some kind of interactive technique. Where the professor and the students got feedback. Other people in the physics department saw that this was working and started to emulate it. – Dr. Okoye, Physical Sciences, University of the Desert.

The initiative demonstrated by Dr. Okoye was exemplary at a time when classrooms lacked the technological capabilities available today and student-centered teaching was less common at his university. This early behavior is consistent with OCB as it goes above and beyond what is generally expected and rewarded by academic departments at research institutions. Such individual initiative is particularly noteworthy as it appears to have been consistent throughout his career:

> So, almost every, many general education classes now use clickers. And so, the reason I say that is; I don't think a lot has changed, but part of that is because I was a pioneer in using some of these techniques that are now used throughout the country in these large lecture classes. So, a long answer to a short question. I mean things have tweaked in how I teach, but because I was using interactive techniques from day one almost, not a lot has changed. – Dr. Okoye, Physical Sciences, University of the Desert.

Dr. Okoye's consistency in using interactive techniques throughout his career is reflective of his dedication to student learning. Unlike Dr. Okoye, however, the majority of faculty interviewed faculty expressed moderate to significant changes in their approach to teaching over the course of their academic careers.

Time and Experience

Nearly all faculty who were interviewed noted that their teaching style had evolved to include less material and increasing levels of engagement with students. In part, this shift was attributed to a greater familiarity with the course material and an increased comfort with the teaching process that results from experience in the classroom. This finding was consistent across departments, rank, tenure status, and institutional type. A few examples highlight how faculty moved away from delivering extensive amounts of material to incorporating more activities in their instruction:

> It's evolved. So when I first started I would tend to do a lot of just problems on the board. It was all focused on either deriving important results or working sample problems on the board. I do much less of that now I'm doing more activities where if I'm doing stuff on the board I try to have it be 20 minutes max and then have something where the class was working on something amongst themselves more. – Dr. Drummer, Physical Sciences, Ocean University

> It's certainly become more, well, I've tried to make it more student centered. I've tried to move towards that more. I definitely was much more of kind of a sage on the stage, just lecturing with slides with lots of words and stuff like that but I've gradually over the years moved away from that. I took a lot of the verbiage out of my slides and I talk more to the students, write more things on the boards or on overheads or something like that or [inaudible] and stuff. I try and do more active learning sorts of things…like classroom activities, think pair shares, using clickers, doing in class discussions and stuff like that in the big classes that I do teach. –Dr Ashford, Life Sciences, Rocks University

> I'd say that I talk less every time. I put less content in every time. It becomes more participatory, like more about process and understanding and less about memorization. I think that's how my courses have generally evolved. – Dr. Avasarala, Life Sciences, Mountain University

Dr. Avasarala's note about her teaching becoming more about the process and less about memorization speaks to shifting views about what learning is and how best to achieve it. In the case of STEM students, while there are certainly heaps of specific information that can be passed on, faculty may be better served by focusing on general processes and problem-solving techniques.

At the University of the Hills, Dr. Draper reveals how her teaching has evolved to include less material, a broader focus, and a deeper emphasis on analytical strategies. She discusses her experiences with teaching early on:

> I've definitely changed a lot. I know, early on, I just wanted to cover as much content as I could. I wouldn't necessarily go into great depth. It would just be sophomore organic chemistry, this reaction, that reaction. "Let's get as many reactions down as we can. Oh, look. We've done everything in the book. Let me show you this other thing that's not in the book." I know, my first year, I just killed my students with that. I also, very early on, felt that if I didn't say it to them that I couldn't hold them responsible for knowing it. So, I had just really jam-packed lectures to try and get every last thing disseminated to them, despite the fact they had a book in front of them that they could've been using. – Dr. Draper, Physical Sciences, University of the Hills

Her struggles with covering the available material and being able to hold students accountable to knowing it speak to the pressures that faculty feel from both students and from the intended curriculum for the course. The fact that faculty across various disciplines and institutions shared their struggles with covering all the material early in their careers may speak to mismatched expectations regarding what is expected to be taught. At the same time, faculty may attempt to cover all the material because they lack experience with teaching the course and recognizing what is more and less important for students to know. Moreover, it is possible that the pressure to produce high-quality research to advance in academia and achieve tenure may not leave much room to review the established curriculum. In other words, faculty may not have the time to thoroughly review the content of their assigned courses and prioritize what they feel as most important for students to learn. Dr. Draper went on to discuss how her teaching has evolved from her early years:

> In general, I do go into more depth now, and less content…Instead, I just try and show them, "Here are the tools that you'll always be able to use, to figure these kinds of things out, no matter what context you might see it in, whether you're an environmental chemist, or in some sort of end of environmental science, and here's ways you can figure out these problems," and so on. So, I try and develop more general tools and make it more about the general learning process and really specific about chemistry. So, a little less content, a little more general, now. – Dr. Draper, Physical Sciences, University of the Hills

Having achieved tenure, Dr. Draper may have more time to tinker with her teaching and isolate the specific strategies and content she would like her students to know. Years of teaching experience may also have led her on the path towards changing her approach to pedagogy.

Flipping the Classroom

STEM faculty varied in the extent to which their teaching approach changed throughout their careers. While some instructors changed their approach to include more active learning strategies in the classroom, others went further in redefining their pedagogy. Dr. Mao and Dr. Holden went so far as to flip their courses, essentially delivering course content electronically to students outside the traditional course period and devoting the entirety of class time to engaging students in active learning activities. The former describes his transition:

> So I initially started teaching the course, it's an analytical chemistry course, I do also teach some others but I've been teaching the same analytical chemistry course since I started. It started off as simply standard lectures, students sitting in the class watching me and now it's entirely a flipped classroom with active learning group work throughout the entire semester. – Dr. Mao, Physical Sciences, Canyon University

When asked what motivated this change in his teaching, Dr. Mao shared the following:

> A little bit of more knowledge of educational theory and practices. Trying different things in the course and learning that students, or seeing some of the failures that students had in just a pure lecture model and realizing that getting them involved with doing the problems was what they needed to do the most of. I fell in with a bunch of people who are doing a lot of curricular development work in analytical chemistry. – Dr. Mao, Physical Sciences, Canyon University

Dr. Mao's experiences in the classroom and his growing knowledge of educational practices led him on the path to revamp his teaching and include more active learning strategies. Perhaps as importantly, his fellow peers in analytical chemistry served as a support network for the application of these adjustments in his course. We cannot overstate the importance of faculty peers in gaining the tools, experience, and confidence necessary to implement significant changes in the classroom. As more faculty begin to implement changes in their teaching, we might expect a snowball effect that can catalyze the use of student-centered pedagogy in STEM classrooms.

A second faculty member who also adopted a flipped classroom approach was Dr. Holden at the University of the Desert. He shared his approach to teaching:

> I've moved to more of the flipped classroom…So, if I'm going to lecture on something, here's a work example I'm going to do, or here's a derivation, I've been slowly and steadily moving all of that to online videos. "Here's my derivation and now you can watch as much as you want. You can pause it, you can go back and forth. The same with work examples, right? Pause it, go back and forth if you get stuck." So I try to save, for classroom, stuff that we can do together as a class. And for the smaller ones then, you can do a lot more, "Hey, let's get in little groups and work on this problem," sort of thing. People have said they've been able to do that with the class of 300. I haven't been able to do that successfully just because chaos breaks out. But it's still the questions, the voting questions, and those sorts of things, I try to do that. So, that's one thing that has changed over the years. – Dr. Holden, Physical Sciences, University of the Desert

Dr. Holden's organic move to a flipped classroom approach underscores his commitment to student learning. His emphasis of the benefits of the flipped approach – "Pause it, go back and forth if you get stuck" – highlights one of the reasons why faculty move towards this approach. When pressed to expand on why he had invested so much time in his teaching and moved towards a flipped classroom approach, including the development of his own resource-filled website, he added the following:

> Yeah, yeah, no and it's even maybe worse than you think because, I mean, I consistently get fine reviews. If I had done none of this, I would still have gotten the highest rating in my yearly evaluation on my teaching because students, I do a fine job, students like me, I get good reviews… And so I want to try something new, I want to move forward. It was an enormous amount of time learning because I went to the beginning learning HTML

> and CSS and then PHP and whatever MySQL or SQL, all that database management stuff just for the website. But it was fun. I mean, it was a huge time sink but learning it was, I enjoyed it immensely. And so I want to see if, and then I can see they love those resources. The students, they think they're great. And so that's pleasant, that's nice. But it's really I've got to find something new to try to improve. If I'm just doing the same thing I did over and over, I just hate all of it and then I can't. And then that's no good. – Dr. Holden, Physical Sciences, University of the Desert

In addition to the satisfaction of knowing students loved these online resources, Dr. Holden also enjoyed learning new skills. Considering the large amount of time and effort that it took to develop these online resources for students and his motivation for doing so, Dr. Holden's transition to a fully flipped classroom is a perfect example of Organizational Citizenship Behavior. In this transition, he displays a self-driven willingness to exceed expectations – especially considering he is already viewed as an effective instructor – despite knowing these actions are unlikely to result in tangible professional benefits (e.g., increased salary). Dr. Holden did not have to undertake these extensive efforts, and that makes them more remarkable.

The Process of Change

Faculty readily admit that making changes to their teaching can be a prolonged and challenging process. While some described themselves as natural teachers, others explicitly talked about the challenge of incorporating student-centered teaching. Dr. Duarte shared her experience:

> I tried some active learning early on, but I just wasn't that good at it. But I've gotten better at it. And so I do give students more time to work in groups in class and I don't feel like it takes away from the rigor of the class or just important material getting disseminated to them. So more active learning, although the style varies from course to course, in year to year just because it's a lot of experimentation that happens with active learning until you've got it right. But yeah, there is more active learning now than there used to be. –Dr. Duarte, Engineering, River University

Gaining experience with active learning strategies in the classroom is certainly a key concern for faculty seeking to transform their approach to teaching. The inability to incorporate such strategies immediately into the classroom may partially explain the large impact of participating in professional development programs that was found in the previous chapter. Participating in these programs may provide faculty the experience, tools, and techniques to gain confidence in using SCP more regularly in their courses.

Although experience certainly matters, teaching the same course over an extended period of time may also be a detriment to the inclusion of different or newer pedagogical approaches as was discussed by one faculty member:

> I think what would make it work for me, maybe, is if I taught something else, because I've taught this class five times, so it's so tempting to just, "Okay, everything's ready," but if I had to do a new course, I would have to do a new course anyway, and that would be an opportunity to put in some of these other methodologies, or try some things that are a little bit different. – Dr. Avasarala, Life Sciences, Mountain University

The concern about settling into a teaching groove is certainly troubling as many faculty may find themselves teaching the same course or set of courses over many years. Although faculty may save the time they may otherwise invest in their teaching if they had to teach new courses more frequently, it is possible that the quality of teaching may decline over time and that the techniques and strategies used in the classroom may become outdated. Dr. Avasarala’s admission that a new course would motivate her to invest additional time in trying new methodologies would suggest that one way to encourage faculty to rededicate additional time and effort into revamping their teaching would be to facilitate the development of new courses or the rotation of existing courses amongst the faculty of a department.

Although Dr. Avasarala conveyed that teaching a new course would provide an opportunity to include new methodologies in her teaching, she also shared several reasons for why she has incorporated active learning practices throughout her career:

> Well, the Top Hat. I didn't use that before, and then Wendy (peer faculty) was like, "Oh, you should use this." I was pretty early adopter of it, but it was definitely something that I

> changed the course from straight lecture to audience response. That's probably the biggest example, but so many things, like the Think-Pair-Share exercise, the Muddiest Point, all the classics, I just tried them all. The students are like, "What pedagogical technique are you trying out on us today?" Like, "I'm trying this one. Here's the evidence for why it works. Here's why I'm trying it out on you." – Dr. Avasarala, Life Sciences, Mountain University

Here, she cited two reasons for using these active learning techniques. First, she recalls the suggestion of a fellow faculty member who helped transform her class. While we will never know whether Dr. Avasarala would have included active-learning techniques in her teaching without the suggestion of one of her peers, it is reasonable to assume that such a suggestion can provide the confidence to do so and possibly accelerate the inclusion of such practices. Secondly, she shared that part of the motivation was the evidence that SCP has an impact on student learning greater than that of traditional lecturing. Clearly, Dr. Avasarala has invested time in learning about pedagogical techniques and the evidence that drives their use. This suggests she is driven to improve her teaching and cares deeply about student learning.

