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Understanding STEM Faculty Members' Decisions About Evidence-Based Instructional Practices

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ABSTRACT

Understanding STEM Faculty Members' Decisions About
Evidence-Based Instructional Practices

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Traditional teaching practices in undergraduate science, technology, engineering, and mathematics (STEM) courses have failed to support student success, causing many students to leave STEM fields and disproportionately affecting women and students of color. Although much is known about effective STEM teaching practices, many faculty continue to adhere to traditional methods, such as lecture. In this study, we investigated the factors that affect STEM faculty members' instructional decisions about evidence-based instructional practices (EBIPs). We performed a qualitative analysis of semistructured interviews with faculty members from the Colleges of Physical and Mathematical Sciences, Life Sciences, and Engineering who took part in the STEM Faculty Institute (STEMFI) professional development program at the university. We also observed the participants' teaching behaviors using the Classroom Observation Protocol for Undergraduate STEM (COPUS) and investigated the relationship between faculty teaching behaviors and the individual, social, and contextual factors identified from the interview data. We found that internal factors, including attitudes and self-efficacy, were significantly correlated with student-centered teaching behaviors, while social and contextual factors were not significantly correlated with teaching behaviors. This result suggests that in addition to promoting positive teaching cultures and reducing barriers, efforts to support faculty change should emphasize changing faculty attitudes.

Keywords: faculty development, higher education, educational change, evidence-based practice, STEM education

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DESCRIPTION OF DISSERTATION STRUCTURE

I used a journal article format for this dissertation, which combined some traditional elements with formatting appropriate for publication in academic journals. This front matter is an overview meant to introduce important ideas and summarize the three articles that make up the body of the dissertation. The main ideas presented here are more fully developed within each article. I plan to focus on publishing articles 2 and 3, so some of the literature review from the first article will be reused in the other articles for the purpose of the dissertation.

Problem Statement

The nation faces an increased need for qualified science, technology, engineering, and mathematics (STEM) graduates in the workforce (President's Council of Advisors on Science and Technology, 2012), even at a time when up to 40% of freshman STEM majors fail to finish a STEM degree. Improving pedagogies in undergraduate STEM courses will provide greater support to STEM majors as they complete degrees and transition into the workforce (Seymour & Hewitt, 1997). This is especially true for students from traditionally underrepresented groups, such as ethnic minorities and women (Haak, Hille Ris Lambers, Pitre, & Freeman, 2011; Lorenzo, Crouch, & Mazur, 2006; Tsui, 2007).

In an effort to address the issue of poor STEM teaching, educational researchers, including discipline-based educational researchers in STEM fields, have identified a variety of evidence-based instructional practices (EBIPs) that improve student learning and retention (Freeman et al., 2014). EBIPs emphasize the actions and efforts of students (student centered) over the actions and efforts of instructors (faculty centered) and learning over teaching. Classrooms tend to fall somewhere on a spectrum from traditional and faculty centered to evidence based and student centered. Throughout this dissertation, traditional instruction is defined as characterized by didactic lectures with some opportunity for questions and answers, and it is relatively common in university STEM classrooms. Even those faculty members who adopt EBIPs may maintain the majority of class time for lecture while occasionally incorporating strategies such as think-pair-share, the use of clickers, or writing to learn. Other faculty members embrace EBIPs that are completely student centered, such as flipped classrooms, process-oriented guided inquiry learning (POGIL), or peer-led team learning (PLTL; Stains et al., 2017).

Despite the evidence supporting the use of EBIPs in university STEM courses, many faculty members still have not yet adopted EBIPs (Eagan et al., 2014; Henderson & Dancy, 2007). Faculty face a variety of barriers to implementing EBIPs, including low personal self-efficacy, knowledge, and skill with novel teaching strategies, as well as a variety of contextual factors, including university reward systems and competing demands on their time (Austin, 2011). There is a body of research about the barriers that prevent faculty from adopting and using EBIPs, and this literature will be explored more fully in the first article of the dissertation.

From this literature, we can identify two significant problems in the field. One is that we still don't know enough about how faculty members make decisions about instruction, especially because these decisions take place in complex contexts that vary among individuals, courses, departments, universities, and disciplinary fields (Hora, 2012). The other is the lack of agreement about conceptual models that can help researchers and practitioners make sense of the many and varied factors that influence faculty adoption and use of EBIPs (National Research Council, 2012).