Another faculty member who was driven to enhance her teaching for the direct benefit of her students was Dr. Roci. Having inherited a slide presentation from a colleague who had previously taught the course, she felt pressured to follow it during her first year teaching at Ocean University. She described how she felt about her teaching during this first year and how her practice has evolved since then:

> One thing that I noticed in the first year was there was a lot of information, like we would have 35 slides to get through in an hour, and it's impossible. I don't even know how you do that. I would just be like jamming through, just trying to tell them everything. I was not really happy with that. The second time I taught it, I cut everything back to like 20 slides. I try not to go above 20, and made a lot more like, "This is a practice problem that you're going to do," kind of things. There was a tradition, people use Clickers here, and so there had been Clicker quizzes that people would use, and stuff like that, so that was good. I added in some other practice problems, more time for the students to practice and process what they were learning. – Dr. Roci, Physical Sciences, Ocean University

After her first year, Dr. Roci felt much more comfortable making changes to her pedagogy and based these modifications on the challenges she faced while delivering content to her students. When asked to describe her motivations for including more student-centered activities in her teaching, she shared the following:

> I'm trying to be more purposeful about the idea of constructing knowledge where there are these concepts that I really want students to understand that are going to help them think with chemical intuition later on. I want to really provide some high-quality experiences for them around those topics. It's a little bit challenging because I think students feel like they don't get the information. You have to find a way to make sure that students feel like they got information after they work for it a little bit. -Dr. Roci, Physical Sciences, Ocean University

Dr. Roci’s motivation for shifting from a more traditional form of content delivery to a more interactive style of teaching was due in large part to her desire to improve the quality of student learning. It is worth noting that her concerns about students’ displeasure with student-centered teaching practices –despite enhanced student learning outcomes – has been noted in the literature (Austin, 2011). Despite these challenges, she remains committed to finding ways to improve student learning. Her dedication in the face of unconvinced students is indicative of her willingness to go above and beyond in her teaching, a characteristic of organizational citizenship behavior.

Contextualized Teaching Experiences

One of the driving stimuli behind this study was the desire to understand the extent to which institutional and departmental contexts shape STEM faculty’s approach to teaching at research universities. Within these settings, the role of faculty peers in motivating instructional change was also explored. Findings support the conclusion that how faculty approach their teaching and the extent to which they utilize student-centered pedagogy is strongly influenced by their professional environment. The remaining sub-sections of this chapter are dedicated to exploring the contextualized teaching experiences of faculty in greater depth.

Institutional Influence

Faculty considered their institutions to be an important contextual factor that shaped their approach to teaching. This influence was achieved through direct or indirect messages via institutional policy, directives, mission, or values. In some cases, these messages were transmitted via academic departments while in others stand-alone messaging complemented or in rare cases conflicted with departmental behaviors. In all cases, faculty had strong opinions about the extent to which their institution supported teaching. Some STEM faculty felt that their institutions were not supportive enough of teaching while others felt their institution was a strong supporter of teaching.

At the University of the Hills, Dr. Draper described a rare instance where departmental and institutional leadership were not quite on the same page. She described how faculty peers in her department valued teaching excellence to a much greater extent than her institution and its leadership:

> I think it's more from department leadership. It's definitely not valued elsewhere on campus. I think they just care that a warm body shows up to put grades into a grade book and pass most of the students. It's not your formal leadership. It's not like our Chair stands up in front of us and says, "Here's our directive to teach good courses." It's everyone who's more senior in the department buying into that and walking that walk. – Dr. Draper, Physical Sciences, University of the Hills

Her blunt declaration that institutional leadership does not value excellence in teaching is quite telling of the environmental context in which she is employed. Clearly, the message Dr. Draper has understood from her institution is that teaching well is not a priority. Importantly, faculty in her department have taken the initiative to give precedence to their teaching.

Dr. Draper's perspective on the lack of support for teaching at University of the Hills is backed by a fellow faculty member at the same university. Dr. Cortazar shared his take on the extent to which campus leadership supported teaching:

> I would say the college sort of talks about how teaching is important and even the mission of the university of students first. Sometimes actions don't always align with words though from upper administration. There is a lot of pressure to do other things that would take away from your teaching. So I'd say sometimes the actions don't line up with the words. But in words, they say that we're a student-centered university and students are first. It's just that sometimes it's like, okay, well if it was really students first then you wouldn't have this policy in this situation. – Dr. Cortazar, Engineering, University of the Hills

While working in different academic departments, these two faculty members come to a similar conclusion. That is, institutional support for teaching is lacking and, as Dr. Cortazar points out, is given lip service by the institution. Despite campus leadership describing teaching as important, Dr. Cortazar feels there is pressure for faculty to devote time to other endeavors. Such pressure can be an important influence on the extent to which faculty engage in activities that support or transform their pedagogical approach.

Just as Dr. Draper and Dr. Cortazar shared a belief that their university was not very supportive of teaching, another pair of faculty felt their institution could place more of an emphasis on teaching. Dr. Ashford and Dr. Inaros shared the following:

> Again, I think that if you do a good job teaching, you get a pat on the head and it's not fully integrated into the kind of culture. I mean, we're still a big research institution. Again, I mean, I think it's just going to be, they need to make it a bigger part of the review process. They need to make it and part of it is it's going to be a slow shift that's going to happen over time. –Dr. Ashford, Life Sciences, Rocks University

> I mean they certainly could. At the campus level, they could sort of prioritize teaching more heavily than it is now. I mean there is a sort of implicit understanding that if you're doing well in research, even if you're kind of subpar on the others, you're still doing okay. So maybe that kind of culture could change, and there could be more clear understanding that teaching is critical. – Dr. Inaros, Life Sciences, Rocks University

Dr. Ashford makes clear that good teaching is not properly rewarded at Rocks University via either compensation or the faculty review process. This view supports the notion that some faculty may be more intrinsically motivated to place an emphasis on their teaching, a perspective in line with Organizational Citizenship Behavior. Dr. Inaros further stresses this point when he admits that being subpar on teaching is okay at Rocks University if you are doing well in your research. Both faculty point to a need to change the "culture" at Rocks University, one that at this time is sending the message that teaching is not rewarded. Although both Dr. Ashford and Dr. Inaros are employed within the Life Sciences, it is likely that faculty in other fields (e.g., Physical Sciences, Humanities, Social Sciences) are also hearing this same message from their university.

The subtle or not-so-subtle message that research is the priority was also quite evident at the University of the Desert. In the opinion of Dr. Dawes, this message came from university leadership as a means of maintaining academic prestige:

> So we're kind of at the bottom of the R-1 list in terms of research productivity. And as a university, we're kind of desperate to maintain that R-1 status. So I think that a lot of the efforts and discussions and activities are really centered around research. I think that what probably needs to change is this idea that STEM is research. And that STEM, at least at my university, is thought of as the way to increase research productivity, and therefore the way to increase rankings and increase stature of the university. So that puts a lot of pressure on STEM faculty in particular to kind of go all-in on the research. And I think that that actually probably plays into kind of the zero-sum game perspective of, "oh, you're spending your time on teaching? You should really be spending that time on research.' – Dr. Dawes, Physical Sciences, University of the Desert

Words like "desperate" and "pressure" highlight the influence that messages about teaching and its relative importance can have on faculty. An outcome of such messaging is the "zero-sum game" mentality where faculty are regularly inferring that time spent on teaching is not as personally and institutionally beneficial as other activities, namely research. Dr. Dawes also brings up a key point about STEM faculty facing increased pressure to deliver research productivity for the university. Relative to their non-STEM peers, STEM faculty may be more strongly influenced by institutional messaging that deprioritizes time spent on teaching and rewards an emphasis on research. STEM faculty may also be directly (not just indirectly) asked by campus leadership to place a greater priority on their research over their teaching.

While some faculty spoke to less-than-supportive institutional environments, others highlighted how their campus leadership, mission, and values strongly encouraged them to focus on their pedagogy. At Canyon University, Dr. Mao shared an example of how campus leadership supported efforts to improve student learning:

> The campus leadership is involved and they've supported us a lot in many of the initiatives that we've undertaken. So one of the things has been the implementation of supplemental instructors for summer general chem courses. And they've found the money to keep that going. We got it started with the course redesign grant and one of our associate deans was part of that redesign and she was, she's been instrumental in making sure that we have money to maintain that through more courses than what we started with because the students began demanding it for the next level and the next level. So they're certainly supportive of it. They, I wouldn't say they necessarily are rewarding us in any way for doing it but they will make sure that the students are getting the resources that we think are most appropriate for being able to teach them if we can prove that it's worthwhile. –Dr. Mao, Physical Sciences, Canyon University

While this example does not specifically highlight an effort to shape how faculty spend their time in the classroom, the willingness to continuously invest funds in these efforts is a powerful message that makes evident student learning is a priority at the university. This is especially important as some research institutions not only fail to support efforts to improve teaching but actively discourage them. This message would not be lost on faculty and there is a strong chance further initiatives to improve pedagogical practice may also be supported by campus administration. The fact that these are faculty-initiated endeavors that are not specifically rewarded makes this a prime example of Organizational Citizenship Behavior as faculty go above and beyond their required responsibilities. These faculty are clearly not motivated by personal gain nor are these initiatives part of their job description.

In addition to investing resources in teaching, faculty also highlighted how their institution's values had a direct impact on their job expectations and performance evaluations. At Ocean University, Dr. Drummer spoke to the impact university values and priorities had on his teaching:

> So, at a general level Ocean University expects us to be good teachers. The stereotype of the big research university is the professors are like their classes are all taught by TAs at least at the beginning level and the professors don't even want to talk to the undergraduates. They'll talk to the graduate students if they are doing something interesting that's a little bit the stereotype of a research university. Ocean University is definitely not like that we have a clear expectation from the administration that we have good teaching. And we have a lot of hard courses that are taught by faculty even at the introductory levels. So, on one hand that is an expectation and an incentive to care about teaching. And of course it's a place where you accept to come here knowing that at the beginning that teaching is going to be an important part of how you're evaluated. – Dr. Drummer, Physical Sciences, Ocean University

On top of the expectation that faculty have good teaching, Dr. Drummer's final point about faculty agreeing to come to Ocean University with the expectation that they have good teaching can be a key factor in explaining how he and his peers approach their teaching. Considering that pedagogical practice plays an important part in performance evaluations, faculty must be mindful to prioritize teaching excellence. Dr. Drummer's perspective on his institution is supported by a fellow faculty in Engineering:

> The board of trustees of Ocean University has said that we will remain a teaching institution primarily, with research to support the teaching. So we won't be an R1 institution. That's not our goal. It's not our desire. So I find, that the infrastructure and all of the incentives and the whole way that the university is set up is strongly in support of, me being a better teacher. And anything that I need, in the way of teaching, is supported by the institution. – Dr. Johnson, Engineering, Ocean University

Both Dr. Johnson and Dr. Drummer point to Ocean University's institutional values as being very supportive of their teaching. This level of institutional support was unique among all the interviewed faculty and establishes an intense focus on teaching that is not commonly associated with research institutions, even within the R-2 classification.