The purpose of this dissertation work is to expand our understanding of the underlying, competing values that inform STEM faculty instructional decisions and to contribute to theoretical models of STEM faculty instructional decision-making.

Methodology

This dissertation work employs a hermeneutic methodological framework, which emphasizes the role of context, including unstated attitudes, social relationships, and the characteristics of the environment that influence STEM faculty actions.

Hermeneutics as a methodological framework emphasizes the way individuals are in the world (Dasein) tacitly and the resultant need to uncover or disclose values that influence their actions, the pursuit of a common understanding among participants and researchers, the importance of context (Shane, 2007), and the cyclical consideration and reconsideration of parts and wholes. Heidegger used the German word *Dasein* to describe the holistic, contextual, and mostly tacit being-in-the-world that characterizes human action. STEM faculty often make instructional decisions in an implicit way as they go about their lives within the context of disciplines, departments, and universities. Hermeneutic methods strive to reveal the underlying principles and values that influence these decisions. The principle of common understanding among participants and researchers is important for this study because I am a faculty member in a STEM department who regularly makes decisions about instructional practices in my own classroom. As such, I had my own experiences with decision-making in this domain prior to beginning the study, and my ideas evolved over the course of the study as I interacted with and came to understand the participants' experiences.

Context is always important in qualitative studies, and this study is no exception. Brigham Young University is a unique institution that may emphasize teaching differently than other institutions of similar size. Parts and wholes become important when considering specific decisions that faculty make within the larger context, or the overall impression from an interview against the line-by-line analysis. The methods used for this dissertation draw on these ideas and adhere to principles of trustworthiness for qualitative research (Lincoln & Guba, 1985).

Article 1, "Factors that Influence Faculty Decisions About Evidence-Based Instructional Practices in Undergraduate Science, Technology, Engineering, and Mathematics (STEM)": The Association of American Universities STEM status report (2017) stated that "the biggest barrier to improving undergraduate STEM education is the lack of knowledge about how to effectively spread the use of currently available and tested research-based instructional ideas and strategies." This article is a comprehensive literature review examining what is known about factors that influence STEM faculty members' instructional decisions about EBIPs.

Article 2, "Factors That Influence STEM Faculty Use of Evidence-Based Instructional Practices: An Ecological Model": The second article is a qualitative study about the factors that influence STEM faculty decisions about EBIPs. This study built on the foundation of work presented in the literature review and responded to the need to "consider the research pertaining to faculty motivation and the factors that affect faculty behaviors" in an effort to improve student learning in STEM fields (Austin, 2011). The participants for this study were drawn from faculty volunteers participating in the STEM Faculty Institute (STEMFI) program at Brigham Young University. These faculty represented the Colleges of (a) Life Sciences, (b) Physical and Mathematical Sciences, and (c) Engineering. Each faculty member participated in a weeklong summer workshop about EBIPs, followed by ongoing mentoring, observations, and cohort meetings throughout the academic year, with the intent of supporting their adoption and use of EBIPs. The primary data sources for analysis were preworkshop individual interviews. All the participants had attempted to use EBIPs in the past, and these interviews captured the challenges faced by STEM faculty adopting or using EBIPs within the authentic context of their work at BYU. In response to the call from the National Academy of Sciences (National Research Council, 2012) for the development of models that can be used to conceptually frame the factors that influence faculty decisions about EBIPs, we considered several models during the analysis of the data and found that an ecological model of STEM faculty instructional decision-making appropriately described the nuances in our data.

Article 3, "Linking Theory and Action: Predicting Teaching Behaviors Based on an Ecological Model of STEM Faculty Instructional Decision-Making": The third article is a mixed-methods study that investigates whether STEM faculty teaching behaviors (as measured by the classroom observation protocol for undergraduate STEM, or COPUS) can be predicted using a rubric designed to measure intention to adopt EBIPs, based on an ecological model of STEM faculty instructional decision-making. The interview data from the prior study were transformed into a rubric score for each individual's internal, social, and contextual factors. From the COPUS data, we extracted a percentage of evidence-based teaching score and regressed that score on the variables from the rubric. This allowed us to see whether the variables from our ecological model could be used to predict evidence-based teaching behaviors.

References for this section are included in the dissertation references at the end of the dissertation conclusion.