Ocean University's focus on teaching creates a scenario where faculty must be willing to align their personal and professional values with the institution. While not all faculty would find Ocean University to be a great fit for what they are looking for, those that do accept positions are at least to some extent more inclined to devote time to their teaching. The notion of being a good fit with their university was described by other faculty members:

> Then at the position at Mountain University, which seemed like a good fit for me, with its combination of being research active, but also having quite a focus on undergraduate education, especially experiential education, which is learning by doing. It's a kind of Mountain University shtick. I like that a lot, so it's been a good fit for me. –Dr. Avasarala, Life Sciences, Mountain University

> And, much of my travel money comes from teaching honors classes here. So, there's financial incentives, to do good teaching. And again, I think that's because this university values teaching. And, it's one reason I like being here. I think I would struggle at a university that minimizes teaching, even more than the standard R1 university does. – Dr. Okoye, Physical Sciences, University of the Desert

While Ocean University is an R-2 institution, Mountain University and University of the Desert are both R-1 institutions who prioritize good teaching and have a clear focus on undergraduate education. Yet, all three of these universities impact teaching and create teaching expectations for faculty via their focus on pedagogy and student learning. In these scenarios, faculty would benefit from being supportive of the university's values and thus might be more inclined to spend time on their pedagogy. In these ways, a university's values and mission may influence the extent to which faculty adapt student-centered teaching practices.

These qualitative findings found no relationship between an institution's status as an R-1/R-2 university and the extent to which it supports effective teaching. The mix of R-1 and R-2 institutions found to be both more supportive and less supportive of teaching strengthens the quantitative finding in the previous chapter that showed no relationship between R-1/R-2 status and individual faculty Student Centered Pedagogy (SCP) scores. Support for good teaching – beyond mere lip service but extending into tangible investments and rewards – was found to be much more complex. In addition to research status, institutional values and mission played a part in influencing the amount of time faculty dedicated to their pedagogy.

Faculty Peers

Faculty peers are a key component in the development and preservation of institutional and departmental cultures that may influence the extent to which individuals adopt student-centered teaching practices. Since constructive social relationships with individual peers may facilitate the transfer of teaching styles from one faculty to another, it was important to examine the extent to which faculty felt their peers had an impact on their teaching. The STEM faculty who were interviewed put forward a mixed bag of results, with some highlighting positive examples of peer influence and others articulating their fellow peers had no impact on their pedagogical style. Within both of these camps, however, some interviewees shared their personal efforts to spark teaching innovation among their peers.

Before diving into several examples that highlight how STEM faculty can be influenced by their peers to modify their teaching style, it is important to reiterate that such influences can be relatively minor in scope and yet the impact that these modifications can have on student learning can be of great consequence. A positive influence on teaching need not be a complete transformation of the process of content delivery nor the adaption of novel technological improvements that radically transform student learning. Many influences are much more subtle in nature, consisting of tips, borrowed ideas, and even motivational boosts. Several of the faculty who were interviewed shared how their peers influenced their teaching in subtle ways. At Ocean University, Dr. Nagata shared the following:

> What a lot of my colleagues have done, and taught me to do just recently, I should have known, is the importance of explaining what you saw. Most of my problems are conceptual problems but a lot of my colleagues have taught me that you should also use an essay or short answer where they can explain why a certain phenomenon occurs. So I haven't implemented that very strongly but after 33 years I am still changing how I teach to make it more active for the students. So next semester I'll be implementing more explanations, telling the students "Explain why something happens", not just saying this is the answer. The object for good teaching is that the student builds inside their mind, inside their brain if you would like, a model of the universe and how it works. – Dr. Nagata, Physical Sciences, Ocean University

Dr. Nagata presents a perfect example of how faculty can take a seemingly minor suggestion from their peers and deliver impactful change for their students. This modification is significant because it involves students in the learning process, moving from repetition and memorization to higher level cognitive processes like analyses and evaluation.

In addition to Dr. Nagata, other faculty also shared how they too had benefitted from their peers:

> A part of that was trial and error just being more experienced as a teacher. Part of it was getting ideas from other people teaching more advanced classes. – Dr. Drummer, Physical Sciences, Ocean University

> Yeah, definitely. I mean a lot of my peers also really take teaching seriously. And so we talk about what we do in the classroom, you know, strategies, things like that. I think there's a lot of really good ideas in the department and so I'll steal their ideas all the time. – Dr. Cortazar, Engineering, University of the Hills

> So I've got some really great peers in my department who have very high expectations for their teaching, and I think that that has been a good motivator. – Dr. Dawes, Physical Sciences, University of the Desert

Evidently, instructors are gaining ideas from their fellow faculty on a regular basis and implementing these into their classrooms. Additionally, Dr. Dawes' admission that peers played a role in her motivation to focus on her teaching is significant since it demonstrates how departmental cultures can adapt to emphasize teaching excellence to a greater extent. In her own words, she explains why peers can be such a powerful influence:

> So you build a peer group, right, with the people that you interact with, and that you share similar values and expectations with. And then it's not like we hold each other accountable, but if somebody's trying out something in their classroom and it's working really well, then I might try that out in my classroom, right? Or if somebody's using a new technology tool to help them with grading that's more equitable and they're telling me about it, then I'm more willing to try that out than for instance if there's a salesperson that comes to my door. – Dr. Dawes, Physical Sciences, University of the Desert

This statement aligns with previous research that has shown STEM faculty are much more amicable to teaching adjustments if those improvements are being advocated for by a fellow STEM peer (Dancy & Henderson, 2008; Weidman, 2017). Considering the unique professional circumstances faculty face in academia (e.g., tenure, rank research demands), it is perhaps not surprising that individuals would be more inclined to gain insights from their peers as opposed to external persons.

In addition to external motivation to improve her teaching, Dr. Dawes also shared unique insights about her personal motivations. She added:

> Yeah, so I think I must've had some internal motivation to be a better teacher, right, in that I went to the professional development exercises even though I wasn't required to do that, and I wasn't necessarily rewarded for doing that as an assistant professor. But then once I got there, I saw that there were other people that were also interested in improving their teaching and being more inclusive teachers. And in many cases I got along with them better than some of the faculty in my college or in my school that were not necessarily interested in doing those sorts of things. – Dr. Dawes, Physical Sciences, University of the Desert

This account is a perfect example of Organizational Citizenship Behavior (OCB). In her own words, she highlights her personal motivation to attend professional development opportunities despite not being rewarded for doing so. Without a doubt, these actions contributed to the improvement of her teaching and therefore, were beneficial to her students and her department.

This statement also supports findings in the quantitative portion of this study that highlight the positive influence of professional development opportunities on the use of student-centered pedagogy. Similarly, the latter portion of this passage may also help explain how faculty who are involved in research across multiple disciplines utilize SCP to a greater extent. Faculty who have shared values and interests with peers outside their departments may be more likely to gain teaching tips and strategies from these peers. These positive collegial relationships could potentially lead to involvement in research that spans multiple disciplines.

Other faculty also spoke to the ways in which professional development opportunities helped connect them with peers within and outside their departments and how these networks have been influential in the adoption of student-centered teaching practices. Dr. Draper shared her experience:

> Especially the younger faculty are a big influence on me, because they come in with new ideas. They're in closer touch to the new generation, as we're adjusting to Gen Z, I've basically just gotten used to Millennials, and moved on, I think. So I look closely at the kinds of things they're doing and how they're getting across to students to see what I can incorporate into my own teaching. Then, similarly, my peers in other departments, especially people outside of science, they think so differently that, when I think about... I love how this accomplishes something very specific for you. How can this be used in something I do? I definitely gather inspiration there. The parallels between teaching O-Chem 2 and writing are tremendous. – Dr. Draper, Physical Sciences, University of the Hills

Dr. Draper's statement about her interactions with peers outside her department offers key insights into why these connections may influence the adoption of student-centered teaching practices. By attempting to draw parallels between teaching practices in the physical sciences and non-STEM fields, she is moving away from content-specific teaching styles and towards an approach focused on student learning. Another faculty member who also benefited from peers within and outside her department is Dr. Avasarala. She states:

> Yes. We have the peer teaching, and we have teaching circles where we meet every month and talk about teaching strategies and styles and problems, challenges, solutions. It's super helpful, so there's quite a bit of support and quite a bit of collegial interaction within and across departments. One of my colleagues, actually the colleague that organizes the class I teach, she is a chair of an HHMI Grant in Inclusive Teaching, so I've been going to all of her inclusive teaching stuff. Yes, they impact me a lot. It's been really good. – Dr. Avasarala, Life Sciences, Mountain University

Consistent teaching-focused interactions have the potential to result in a pollination of effective teaching practices across a university. Since Dr. Avasarala is evidently quite involved in professional development activities, she is likely to receive maximum exposure to novel teaching practices, strategies, and styles. This is especially important as faculty who participate in professional development opportunities have been found to have increased conversations about teaching with their peers after participating in these activities (Manduca et. al, 2017). In this way, these faculty may serve as a catalyst for the implementation of student-centered pedagogy in their departments.

In a similar way, a couple of the interviewed faculty shared how they influence their peers to adopt active learning teaching styles and activities:

> I think it's largely been my desire to adapt technology and adopt technology into the classroom and use it in different ways. I was the first to do any kind of video recording of my lectures. Now we have built in systems within the classrooms for most large lecture halls. Cell phone based polling, flipped classrooms, all these kinds of things. I've generally been the first one to adapt it or attempt it and then some others have followed along some of these aspects. – Dr. Mao, Physical Sciences, Canyon University

> I started doing this professional development actually for other faculty, where we were teaching them how to do student centered teaching, and active learning, or evidence based instructional practices, whatever you want to call it. – Dr. Roci, Physical Sciences, Ocean University

While Dr. Mao serves as an influence for his peers by taking the initiative and adopting active learning practices, Dr. Roci has taken a more active role herself by leading professional development activities for other faculty. In both cases, these faculty serve as catalysts for the implementation of student-centered teaching in their departments and their institutions. Not surprisingly, both also expressed that their peers don't influence their teaching all that much given their pedagogy is already at an excellent level:

> Within the department, no. I think I'm probably more influential on them than they have been on me although we recently hired a CER faculty, so chemical education research. So she's going to be a benefit to everyone in getting some better understanding of how we can improve teaching. – Dr. Mao, Physical Sciences, Canyon University

> That's a great question. I think probably very little. I think that in my department, I am on the forefront of high quality teaching, and there are some other people in the department that are also doing a really good job with teaching, but I'd say most people are pretty traditional. I think it doesn't influence me that much, with the exception being that for this course for 105-106, there is literally a schedule of what we're supposed to do every day. We're supposed to be synced up, and we have common exams. In terms of content, I think that they have a large influence, but aside from agreeing on content and telling me what the GPA for my class should be, they don't really influence my teaching at all. – Dr. Roci, Physical Sciences, Ocean University

Even though she shares a course schedule with some of her peers, Dr. Roci is not influenced by their teaching style. She charts her own course in the classroom on top of serving as a role model for other faculty through professional development programs.

Whereas Dr. Mao and Dr. Roci served as SCP catalysts even when they themselves were not influenced very much or at all, other faculty simply felt that they were not influenced by their peers. At Tree University, Dr. Burton shared the following:

> Not really. I guess I try to make sure that's true. No, not really, just because I guess I have evolved. What evolution there has been in my own teaching approaches and philosophies, I think I have done myself through my own classes. Nothing jumps out at me as something I may have heard from one of my colleagues and I was like, "Oh, that's amazing, I have to do that in my class." Sorry. I don't have a good example for that one. – Dr. Burton, Engineering, Tree University

Dr. Burton attributes the development of his teaching to his personal evolution rather than external stimuli. Other faculty also felt that they were not influenced all that much by their peers, largely due to a lack of conversations about teaching within their departments:

> Have my faculty peers influenced in any way? I would say a little, just a little. I don't know that I learn so much from my peers. And I think that is one thing I'm not so happy

> about is that we really don't share that much what we do in the classroom. I don't know, maybe we just don't get around to it. It's not like we're hiding, but it's not really something we talk about. I actually talk with very little with my faculty colleagues about teaching. -Dr. Duarte, Engineering, River University

> Not so much. I mean it's usually not something we discuss very much at all. –Dr. Inaros, Life Sciences, Rocks University

> Sometimes. I mean, when you can actually have conversations about teaching, which doesn't happen very often. It's always nice to hear what other people do and things like that but to be honest, it doesn't happen that often just because it's not something that's often talked about that much. Dr. Ashford, Life Sciences, Rocks University

Given the focus on research productivity that is prevalent within research institutions, it is not surprising that conversations about teaching are lacking within STEM departments. However, it is concerning that such conversations are not taking place because of the powerful impact that peers can have on the adoption of active learning practices. It is evident that departmental culture can have a dominant impact on the extent to which these conversations take place. The fact that two faculty representing the life sciences at Rocks University both admit these discussions fail to happen on a regular basis indicates that departmental culture can inhibit the adoption of SCP at the individual level. The pivotal role that departmental culture plays in the extent to which faculty utilize SCP will be explored further in the following section.