ARTICLE 1

Factors That Influence Faculty Decisions About Evidence-Based Instructional Practices in Undergraduate Science, Technology, Engineering, and Mathematics (STEM)

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Introduction

There is a pressing national need for larger numbers of highly qualified scientists and engineers to enter the workforce (President's Council of Advisors on Science and Technology, 2012), a need that has not been met with current practices in higher education (Baldwin, 2009). About half of bachelor's degree students who declare a STEM major either switch to a different degree program or don't complete a degree at all within six years (Chen, 2013). Poor student performance in or withdrawal from introductory STEM coursework is highly predictive of a student's choice to leave a STEM major (Chen, 2013, p. 39). Among students who change majors from STEM subjects to non-STEM subjects, 90% cite poor teaching by STEM faculty as a concern and 36% cite low teaching quality as a deciding factor in their decision to switch fields (Seymour & Hewitt, 1997). Improving the quality of teaching at the undergraduate level with the goal of also improving student performance in introductory STEM courses will be necessary to meet the goal of one million more graduates qualified for work in STEM fields (President's Council of Advisors on Science and Technology, 2012).

The most effective way to improve undergraduate STEM teaching is to use instructional practices that have been studied and shown to affect student learning. While other terms such as active learning, student-centered learning, and learner-centered teaching describe reformed teaching methods that depart from the traditional lecture, we will use evidence-based instructional practices (EBIPs) for the purposes of this review. EBIP is a relatively new term that emphasizes the empirical validation of new or alternative teaching strategies and encompasses a wide variety of such strategies described in the literature. There is a spectrum of EBIPs, which vary from simple, fast, formative assessments to full course redesign. For example, simple strategies might include a think-pair-share dialogue or a one-minute paper. Course redesign strategies might include employing the 5E lesson cycle or flipping the classroom.

Types of EBIPs and the evidence supporting their use have been extensively reviewed elsewhere (Cooper, 2014; National Research Council, 2012). Notably, the use of EBIPs improves course completion rates and raises grades in introductory college coursework, including in the gateway courses that often prevent students from continuing their studies in a STEM degree. After completing a meta-analysis of the research on active learning, Freeman et al. (2014) boldly claimed that if this were a medical trial on EBIPs with similar dramatic effects, it would be unethical to continue lecturing in the traditional sense. These teaching strategies are robust and largely discipline independent, meaning that what works in one STEM discipline will work in any STEM discipline (Fairweather, 2008).

Even though there is significant evidence to support the use of EBIPs, the majority of STEM faculty have not adopted these methods (Henderson & Dancy, 2007; Landrum, Viskupic, Shadle, & Bullock, 2017; Stains et al., 2018). This is true despite the significant investment of time, energy, and money in the improvement of STEM teaching at the undergraduate level (Executive Office of the President, 2011). Many of these funded projects were successful in helping individual faculty members change their practices, but very few projects succeeded at widespread adoption of EBIPs either within the university or in the larger community (Fairweather, 2008).

Given the abundant evidence of effective teaching methods in STEM, why do STEM faculty persist in teaching undergraduate courses using traditional, less effective methods, such as lecturing? STEM faculty operate in complex contexts involving their personal knowledge and attitudes about teaching and learning, social interactions with colleagues and students, and teaching environments with varying access to support and resources. Any attempt to modify faculty behavior must begin with an understanding of the factors that influence their current instructional decisions. Thus, understanding what the existing literature teaches about factors that influence university STEM faculty decisions about EBIPs is a critical first step and the focus of this paper.

Literature Review Question and Methods

Guiding my inquiry of the literature was the following question: What is empirically known about the factors that influence STEM faculty decisions about evidence-based instructional practices?

To answer this question, we searched the ERIC database for articles at the intersection of three fields: STEM, EBIPs, and higher education, published between 1998 and 2018. Articles were excluded if they simply reported on an educational innovation or the relationship between EBIPs and improved student performance without addressing the issues that faculty face when making these curricular changes. Likewise, articles that described a professional development program for STEM faculty without addressing faculty decision-making were excluded. Additionally, this review focused only on the adoption of EBIPs in undergraduate education, so articles that described changes in K–12 or graduate STEM education were excluded. The group of people we considered STEM faculty was broadly defined as individuals who act as primary instructors for undergraduate STEM courses. Thus, studies involving postdoctoral scholars with facultylike positions were included, and we did not distinguish between full-time, part-time, tenure-track, or non-tenure-track faculty. Some studies investigated faculty instructional decision-making in all disciplines, and these were excluded unless results for STEM faculty were differentiated from the general results.