Departmental Culture

Previous sections of this chapter highlighted numerous factors and characteristics that influence how STEM faculty make decisions about their pedagogy and the extent to which they include active learning strategies in their teaching. These include the incentive system in academia, professional development, financial incentives, institutional goals and values, and peer faculty. While these undoubtedly contribute to the creation and preservation of a distinctive departmental culture, additional attention must be paid to if and how departmental leadership creates an environment that is conducive to faculty investing time in their teaching. This focus includes conversations about teaching, policies and practices that promote effective teaching practices, and whether faculty feel their department encourages or discourages investing time in your teaching.

Interviewees spoke to the prevalence of conversations about teaching within their departments. While in some cases these conversations were frequent and substantive, in others they were rare or nonexistent. Several examples illustrate the lack of formal conversations about teaching within some STEM departments:

> We've had fewer of those... there are fewer discussions that have focused on here's a teaching technique that is useful but we've talked about having those too. It hasn't happened yet though. – Dr. Drummer, Physical Sciences, Ocean University

> I mean, it's pretty low. I mean, there isn't... When I started, there was an organization within the department that would meet periodically to talk about teaching, but that doesn't exist anymore. –Dr. Holden, Physical Sciences, University of the Desert

> Yeah, I don't think I've ever had a conversation with my chair about teaching. They basically send us a letter every year saying, "This is the course you'll be teaching," we sign off and that's that. – Dr. Inaros, Life Sciences, Rocks University

Across these three research universities, conversations about teaching were not happening in these departments. While some efforts have been made to have these discussions, it is clear that they have not been prioritized enough to become a frequent component of departmental discussions. Inevitably, the lack of discussions around teaching sends the message that it is not a priority for the department. In the last example, Dr. Inaros' admission that he has never had a conversation with his chair about teaching is incredibly worrisome considering that leadership can set the tone for the department.

Although research has demonstrated many STEM faculty believe their departments to be unsupportive of enhanced teaching efforts (Dancy & Henderson, 2010; Wieman, 2017), some studies have shown faculty to be influenced by how supportive they perceive their departmental culture and faculty peers to be. Given their less than supportive environments, we might expect that Dr. Drummer, Dr. Holden, and Dr. Inaros (cited above) would be less inclined to significantly invest time in their teaching. Yet, the individual SCP scores of these faculty fail to reveal a distinct pattern. Dr. Drummer's score (SCP = -0.09) is below that of his institutional peers while Dr. Holden's (SCP = 0.48) is above that of his peers (Table 5.2). While both faculty's scores are within one standard deviation of their institutional peers, Dr. Inaros (SCP = 1.24) is more than one standard deviation above his peers at Rocks University (SCP = -.26; SD = .96). While it is certainly possible that a non-supportive culture can inhibit the use of student-centered pedagogy, it appears more likely that the bulk of faculty's use of SCP is independent of or at least despite these environments.

Conversations with faculty about the extent to which they felt teaching was supported in their department revealed interesting insights into departmental culture. At the University of the Desert, Dr. Dawes spoke extensively about how professional development activities are viewed in her department:

> Yeah, I think one way is to stop punishing them for doing these things, right? Even though it might not be explicitly punishing them. So, I mean kind of judging, right, for where people are spending their time. So, I spent my time in professional development things. Number one, because I wanted to increase my teaching efficacy. Number two, to meet people. And number three, to kind of bolster my mental health, right? And I think recognizing that people have various reasons for participating in professional development, so I'm going to professional development activities not because I'm a bad teacher, which was the interpretation of some people. They think the bad teachers go to professional development activities, right? Instead have it be the expectation or the assumption that everybody is going to go to professional development activities, or that the good teachers are going to go to professional development activities. Kind of changing that frame of reference from this is a punishment for being a bad teacher to, "oh yeah, this is a great thing to spend your time on." – Dr. Dawes, Physical Sciences, University of the Desert

Considering the positive association between participation in professional development and use of active learning strategies in the classroom witnessed in the quantitative results of this study, negative views on these activities can inhibit teaching excellence and student success. At the same time, studies have found a shift in departmental culture towards a more supportive environment after some of the department's faculty have participated in these programs (Manduca et al., 2017; Owens et al., 2018). Departments such as the one cited above may suffer not just from individual faculty losing out on professional development opportunities but from the collective benefit that would ensue because of greater participation.

While the above examples highlight departments that are perceived to be unsupportive or uninterested in having conversations about teaching, other faculty spoke glowingly about how they felt supported in their pedagogy. At Mountain University, Dr. Avasarala shared her thoughts on the wide range of support programs sponsored by her department:

> I had future faculty coursework as both a graduate student and a post-doc, and then we have peer mentoring for teaching in our faculty, so each new faculty person has a peer mentoring group that meets with them to help them learn how to teach… We have the peer teaching, and we have teaching circles where we meet every month and talk about teaching strategies and styles and problems, challenges, solutions. It's super helpful, so there's quite a bit of support and quite a bit of collegial interaction within and across departments. – Dr. Avasarala, Life Sciences, Mountain University

Such comprehensive support for teaching was quite rare at the institutions where faculty interviewees were employed, regardless of whether the campus was a Research-1 or Research-2 institution. When asked to elaborate on the prevalence of teaching conversations within her department, Dr. Avasarala offered the following:

> It's pretty prevalent. The associate chair is the person that does the Inclusive Teaching and the teaching circles. She, of course, is on the executive committee, as well as the Director of Undergraduate Studies and the Director of Graduate Studies, so three of the five people on the executive committee are teaching-focused, and we have a large number of teaching faculty, so we have tenure-track, of course, but then we also have a

> professional teaching faculty position, so instead of using adjuncts, we have professionals that are dedicated to teaching and scientific advancing methods in teaching. It might even be close to half. I think we have at least 10 of those guys, so we have quite a professional cohort in teaching in the department. – Dr. Avasarala, Life Sciences, Mountain University

In addition to a wide array of support programs, departmental leadership is significantly involved in and leads efforts to improve teaching within the department. In this way, leadership sets the tone for the department, which can be particularly helpful for younger faculty who may be interested in improving their teaching. At the same time, such commitment can serve as a powerful signal for faculty who might be reluctant to adopt active learning practices. These faculty – particularly if they have yet to reach tenure – may be more strongly influenced to reconsider how much time and effort they invest in their teaching. Dr. Avasarala’s admission that nearly half of the department consists of professionals dedicated to teaching and advancing scientific methods in teaching also underscores the departments emphasis on teaching excellence. As research has shown, these faculty can serve as catalysts for the implementation of student-centered teaching practices and departmental conversations about effective teaching strategies in addition to their own outstanding pedagogy (National Research Council, 2012; Chasteen et al., 2015).

Conversations about teaching were also frequent at other institutions and in different academic disciplines. These examples highlight how faculty can benefit from being part of professional development activities within the department:

> Well, I would say they happen quite frequently. And again, part of that is because, the monthly meetings that I mentioned where we're given a chance to focus on teaching, becoming better teachers, we know that it matters to the university and to the college. – Dr. Johnson, Engineering, Ocean University

> And, we have actually done this on and off in my 20 some years here. Where we bring in interested faculty, to talk about some of the better techniques of teaching what's been

> done in physics education research. And, things like that. And so, there has been an effort, kind of a grassroots effort by some of the better teachers in the department. To bring together particularly young faculty. But, anybody interested and talk about what we know as good teaching pedagogy, from what's going on in physics education research… And, I think those kinds of things might've been helpful for me. – Dr. Okoye, Physical Sciences, University of the Desert

In the latter example, some of the faculty Dr. Okoye identifies as the "better teachers" are leading efforts to encourage especially younger faculty to become more effective teachers. These peer-led efforts can be particularly useful as they have been shown to be positively associated with the use of more effective teaching strategies (Colbeck, 2002). Younger faculty may take cues from their more seasoned peers and may be influenced to fit in with the departmental efforts to focus on teaching. This is precisely the case that Dr. Draper highlights at the University of the Hills:

> So, I think the more senior faculty are continuing to pull the younger faculty along to keep seeing great teachers. In fact, the people who come in being mediocre teachers, and don't seem to be making an effort to change, they wind up not lasting here, and not because we fire them, but because they feel like they don't fit into the culture in the department. – Dr. Draper, Physical Sciences, University of the Hills

It is evident that departmental culture strongly supportive of teaching may influence faculty to move on from or remain at their position. For a department like Dr. Draper's, this culture may encourage faculty to spend significantly more time on their teaching than they may have otherwise at another institution.

Beyond conversations about teaching, supportive environments were also found to influence promotion and tenure within the department. At Tree University, Dr. Burton shared how his department's support for teaching influences the way he views faculty promotions:

> I would say absolutely encourages it. I chair our tenure and promotion committee, so I pay a lot of attention to our faculty, obviously particularly our junior faculties. Their teaching philosophies, not just their evaluations but based on their evaluations what they're doing inside and outside of the classroom to continue to improve those. We do

> pay a fair amount of attention to that. Obviously that has to be balanced against everything else as well. But it is certainly not under appreciated. Recognizing that again, everybody is going to weight them differently. But they won't get tenure and/or be promoted if they are not at all attentive to their teaching... Again, they don't have to be five out of fives. But they absolutely can't take it for granted. – Dr. Burton, Engineering, Tree University

Dr. Burton's leadership position on the tenure and promotion committee is a powerful avenue to broadcast support for teaching in the department. While teaching may be taken seriously in promotion decisions in Dr. Burton's department, this was not the case at Dr. Ashford's department:

> I would say discourage. I think they will play some lip service to it in terms of like we value teaching and teaching factors into your merit reviews and things like that. They say this to the ladder faculty but the reality is it's actually not true for the ladder faculty and stuff like that. Obviously it's a big part of what I get judged on because that's the primary part of my position but in terms of a normal ladder faculty here, they will play lip service to it but I guarantee if there was somebody who was really good at teaching but didn't bring in a grant, that person's not going to get tenure. – Dr. Ashford, Life Sciences, Rocks University

Even though his position is not on the tenure-track, Dr. Ashford makes clear how teaching plays an insignificant role in promotion and tenure decisions within his department. He points out that departmental leadership is dishonest about the role teaching plays in these merit decisions. The contrasts between Dr. Burton and Dr. Ashford's departments underscores the broad range of importance that is assigned to teaching at research universities and their STEM departments.

STEM faculty spoke to the departmental conditions that they have observed in their current positions. While in some cases faculty felt that their department was supportive of efforts to improve teaching individually or collectively, others noted that their departments and, in some cases, their departmental leadership were not supportive of spending time and energy on these activities. In extreme cases, some faculty observed actions and statements that actively sought to deny instructors the opportunity to improve their teaching, oftentimes in favor of research activities. The diversity of departmental positions with respect to teaching support falls in line with the broad range of student-centered pedagogy scores observed in the quantitative phase of this study. In these interviews, it became clear that support for teaching (or lack of) was highly dependent on the tone and culture established by departmental leadership and senior faculty members. While this support generally transcended institutional characteristics (e.g., control, research prestige) and academic discipline, some individuals relied heavily on a research-focused platform to push for a culture that prevented (deliberately or by consequence) the enhancement of teaching strategies.

CHAPTER 6: DISCUSSION

Introduction

The emergence of the COVID-19 virus and its evolution into a worldwide pandemic has laid to bare the critical, indeed vital, obligation to nurture scientific talent in the United States. While American scientists have significantly contributed to vaccine research and development efforts, the horrific devastation of the pandemic and its long-term impacts have only the heightened the importance of expanding America's scientific and medical ranks. Quite simply, the country could certainly benefit from having more biologists, researchers, chemists, doctors, nurses, etc. during this time. While the impact of the pandemic on STEM retention and graduation rates will not be known for several years, students at research universities were already leaving these majors in troublingly high rates prior to the crisis (NCES, 2018; PCAST, 2012). The present health emergency and the importance of remaining globally competitive in an increasingly scientific and tech-driven geopolitical climate adds additional pressure on research institutions to incorporate outcomes-based pedagogical methods that can boost baccalaureate degree production in STEM disciplines.

Recognizing that innovative and engaging teaching strategies have been consistently shown to result in increased student learning (Freeman et al., 2014; Jensen, Kummer, and Godoy, 2015), this study sought to understand the opportunities and barriers that impact the extent to which faculty incorporate active learning strategies in their classrooms. Drawing from Resource Dependence Theory (Pfeffer and Salancik, 1978) and Organizational Citizenship Behavior (Bateman & Organ, 1983; Smith, Organ, & Near, 1983), this study employed a mixed-methodological approach that could thoroughly understand both the external and internal sources of motivation in the decision to include (or not) evidence-based teaching practices in the STEM classroom. Special attention was paid to the effect of institutional and departmental contexts in hindering or catalyzing the adoption of student-centered pedagogy. By focusing on the time demands, opportunity structures, environmental contexts, and personal and professional characteristics that shape STEM faculty's instructional approaches, this study offers new insights that university administrators, departmental chairs, and faculty can utilize to implement new policies and practices – or modify existing ones – to improve the educational achievement of students with an interest in STEM degrees.

This final chapter achieves the following objectives. First, it summarizes the results of both the hierarchical linear model and the semi-structured interviews conducted with STEM faculty across the country. Second, it takes a deep dive into significant findings and examines how these fit in within Resource Dependence Theory and Organizational Citizenship Behavior while contributing to current scholarship in STEM education. Third, it discusses implications relating to theory, research, and practice while offering recommendations for academic departments, research universities, and professional organizations. Finally, this chapter highlights areas of future research that can advance scholarship and contribute to the growing understanding of how universities can boost STEM degree production.

Summary of Findings

The following section highlights key findings for each of the research questions guiding this study. Distinctions are drawn in the case of divergent findings between the quantitative and qualitative phases.

Research Question 1: What are the competing time demands, perceptions, contexts, and personal and professional characteristics that explain variation in STEM faculty's utilization of student-centered pedagogies at research universities?

Given the literature cited in Chapter 2, it was expected that Hierarchical Linear Modeling results would indicate time demands and faculty activities would be a significant predictor of variation in student-centered pedagogy. While this block of variables accounted for the largest share of explained variance in the model among the four blocks of predictors, several findings would seem to diverge from previous literature. For example, whether faculty had written research grants or received state or federal government funding in the last three years – activities which would reasonably be expected to be a consistent and time-consuming part of STEM faculty's workload – had no bearing on the extent to which they included active learning in their classrooms. Moreover, even though the number of accepted or published writings in the last three years (another time-expensive activity) was found to be statistically significant, its influence on the outcome was null. Most importantly, the number of hours per week that a faculty member devoted to preparation for teaching, committee work and meetings, and research and scholarly writing all were found to be insignificant predictors of SCP.

In the qualitative phase of this study, faculty routinely cited time concerns as a major impediment to the inclusion or expansion of active learning strategies in their courses. The interconnected nature of academic rank, tenure status, and the significance of research productivity within their career trajectory were discussed as having an important influence on how much time faculty could afford to invest in their teaching, particularly early in their careers. Faculty across the academic ladder (i.e., assistant, associate, full professor) at both Research-1 and Research-2 institutions spoke to the lack of time to focus on their pedagogical craft, support from campus administrators (including department chairs), and rewards for investing time in your teaching, especially as an assistant professor. These results support previous literature highlighting the connection between time concerns and faculty willingness to embrace active learning teaching methods.

The strongest predictor of variation in student-centered teaching practices in the hierarchical linear model were faculty who are employed outside the tenure-track at an institution with a tenure system. These positions are likely to reflect the growing trend of Science, Technology, Engineering, and Mathematics departments hiring faculty with an expertise in teaching and/or education research in their discipline. Considering these individuals are likely to be better acquainted with novel teaching practices and in some cases more appropriately trained by either their graduate programs or professional development opportunities, it is not surprising that this professional characteristic would be a key predictor of student-centered pedagogy. What was surprising, however, was the growing strength of this predictor as additional variables entered the HLM. The largest increase in both predictive power and statistical confidence in the result came with the inclusion of faculty activities and time commitments in the model. While it would normally be expected that coefficients would decrease in predictive strength as additional variables enter the model, this increase is because faculty in these non-tenure track positions are indicating they are less likely to conduct academic research across multiple disciplines and participate in the development of curriculum. In other words, when you control for whether faculty engage in multidisciplinary research or curriculum development, the positive relationship between being a non-tenure track faculty member and variation in student-centered pedagogy becomes more pronounced. This effect speaks to the professional constraints of these faculty members' job descriptions and institutional cultures that do not support these individuals stepping outside their formal responsibilities. Faculty who are outside the tenure-track may not be allowed to participate in professional development activities related to curriculum development.

Additional relationships were also found to be strongly associated with the dependent variable of interest. Particularly strong were the negative relationships between being a faculty member in the Physical Sciences or Mathematics/Statistics departments (See Appendix A for a full list of departments within these fields). While the latter was not represented in the interview phase of this study, faculty in the Physical Sciences spoke to conditions within their departments that may have influenced them and their peers' student-centered pedagogy scores. For example, faculty cited concerns with being discouraged from making changes to an inherited curriculum or being judged in a negative light for attending teaching-related professional development opportunities. These experiences set the tone within a department and may have a negative impact on the extent to which faculty incorporate active learning strategies into their daily teaching.

Although some faculty revealed that their peers and/or their department chair frowned upon involvement in teaching-related professional development, these activities were found to be associated with a higher SCP score. Faculty who had participated in organized activities around enhancing pedagogy or student learning, curriculum development, or a funded workshop focused on teaching all demonstrated higher SCP scores than their peers who did not participate in such activities. These results are corroborated by faculty testimony highlighting the benefits of attending these types of professional development programs. Faculty shared that they had taken part in department-led teaching seminars, interdepartmental programs, and National Science Foundation (NSF) sponsored activities. Although the breadth and type of opportunities that were available to faculty on and off campus varied from interview to interview, the benefits commonly cited included a strengthened teaching approach, exposure to novel teaching methods, and validation and support for spending time on their pedagogy.

Like attending professional development opportunities, engaging in academic research across multiple disciplines may also have exposed faculty to new teaching strategies via their peers outside their department. This may help explain its positive influence on SCP. Additional items that were also found to have a sizable impact on variation in SCP included undergraduate engagement and the number of hours per week that a faculty member devotes to community or public service. These last two findings will be explored in further detail later in this chapter while examining how key findings fit with our understanding of Organizational Citizenship Behavior.

Research Question 2: How do STEM faculty describe the evolution of their pedagogical approach– what individuals, resources, or contexts have informed their current approach and thinking about their teaching strategies?

Our understanding of how faculty participants in the Higher Education Research Institute's Faculty Survey describe the evolution of their pedagogical approach was informed exclusively by the qualitative phase of this study. A key focus of the semi-structured interviews was uncovering the extent to which faculty had modified their teaching style throughout their careers and the underlying reasons for motivating such changes, if any changes were made at all. Unsurprisingly, conversations with faculty revealed that a majority (n=14) of the 17 participants had adjusted the way they delivered course content throughout their academic careers, including early-career assistant professors. For the few who expressed a consistent approach in their teaching, this did not necessarily reflect a tendency to maintain a passive teaching approach (e.g., lecturing the entire class period). In fact, the student-centered pedagogy scores for these three faculty members (Dr. Kamal, Dr. Burton, Dr. Okoye) show that two of these faculty are well above both the mean scores for their respective institutions and the overall mean of all faculty who participated in the Faculty Survey (See Table 5.2). Dr. Okoye in particular spoke at length about his use of active learning teaching strategies since the beginning of his professional career and confessed to being an agent of change within his department, motivating peers to adopt student-centered techniques.

Across departments, academic rank, tenure status, and institutional type, faculty who spoke to an evolving approach to content delivery attributed this development in part to greater comfort with the course material. At the outset of their careers, faculty concerns with covering large quantities of course material led them to spend most of their class time lecturing their students. These concerns are exacerbated by the fact that most interviewees lacked formal teaching experience in their graduate programs. While lecturing is not necessarily a poor pedagogical approach, the absence of additional methods of content delivery that can more effectively engage students and promote greater understanding represents a missed opportunity for student success. As faculty became more comfortable with their course content, many shared that they adjusted their courses to cover *less* material and more *depth* of the content while generating greater levels of student engagement with the class material and with their peers. In the words of one faculty member, "…more about the process and understanding and less about memorization."

Some faculty members' teaching approach evolved to include not just active learning strategies but a fully flipped classroom where course content is delivered electronically outside the traditional course hours and class time is devoted entirely to engaging students in student-centered activities. For the faculty who employed this approach, the change in pedagogy was motivated by exposure to educational theory and practices, interactions with peers pushing for enhanced teaching in STEM, and a personal desire to improve student success. This final point supports the findings connecting the use of more effective teaching practices and greater job satisfaction. Several interviewees spoke to having more fun and satisfaction with their teaching when they utilized teaching practices that involved the students in the learning practices. Others added that they had previous teaching experience in high schools or community colleges and that this component of their current job responsibilities was something they thoroughly enjoyed and had partially motivated them to become faculty members.

Although the majority of faculty confessed that they had made changes to their teaching over the course of their careers, these changes did not come easily or smoothly. Interviewees recalled struggling with active learning practices, especially early in their careers if they had not been previously exposed to these activities. Several faculty found it challenging to get "good" at running a classroom with a student-centered approach. This may partially explain why other STEM faculty may be hesitant to embrace more effective teaching practices. An additional barrier described by some faculty was the natural comfort that comes with teaching the same course several times. While this is commonplace for university faculty and some pointed to this fact as a benefit in their development of more student-centered teaching, others revealed that having to teach a new course or a revolving set of courses would have motivated them to revamp their teaching approach by including more interactive activities.

Research Question 3: To what extent do institutional and departmental contexts shape faculty's approach to teaching?

The hierarchical linear model in the quantitative phase of this study showed no differences between institutions with respect to variation in student-centered pedagogy. This implies an even distribution of faculty who utilize student-centered pedagogy to varying degrees between universities. Said differently, faculty who use SCP minimally, to a great extent, or not at all appear to be found at all institutions. Since none of the institutional characteristics (student-faculty ratio, selectivity, institutional control, research status, minority-serving institution) had any association with the outcome, all the variation in student-centered pedagogy was found within institutions. This lack of variation between institutions is supported by interviews with faculty members who felt that their universities did not support teaching enough, played lip service to it, and did not adequately reward teaching excellence. On the other hand, some faculty felt that their institutions leadership, mission, and values encouraged them to focus on their pedagogy through direct investments in teaching-related initiatives and a greater emphasis on the quality of their teaching in performance evaluations compared to other research universities. The mix of research-one and research-two institutions found to be both supportive and not supportive of teaching supports the quantitative findings of no relationship between type of institution and student-centered pedagogy.

A strong association was found between a faculty member's home department and student-centered pedagogy. Compared to their peers in the Life Sciences, faculty in the areas of Physical Science and Mathematics/Statistics displayed negative relationships to student-centered pedagogy that were some of the strongest in the hierarchical model. While no other STEM area was found to have a relationship with the outcome, these results clearly indicate that a faculty member's home department has a powerful impact on their use of student-centered pedagogy. Although no Mathematics/Statistics faculty were included in the qualitative phase of this study, the Physical Sciences were well represented among interviewed faculty.