We included articles in the literature review if they addressed STEM faculty attitudes, changes in instructional practices, or professional development. To make the search comprehensive, we also screened the references cited in the included articles and identified other relevant papers that have cited the included articles, using Google Scholar.

The title and abstract of each article were analyzed for initial inclusion or exclusion. Those articles that passed the screening were read and analyzed further. Articles that did not address the factors that influence STEM faculty decisions about EBIPs were excluded. Articles included for further review addressed the how and why of reform, not just the what. Included studies were analyzed to determine whether they were empirical, practical, or conceptual. Studies were classified as empirical if they used qualitative, quantitative, or mixed methods to systematically examine a question of interest. Articles classified as practical were related to the experiences of individuals who had participated in STEM education reform. The conceptual category was broader and included policy statements advocating for particular actions, reviews of the literature, and theoretical pieces not based directly on empirical work. The empirical studies were further analyzed to determine the types of methods that were used and to summarize the main findings.

The literature search returned 67 articles about STEM faculty instructional decision-making, including 32 empirical, 11 practical, and 24 conceptual reports. The empirical studies consisted of 13 qualitative studies, 12 quantitative studies, and seven studies using mixed methods. These 32 empirical studies are reviewed further below.

Results

A significant effort has been made to characterize the factors that STEM faculty consider when making instructional decisions about EBIPs. These studies recognize the complex environments within which faculty operate, with multiple and sometimes competing stakeholder demands, limited time and resources, and high-stakes career outcomes dependent on teaching quality (National Research Council, 2012, p. 183). Hora (2012) classified these factors at the individual, sociocultural, and structural levels, acknowledging that despite the presence of common institutional characteristics, instructional decision-making is idiosyncratic and unique to individuals. Other authors have used a variety of frameworks to organize their findings, but there hasn't been consensus within the field about models that facilitate understanding of the complexity of influences on STEM faculty instructional decision-making.

For the purpose of this review, we group these influences into personal, social, and contextual categories. Personal factors include faculty members' own educational experiences, their knowledge of EBIPs, and their attitudes toward EBIPs. Social factors, such as the influence of colleagues and students, also affect decisions. Contextual factors include access to resources and characteristics of the course or students. An analogy can be made between this system (personal, social, and contextual) and the levels of biological organization (individual organism, population/community, and ecosystem). In biology, as we consider each new level of increasingly complex organization, we discover emergent properties that make the whole greater than the sum of its parts. Considering STEM faculty, we can think of the individual with his or her personal characteristics; the population of STEM faculty and the community of stakeholders, such as students and administrators, as social concerns; and the ecosystem of the university, including physical and material resources, as contextual factors (Figure 1). Ecological models have been used extensively in public health research and policy, and several types have been reviewed elsewhere (Sallis & Owen, 2015).

Table 1 lists the research articles included in this review and indicates which articles discuss personal, social, and contextual factors. The findings from these studies are described in detail in the sections that follow.