Departmental culture may help explain why some disciplines may be more or less likely to facilitate the adoption of student-centered teaching practices. During interviews, faculty in the physical sciences spoke about having limited opportunities to discuss effective teaching within their departments and being judged in a negative light for attending professional development opportunities related to teaching. In one case, a faculty member shared that their departmental colleagues viewed attending professional development as a punishment reserved for "bad teachers." On the other hand, some faculty spoke to more supportive departmental environments, including at the same universities and within the same STEM areas (i.e., Physical Science) as faculty who felt unsupported by their peers and leadership. These differences demonstrate how organizational cultures at the department level and the individuals that make up these environments (e.g., chair, faculty peers) play a critical role in shaping the extent to which faculty adopt student-centered teaching practices. While some faculty highlighted colleagues who had encouraged them to improve their teaching or served as role models motivating modifications in their pedagogy others shared that they themselves acted as agents of change within their departments. Being early adopters of student-centered teaching, they promoted the use of such practices among their peers and slowly convinced some faculty to adopt these techniques.

Interpretation and Meaning of Significant Findings

Resource Dependence Theory

This study draws from Pfeffer and Salancik's (1978) Resource Dependence Theory (RDT) to examine the environmental factors and structural challenges that inhibit or promote the adoption of student-centered teaching practices. Focusing specifically on RDT's contributions to understanding how organizations and their individual sub-units make decisions in the face of limited resources, the extent to which faculty incorporated student-centered pedagogy into their courses can be understood as a decision influenced by the availability or scarcity of resources (e.g., time, funding). Within this study, research universities are understood as organizations, departments as both sub-units of the university and an organization, and faculty as sub-units within STEM departments and subject to the demands and constraints of this hierarchical structure (Emerson, 1962; Pfeffer & Salancik, 1978). In this way, faculty are subject to the pressures placed on them by their university and especially their department.

This study conceptualizes time as the most critical resource available to STEM faculty. For most faculty, the availability of sufficient time was a critical factor in determining whether and the extent to which they employed active learning in their courses. As a resource that is at least partially controlled by their department, faculty must make decisions with respect to how they respond to its limited availability (Davis & Cobb, 2010). In support of findings from previous studies (Dancy & Henderson, 2008; Michael, 2007), faculty iterated that the interconnected nature of structural and position-related characteristics (e.g., tenure, rank, research productivity) combined to steer them away from investing time in their teaching. This (dis)incentive system has been regularly cited as one of the most critical barriers that impedes the widespread adoption of student-centered pedagogy (Austin, 2011, Fairweather, 2008, Wieman, 2017).

Faculty talked about the messages they directly and indirectly received regarding how they should spend their time. These messages were particularly acute early in their careers, originated from both department chairs and fellow faculty members, and were especially geared towards reminding faculty achieving tenure was the principal goal to keep in mind. For example, individuals shared that they were asked to focus on research and not participate in professional development nor spend too much time on their teaching. These results suggest that faculty may postpone strengthening their teaching until they have achieved tenure, a position that appears to be common in STEM (Hayward, Kogan, and Laursen, 2016; Wieman, 2017). In addition to messages, faculty were keenly aware that teaching plays a relatively minor (if any) role in hiring, promotion, and tenure decisions at the department. Furthermore, even though teaching may constitute a sizable portion of a faculty member's official job duties (e.g., 30% or 35%), some faculty expressed significant doubt that it was considered so strongly in tenure decisions and others even shared that they were told, "just don't mess it up." These messages undoubtedly play into the cost and benefit analysis that STEM faculty (especially assistant professors) must consider as they decide how much time to invest in their teaching. Via these messages, departments wield significant influence over how faculty allocate time to their various job responsibilities (Pfeffer & Salancik, 1978).

Organizational Citizenship Behavior

Drawing from Organizational Citizenship Behavior (Bateman & Organ, 1983), this study proposes that faculty are motivated by a sense of citizenship to contribute to their organization's (institution/campus) success above and beyond their required job responsibilities. Although universities and departments place some restrictions on faculty with respect to teaching and generally express the expectation of teaching excellence, *what* and especially *how* faculty teach remains largely within the purview of the individual instructor. In this case, faculty are going above and beyond in their teaching approach by investing additional time and energy – including active learning techniques – in their curriculum. Their willingness to surpass expectations in the execution of their teaching responsibilities and achieve a greater degree of student learning and success is commendable and goes largely unrewarded, as previous studies have shown (Austin, 2011). From an Organizational Citizenship Behavior (OCB) perspective, these efforts cannot be explained by traditional motivational bases (e.g., salary, bonuses, awards) that have historically induced people to join, stay, and perform within their prescribed roles (Bateman & Organ, 1983; Smith, Organ, & Near, 1983).

Despite the lack of a contractual obligation or consistent rewards related to the inclusion of student-centered pedagogy in their courses, some faculty were motivated by the satisfaction and value they attached to teaching more effectively. Although most faculty expressed some degree of satisfaction with teaching, some conveyed much stronger feelings towards teaching, going so far as to say they “love teaching”, caught the “teaching bug”, or were motivated to pursue a career in academia based on their passion for teaching. While none of these factors guarantee that faculty will incorporate student-centered teaching practices in their courses, they parallel findings from the hierarchical linear model that also lend credence to an OCB explanation for variation in student-centered teaching. Specifically, the statistical significance of items such as attending professional development activities, devoting a higher number of hours per week to community or public service, higher levels of undergraduate engagement, and a close alignment between work and personal values speak to prosocial values that may motivate faculty to invest substantially more time and energy into teaching practices that cater more directly to the needs of learners. These findings suggest that faculty are intrinsically motivated to include more effective teaching practices in their courses because of their personal affinity for student success, teaching, and their commitment to organizational success.

Academic Discipline and Culture

Relative to their peers in Life Science, faculty in Physical Science and Mathematics departments were much less likely to incorporate active learning practices into their courses. These strong negative relationships highlight departmental cultures that prevent the adoption of more effective teaching practices – suggesting that characteristics and traits inherent to these disciplines and the faculty members in these departments are responsible for the vast differences in departmental associations with student-centered pedagogy. While there is extensive literature examining the impact that active learning can have for students in these fields (Chasteen et al., 2015; Dancy & Henderson, 2008; Henderson, Beach, & Finkelstein, 2011) and the broad challenges that STEM faculty face in implementing these pedagogical practices, research highlighting issues specific to these disciplines is less common. Even when research has been carried out (Henderson & Dancy, 2008), the barriers that are examined (e.g., large classrooms, unfamiliarity with methods, lack of time, etc.) fail to thoroughly examine the influence of the culture that is maintained within these departments. More research is needed that examines STEM departments as organizations with their own set of values, belief systems, rituals and importantly, with individuals (e.g., department chair, senior faculty) who can significantly shape the direction of the department with respect to teaching based on their own set of ideals.

The fact that no Mathematics/Statistics faculty responded to multiple invitations to participate in the qualitative phase of this study may provide insight into the culture within these departments. A total of 72 faculty provided their consent to be contacted in Mathematics and for comparison, a total of 112 Engineering faculty also consented with four individuals volunteering to participate in this study. While Physical Science faculty numbered 156 in the group consenting to be contacted, they represented more than half of the qualitative sample (n=9). It is possible that faculty in Mathematics/Statistics were simply not interested in speaking about the barriers to active learning. Since participants can sometimes be drawn to participation in research that aligns with their personal and professional values (Maxwell, 2013), it is possible that the opposite may be true as well. Faculty in these departments may have chosen not to participate because they lack affinity for these instructional methods.

Several reasons may help explain why mathematics faculty fared much lower than their peers in SCP scores. Loch and Borland (2014) argue that relinquishing the center stage and moving away from the traditional “chalk and talk” method of content delivery does not come naturally to mathematics faculty. Most mathematics faculty have not experienced other types of instructional methods and there is a general belief that as a discipline, mathematics is different from other disciplines and does not require a move towards more student-centered pedagogy (Loch & Borland, 2014; Pritchard, 2010). Wieman (2017) also found evidence of mathematics faculty being more likely than their fellow STEM peers to resist research-based instructional practices and attribute the shortcomings of undergraduate STEM education to shortcomings in the students (e.g., preparation, skills). Furthermore, mathematics is viewed as a highly structured, objective discipline and is considered to utilize lectures differently from other disciplines (Pritchard, 2010). Lastly, mathematics faculty may find that their discipline lacks sufficient overlap to enable inter-departmental collaboration with other STEM and non-STEM peers.

As the results of this study have shown, such collaborations tend to be associated with higher levels of SCP. If faculty are more isolated within their departmental bubbles, they may be less likely to be exposed to new teaching methods and motivated to include them in their courses. Furthermore, research has shown that disciplinary norms and the extent to which faculty adhere to these norms can factor into decisions about pedagogical approaches (Brownell & Tanner, 2012). These reasons may help explain why these faculty not only chose not to participate in the qualitative phase of this study but may also help explain the strongly negative relationship between faculty in this department and inclusion of active learning strategies seen in the hierarchical linear model.

Faculty Outside Tenure-track

The strongest predictor of variation in student-centered pedagogy was whether faculty members were employed at an institution that has a tenure system but were themselves not on the tenure-track. This relationship was stronger than other positive associations such as engaging in research across multiple disciplines, participating in curriculum development, and undergraduate engagement and stronger than the negative associations between Mathematics/Statistics and Physical Sciences faculty and SCP. These positions may be more likely to adopt active learning techniques for several reasons. First, the absence of a tenure path undoubtedly removes pressure from these faculty to invest significant time and energy into developing a research portfolio leading to tenure. Second, many of these positions are specifically constructed with teaching in mind. A faculty candidate's experience and expertise in the classroom along with their willingness to invest in their teaching may play a larger role in the recruitment and hiring process for these positions than it might for traditional tenure-track positions (Wieman, 2017). Third, faculty who are attracted to this type of position may intrinsically possess prosocial values that enable them to invest their energy in student learning and success (Organ, 2018; Rioux & Penner, 2001). Lastly, the rise of these types of positions speaks to the increasing opportunities for graduate students to receive training in both their academic discipline but also in innovative teaching methods and research on student learning (National Research Council, 2012).

The growth of faculty positions that place additional emphasis on teaching cannot be ignored. While the specific characteristics, responsibilities, and titles of these positions may vary between institutions (e.g., discipline-based education researcher, professional teaching faculty, etc.), these positions generally stress excellence in curriculum development, education research in the discipline, innovative teaching practices, and advanced learning assessment strategies in addition to research responsibilities. According to these faculty, a primary impact of these positions has been an influence over the teaching practices of their fellow scientists (Bush, Rudd, Stevens, Tanner, & Williams, 2016). The significant effect of this professional characteristic on SCP variation suggests that these positions can serve as change agents within their departments and catalyze the implementation of active learning strategies. HLM results are supported by the fact that interviewees spoke about influencing their departmental peers' teaching vis-à-vis the adoption of SCP in their own courses lends support to the potential for change represented by these teaching-focused positions. Considering the increasing number of faculty who are being hired into these types of positions in recent years and their extensive training in not only their discipline but education research (Bush, Stevens, Tanner, & Williams, 2019), we can expect that these faculty will have an impact on their peers for years to come. While change may come slowly within some departments, it is noteworthy that these positions are gaining traction across all types of institutions and disciplines (Bush, Stevens, Tanner, & Williams, 2019). Departmental leadership across STEM disciplines would be wise to embrace these positions and provide them with the necessary tools and support for diffusing active learning strategies across the department.

Implications and Recommendations

The previous sections summarized key findings, discussed this study's contributions to the research literature, and explored salient findings in greater depth. Collectively, this study's findings paint a clear picture of the factors and characteristics that shape the extent to which STEM faculty incorporate active learning in their courses. With this knowledge in hand, stakeholders can design and implement policies, programs, and practices that can positively influence the number of students who graduate in STEM disciplines. Transforming teaching in STEM has the potential to not only boost overall success measures, but close achievement gaps for underrepresented students. Studies have shown a disproportionate benefit of active learning for underrepresented students (Haak et. al, 2011; Theobald et. al., 2020) and this boost has been shown to close achievement gaps in STEM (Harris, Mack, Bryant, Theobald, & Freeman, 2020). As research universities face increasing political, social, and financial pressure to close achievement gaps in STEM, they would be wise to take steps to accelerate the spread of active learning strategies.

This section takes a closer look at the implications of this study's findings and highlights recommendations that can increase the implementation of student-centered teaching. As previously shown, these recommendations have the potential to boost both overall success rates in STEM and close achievement gaps for underrepresented students in these fields. Implications and recommendations are discussed for the federal government and for research universities and their STEM departments.

Federal Government

In an increasingly competitive scientific world, the federal government has a vested interest in nurturing the STEM talent pipeline in the United States. While federal agencies (e.g., National Science Foundation, National Institutes of Health) have made substantial investments in efforts to enhance teaching and learning in the sciences (National Science Foundation, 2021), more can be done to prepare STEM faculty to teach undergraduate students at research universities. As has been shown, participation in professional development programs has a positive effect on the extent to which faculty incorporate SCP into their courses. Considering that faculty can potentially be employed at a university for many years and can teach hundreds or thousands of students, increasing the number of faculty who incorporate SCP into their curriculum can have a profound effect on student learning and achievement. As such, it is important to create programs specifically geared towards early-career faculty that can plant the seed of active learning pedagogical techniques.

Invest in New Faculty

The federal government should replicate the NSF-sponsored *Workshop for New Physics and Astronomy Faculty* with all disciplines across STEM. This program is a partnership with national organizations (i.e., American Association of Physics Teachers, American Astronomical Society, American Physical Society) that brings together early-career tenure-track faculty for several days each year to discuss findings of physics and astronomy education research, instructional strategies, and course materials for participants to learn about recent developments in pedagogy (Henderson, 2007). Given the unique culture and barriers that are faced within each discipline, it is critical that these programs are tailored specifically to faculty within a specific discipline (Wieman, 2017). Replicating this program in disciplines like mathematics, chemistry, computer science and others across STEM can have a critical impact on the adoption of student-centered teaching practices at research universities. As Henderson (2007) made clear, significant gains were witnessed in the number of faculty who incorporated student-focused instructional practices and nearly all faculty participants who made changes to their teaching attributed these modifications to their participation in this workshop. Bringing together faculty in each discipline to hear from notable experts in their field who can speak to the latest educational research and instructional strategies in the discipline can serve as an inspirational moment for newer faculty members. These early-career faculty might then serve as change agents within their own departments at their home institutions (Bush, Rudd, Stevens, Tanner, & Williams, 2016).

Research Universities

The following sections magnify key findings of this study and provide recommendations for research universities and STEM departments. Since STEM departments are situated within research universities and operate under the guidance and policy set forth by their university, these recommendations are understood to be collaborative efforts between a department and their institution.

Create STEM-focused Professional Development

Regardless of the extent to which the federal government and professional associations invest in training and professional development opportunities for STEM faculty, research universities should invest their own resources in developing pedagogical capital on their campuses. Campus-lead professional development opportunities can help faculty learn about alternative teaching practices that can help improve student learning (Freeman, et al., 2014) and inspire faculty to continue to improve their teaching (Manduca et al., 2017; Owens et al., 2018). This study supports these findings, stressing the importance of attending teaching-focused professional development and being involved in curriculum development. Given the high likelihood that faculty may share some of their newfound knowledge with their departmental peers either formally or informally, the impact of professional development extends beyond those in attendance.

Campuses would be best served to invest resources in a faculty development center on campus that can support the spread of student-centered teaching practices in STEM disciplines. Although many campuses already deploy resources to faculty development centers, a central hub that can specifically focus on faculty development in STEM would be particularly beneficial given the extent to which traditional teaching methods are commonplace in these fields (Stains et al., 2018) and the significant student achievement gaps in these disciplines (Gregg-Jolly et al., 2016; NCES, 2018). One such center is the Center for Education Innovation & Learning in the Life Sciences (CEILS) at the University of California, Los Angeles. CEILS leads initiatives to train current and future faculty in creating student-centered classrooms, partners with faculty to advance science education research and acquire funding for STEM education initiatives, and fosters a supportive learning community for graduate students, postdoc scholars, and faculty to embrace student-centered teaching approaches (UCLA CEILS, 2021). Since faculty who attended funded workshops focused on teaching were more likely to incorporate SCP into their courses, the impact of STEM-focused centers such as CEILS can be quite potent even with a limited budget and range of programs. Universities should invest resources in these centers and enable them to acquire external funding to support on-campus professional development programs in STEM.

Reward Teaching Excellence

In accord with previous research literature (Austin, 2011; Fairweather, 2008), this study found that nearly all interviewees shared concerns about the minimal role that teaching plays in promotion, tenure, and reward decisions at their department. These concerns included beliefs that teaching played a smaller role in rewards decisions than it did in official job responsibilities. Campuses and departments need to ensure that, at minimum, teaching plays an equal role in official job duties and personnel rewards. In addition, universities and STEM departments must reward the significant time commitment that is required to shift pedagogical practice from a traditional lecture-heavy approach to student-centered techniques. Until this happens, faculty may continue, and rightfully so, to resist this pedagogical shift (Brownell & Tanner, 2012).

STEM departments have been known to provide statements of support for teaching that are rarely backed up with substantive actions (Dancy & Henderson, 2010). The following are ways in which departments and universities can reward teaching excellence. First, in line with current trends that have seen the rise of Discipline-based Educational Researcher-type of positions (National Research Council, 2012), universities should create tenure-track teaching positions that can bring quality teaching to the forefront of STEM classrooms. Campuses need to recognize that excellent teaching requires a great deal of skill and should be rewarded with tenure. While it would require a fundamental shift in attitudes about teaching and scholarship, the stability and resources that come with tenure should be made available to teaching faculty. Second, campuses should embrace education research as a rigorous form of scholarly activity that is given serious weight in promotion and tenure decisions. Publications in education-focused journals such as *CBE—Life Sciences Education*, *Journal of College Science Teaching*, or the *Journal of Chemical Education* should be recognized as valuable and rewarded on par with traditional publication avenues.

Third, departments should devise ways to assess and reward faculty who consistently demonstrate excellence in teaching by using enhanced pedagogical approaches, revitalizing curriculum, and delivering stellar student success outcomes. It makes little sense that student evaluations are the principal method of evaluating teaching – especially as it relates to promotion and tenure decisions – when students are pedagogical non-experts. Furthermore, the literature is saturated with studies highlighting issues of reliability, validity, and gender bias with student evaluations (Boring, Ottoboni, & Stark, 2016; Esarey & Valdes, 2020; Hornstein, 2017; Wright, 2006). Shifting some of the weight of student evaluations on assessments of faculty teaching will go a long way towards ensuring that faculty are not hesitant to embrace novel teaching methods (Hayward, Kogan, and Laursen, 2016; Henderson, 2008). Research universities should embrace a peer review model based on classroom observations, review of course materials, design, assignments, and teaching reflections (Flaherty, 2018). Such a review could incorporate tools such as the Classroom Observation Protocol for Undergraduate STEM (Smith, Jones, Gilbert, & Wieman, 2013) and the Teaching Practices Inventory (Wieman, 2017) to document and evaluate the teaching activities utilized in a class period or course. While student evaluations should still be utilized to provide feedback for instructors with respect to student satisfaction and levels of engagement, replacing them in promotion and tenure decisions with a peer review model would unleash faculty to innovate in the classroom and create tangible rewards within academia for instructors who excel in their teaching. Finally, rewards for teaching excellence can also take the form of financial support for a research assistant, postdoctoral scholar, or teaching assistant, a reduction in teaching load, support for continuing professional development, release time, summer salary, or an expanded budget for research equipment (Major & Palmer, 2006; Pelletreau et al., 2018).

Train the Next Generation

Although the HLM results of this study showed a slightly positive relationship between faculty feeling that graduate training prepared them well for their role and the inclusion of SCP in their courses, this item is not specific to teaching and faculty would be expected to interpret this statement in a broader sense to refer to not just teaching, but also research and service responsibilities. In interviews, nearly all participants shared they had little to no teaching experience as a graduate student and some disclosed that most STEM faculty they knew had no training as teachers. This is problematic as faculty are typically expected to teach courses from their very first term as an assistant professor, and in most cases, multiple courses per term. Undoubtedly, the lack of experience and skills required to teach effectively in a university classroom can have a negative impact on student success outcomes, which have been shown to lag in STEM disciplines (Eagan et al., 2014; NCES, 2018; PCAST, 2012; Stains et al., 2018). As operational budgets become more constrained and accountability measures tighten – particularly with the ramifications of the COVID-19 pandemic – institutions of higher education will face increasing pressure to deliver a quality education to their students (Dickler, 2020). In the face of increasing accountability, STEM departments stand to benefit from providing pedagogical training, teaching-related professional development, and actual teaching experiences to their doctoral students. The following are some of the key benefits that would result from these enhanced opportunities.

First, providing these opportunities to their doctoral students will help take pressure off their faculty by building teaching capacity. If provided training in teaching and pedagogy, these students could provide a greater degree of support to student success and more advanced students with greater content knowledge could even co-teach courses with faculty. While there may be policy and classification issues to overcome for doctoral students to be more involved in teaching, the benefits surely outweigh the risks. Second, student success may benefit as doctoral students can provide an additional avenue for receiving support and may be more accessible than faculty, which may positively influence student success outcomes. Lastly, the difficulties in landing a traditional tenure-track position at a research university are well-known. Building teaching capacity within the doctoral student ranks will enhance the skillset of these faculty candidates and make them more competitive in the job market. With the rise of DBER-style positions across the country (Bush, Stevens, Tanner, & Williams, 2019; National Research Council, 2012), teaching-trained doctoral students will be better prepared to face a changing job market.

Changing the Culture

HLM results highlighting the powerful influence of specific academic disciplines (i.e., physical sciences, and mathematics/statistics) on SCP and results from conversations with faculty make clear that the organizational culture within STEM departments has a significant impact on the extent to which faculty incorporate student-centered techniques into their teaching. In addition to the (dis)incentive system of rewards that has been well documented in this study and the literature (Austin, 2011; Fairweather, 2008; Hayward, Kogan, and Laursen, 2016), the actions and beliefs of departmental chairs and faculty peers create a working environment that inhibits the spread of more effective teaching practices. Being discouraged from attending professional development by the department chair, receiving negative votes on tenure because your teaching is good (despite outstanding research), being perceived as not spending enough time on research simply because your teaching is very strong, and being perceived as a “bad” teacher because you attended professional development are just a few examples faculty shared of culture-defining messages they received. For those faculty who want to dedicate time and effort to their pedagogy, these messages can be rather demoralizing and detrimental to organizational collaboration and effectiveness. Faculty members who feel out of place or unsupported in their department may be more likely to leave the institution for one that more closely aligns with their values.

In addition to supporting efforts to create STEM-focused professional development, reward outstanding teaching, and create tenure-track teaching positions, departments can also take additional steps to nurture a climate supportive of teaching excellence. With respect to hiring, efforts can be made to consider and value the teaching expertise and skill that faculty candidates can bring to a department in addition to their research. Departmental chairs and senior faculty can also embrace the idea that attending professional development should be viewed not as a punishment for bad faculty or as time spent away from research, but rather as activities that are beneficial to the individuals and to the department, particularly for faculty who are already excelling in their research. Departmental leaders can set the tone for their peers and sending messages that are supportive of faculty who choose to attend these activities can go a long way towards nurturing faculty talent and creating a supportive departmental climate. Another recommendation would be to develop an education committee within the department with the explicit goal to assess, promote, and implement further developments in teaching. This body could tackle issues such as the prevalence of research-based instructional practices, enhancing student outcomes assessment practices, and creating mechanisms for faculty feedback (e.g., peer evaluation of teaching).

Further Research

The findings of this study support considerations for additional avenues of research regarding STEM faculty's use of student-centered pedagogy. First, future studies could center the experiences of faculty who are employed outside the tenure-track at research universities. These faculty were found to employ SCP at higher rates than their tenure track peers, but their experiences could have been better represented in this study, particularly in the qualitative phase where only one faculty was included. Additional research could bring light to their educational background and teaching experience, interactions with their faculty peers and administration, and motivations for utilizing active learning practices to a greater extent than their colleagues. These directions could help contextualize the findings of this study.

Second, additional investigation is needed to understand the organizational culture of STEM departments. This could involve a case study approach whereby interviews are conducted with administrators, chair, and faculty to fully understand the impact of messages regarding teaching and learning, the importance of research, and student success. This insight would be particularly fruitful for disciplines such as mathematics and those in the physical sciences since faculty in these departments were shown to have a much lower rate of SCP utilization. Along the lines of departmental culture, the role played by the department chair and/or senior faculty members is particularly intriguing. Additional avenues of investigation could examine the specific role that department chairs play in the inclusion of active learning techniques. Specifically, qualitative research could provide answers to the following questions, 1) To what extent do chairs feel responsible for influencing the use of student-centered pedagogy among their faculty? 2) How do chairs describe the culture of their department and the role they play in shaping this culture? 3) How do chairs feel about faculty spending time in teaching-related activities such as professional development programs? These types of questions will help illuminate the role that department leadership plays in promoting or inhibiting SCP growth.

As some institutions shift from relying on student evaluations as the sole assessment of teaching quality to a peer-based evaluation model (Flaherty, 2018), insights can be gathered to examine how these changes in the way teaching is evaluated impact the role of teaching in faculty rewards. In-depth faculty and administrator interviews could examine how the role of teaching in merit, promotion, and tenure decisions has changed with a shift to a peer review model of teaching assessment. As more STEM departments adopt these evaluation practices, it is critical to understand the extent to which faculty's perspective of their department's culture with respect to teaching has shifted.

Further studies could increase the representation of underrepresented groups in STEM. Although this study's representation of underrepresented racial minorities (URM) and women in both the quantitative and qualitative phases roughly reflect national figures, the inclusion of additional URM faculty, especially in the qualitative phase where only one was interviewed, could help elevate their voices and understand whether their experiences with teaching pedagogy resemble those of their White peers. Finally, as with all survey research, additional investigations could improve upon variables that were included in this study. The extent to which this study's results remain true while including the use of flipped classrooms, clicker questions, or think-pair-share activities in the definition of active learning is a worthwhile question that warrants answering. Additional variables that could be incorporated in the survey research include items that ask about teaching experience prior to a faculty position, graduate training related to teaching, the extent to which faculty enjoy teaching, and perceptions about undergraduate students.

Final Thoughts

This study stemmed from both my personal affinity for teaching and the realization throughout my career in student and academic affairs in higher education that too many students intending to major in STEM– especially underrepresented students –fail to graduate with degrees in these disciplines. My interest in faculty developed during my graduate studies and thus my interests merged to form this investigation. Utilizing a resource dependence theory and organizational citizenship behavior framework, I attempted to discover the factors that shaped faculty's use of student-centered pedagogy. Professional characteristics, professional development related to teaching, and departmental culture emerged as the principal factors that shape the use of student-centered teaching practices at research universities. Organizational Citizenship Behavior materialized as a powerful lens for interpreting the teaching-related behavior of faculty and provides an insightful tool for shaping federal and institutional policies and practices. Hopefully, this study has provided evidence that can be used to transform the teaching enterprise of STEM disciplines at research universities and inspire additional investigations in this area.

Appendix A: List of STEM Majors

Life Science
Biochemistry
Molecular Biology
Botany/Plant biology
Microbiology and immunology
Physiology, pathology and related sciences
Zoology/animal biology
Biological and biomedical sciences

Computer Science
Computer information/technology
Computer programming
Computer science
Computer software and applications
Computer systems analysis
Data processing
Information science
Computer systems analysis
Other computer science

Engineering
Biomedical engineering
Chemical engineering
Civil engineering
Computer engineering
Electrical engineering
Mechanical engineering
Environmental engineering
Engineering technology
Other engineering

Mathematics and Statistics
Mathematics
Statistics

Physical Sciences
Astronomy and astrophysics
Atmospheric sciences and meteorology
Chemistry
Geological & earth sciences/geosciences
Physics
Other physical sciences

Appendix B: Independent Variables and their Coding Schemes

Independent variables and their coding schemes	
Background Characteristics	
Sex	1=Male, 2=Female
Underrepresented racial minority	1=Non-URM, 2=URM
Professional Characteristics	
Years since first academic appointment	1=2017, 2=2016, 3=2015, . . ., 71=1947
Salary	1=Less than $10,000
	2=$10,000-19,999
	3=$20,000-29,999
	4=$30,000-39,999
	5=$40,000-49,999
	6=$50,000-59,999
	7=$60,000-69,999
	8=$70,000-79,999
	9=$80,000-89,999
	10=$90,000-99,999
	11=$100,000-124,999
	12=$125,000-149,999
	13=$150,000-199,999
	14=$200,000-249,999
	15=$250,000-499,999
	16=$500,000 or higher
Assistant Professor (Associate)	0=No, 1=Yes
Professor (Associate)	0=No, 1=Yes
Not tenure-track faculty	0=No, 1=Yes
Physical Science (Life Science)	0=No, 1=Yes
Engineering (Life Science)	0=No, 1=Yes
Mathematics/Statistics (Life Science)	0=No, 1=Yes
Computer Science (Life Science)	0=No, 1=Yes
Faculty Activities and Time Commitments	
Past three years: Engaged in academic research that spans multiple disciplines	0=No, 1=Yes
Past three years: Written research grants	0=No, 1=Yes
Past three years: Received state or federal government funding	0=No, 1=Yes
Past three years: Number of accepted or published writings	1=0, 2=1, 3=2, . . ., 22=21+
Hours per week: Preparing for teaching	1=None, 2=1-4, 3=5-8, 4=9-12, 5=13-16, 6=17-20, 7=21+

Hours per week: Committee work and meetings	1=None, 2=1-4 , 3=5-8, 4=9-12, 5=13-16, 6=17-20, 7=21+
Hours per week: Research or scholarly activity	1=None, 2=1-4 , 3=5-8, 4=9-12, 5=13-16, 6=17-20, 7=21+
Hours per week: Community of public service	1=None, 2=1-4 , 3=5-8, 4=9-12, 5=13-16, 6=17-20, 7=21+
Participated in organized activities around enhancing pedagogy or student learning	1=No, 2=Yes
Participated in curriculum development	1=No, 2=Yes
Past year: Attended funded workshop focused on teaching	0=No, 1=Yes
Undergraduate engagement	Factor: 4 items
Perceptions of Profession and Institution	
Formally recognized for outstanding teaching	1=No, 2=Yes
Graduate training prepared you well for faculty role	1=Not at all, 2=To a small extent, 3=To some extent, 4=To a large extent, 5=To a very large extent
Close alignment between work and personal values	1=Not at all, 2=To a small extent, 3=To some extent, 4=To a large extent, 5=To a very large extent
I try to dispel perceptions of competition	1=Strongly disagree, 2=Disagree somewhat, 3=Agree somewhat, 4=Strongly agree
Achieve a healthy balance between personal and professional life	1=Strongly disagree, 2=Disagree somewhat, 3=Agree somewhat, 4=Strongly agree
I have to work harder than my colleagues to be perceived as a legitimate scholar	1=Strongly disagree, 2=Disagree somewhat, 3=Agree somewhat, 4=Strongly agree
Career stress	Factor: 8 items
Job satisfaction: Workplace	Factor: 6 items
Job satisfaction: Compensation	Factor: 6 items
Institutional Characteristics	
Student-faculty ratio	Ratio
Selectivity	Average SAT score
Control	0=Public, 1=Private
Minority-serving institution	1=No, 2=Yes
Research 1	0=Research 2, 1=Research 1

Appendix C: Factors and their Parameters

Factors and their parameters

Factor	α	Loadings
Student-centered Pedagogy (Dependent Variable)	0.83	
Class discussions		0.56
Cooperative learning (small groups)		0.67
Experiential learning/Field studies		0.55
Performances/demonstrations		0.47
Group projects		0.70
Using real-life problems		0.54
Using student inquiry to drive learning		0.61
Student presentations		0.65
Student evaluations of each other's work		0.60
Undergraduate Engagement	0.84	
Presented with undergraduate students at conferences		0.81
Published with undergraduates		0.75
Engaged undergraduates on your research project(s)		0.82
Worked with undergraduates on their research project(s)		0.61
Career Stress	0.75	
Committee work		0.57
Faculty meetings		0.49
Students		0.46
Research or publishing demands		0.49
Teaching load		0.51
Lack of personal time		0.65
Self-imposed high expectations		0.44
Increased work responsibilities		0.61
Job Satisfaction: Workplace	0.84	
Autonomy and independence		0.56
Departmental leadership		0.61
Departmental support for work/life balance		0.83
Institutional support for work/life balance		0.80
Prospects for career advancement		0.72
Flexibility in relation to family matters or emergencies		0.57
Job Satisfaction: Compensation	0.81	
Salary		0.66
Health benefits		0.65
Retirement benefits		0.72
Opportunity for scholarly pursuits		0.66
Teaching load		0.60

Leave policies (e.g. paternity/maternity leave, caring for a family member, stopping the tenure clock)	0.55

Appendix D: Interview Protocol

Building Rapport

1. Can you please tell me about your trajectory to becoming a faculty member in STEM? What drew you towards this career path?
    a. How would you describe your role as a faculty member?
    b. Are there specific aspects of your role that you enjoy the most?

Teaching

2. How would you describe the preparation you have received to teach undergraduate courses as a faculty member?
    a. Tell me about how you were prepared to teach during your graduate program? Postdoc experience (if any)?
    b. How have professional development opportunities impacted your level of preparation?
    c. Can you think of anything that was missing from your preparatory experiences or professional development opportunities that may enhance your teaching?
    d. How are you keeping pace with technological improvements with respect to integrating technology in your classrooms?
3. How has your teaching evolved over the course of your career? Or, if it has remained consistent, why do you think that has been the case?
    a. How might you describe your current approach to teaching?
    b. What importance would you assign to teaching within your role as a faculty member?
    c. Have your beliefs about student learning changed throughout the course of your career?
4. Do you feel the way you teach impacts student learning?
    a. In preparing for your courses, do you consider how students learn?
    b. In what ways might student feedback impact your teaching?
    c. If you could speak to your previous instructors, what might you suggest they do to teach more effectively?
5. If you could improve your teaching, what might you do differently?
    a. Are there specific approaches or techniques you might integrate into the classroom?
        i. What prevents you from integrating these approaches or techniques?
    b. If you had all the time in the world, what might you do differently?
6. What specific factors influence the way you teach?
    a. How do your additional responsibilities (e.g. research and service) impact the way you teach?
    b. How have your peers, both within and outside your department, influenced the way you teach? Mentors?

c. What role do incentives play in how you teach? Would additional funding, release time, or lighter responsibilities impact how you teach?
d. Do you feel your level of job satisfaction impacts the way you teach? Career stress? Compensation? Recognition?
e. Can you think of any obstacles that prevent you from teaching differently?

Institutional Context

7. How would you describe the level of support for teaching that exists within your department?
    a. Do you feel your department encourages or discourages faculty from investing time in their teaching?
    b. How prevalent are conversations about teaching amongst faculty in your department?
    c. How satisfied are you with the professional development opportunities offered by your department with respect to teaching? What kinds of professional development opportunities would be helpful in improving your teaching?
8. Do you believe teaching is adequately rewarded by your department? Institution? Professional community?
    a. How is teaching talked about among faculty peers and academic leadership?
    b. How seriously are teaching evaluations taken into account and how seriously do they impact how you approach your teaching?
    c. Can you think of ways your department could reward faculty for effective teaching? Institution? Professional community?
    d. STEM gets a bad reputation for teaching, what do you think needs to change at the department, institution, or professional level to change that reputation?

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