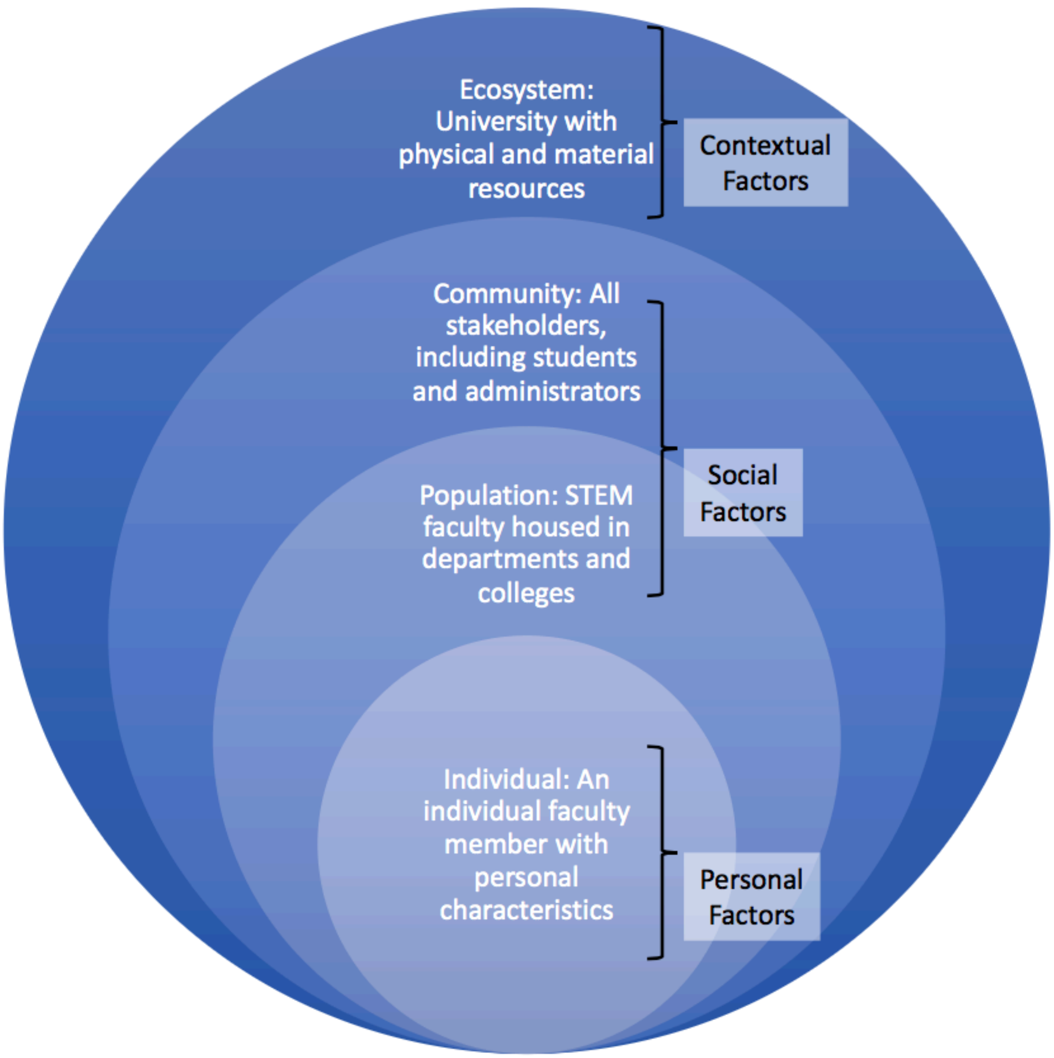

Figure 1. An ecological model of STEM faculty instructional decision-making. Individuals, with personal characteristics, are part of the population of STEM faculty within a department or college, who interact with other populations such as students and administrators to form the community. These living things interact with the nonliving parts of the environment, such as resources and classroom spaces, to form the ecosystem.

Table 1

Summary of Articles Included in This Review

Article	Personal Factors	Social Factors	Contextual Factors
Andrews, Conaway, Zhao, & Dolan, 2016		X	
Andrews & Lemons, 2015	X		
Brickman, Gormally, & Martella, 2016		X	
Bunce, Havanki, & VandenPlas, 2008	X	X	X
Colbeck, 1998		X	X
Dancy, Henderson, & Turpen, 2016	X	X	X
Derting et al., 2016	X	X	
Ebert-May et al., 2011		X	X
Ebert-May et al., 2015	X	X	X
Foote, Neumeyer, Henderson, Dancy, & Beichner, 2014		X	X
Gess-Newsome, Southerland, Johnston, & Woodbury, 2003	X	X	X
Gibbons, Villafañe, Stains, Murphy, & Raker, 2018	X		
Henderson, 2005	X		X
Henderson & Dancy, 2007	X	X	X
Henderson & Dancy, 2008	X		
Henderson, Dancy, & Niewiadomska-Bugaj, 2012	X	X	X
Hora, 2012	X	X	X
Landrum, Viskupic, Shadle, & Bullock, 2017	X	X	X
Leslie, 2002			X
Light, Calkins, Luna, & Drane, 2009	X		
Lindblom-Ylänne, Trigwell, Nevgi, & Ashwin, 2006	X	X	
Manduca et al., 2017	X	X	X
Marbach-Ad & Rietschel, 2016	X	X	X
Michael, 2007			X
Owens, Trujillo, Seidel, Harrison, Farrar, Benton . . . Tanner, 2018	X	X	
Pfund, Miller, Brenner, Bruns, Chang, Ebert-May . . . Handelsman, 2009		X	X
Pundak, Herscovitz, Shacham, & Wiser-Biton, 2009	X		X
Samuelowicz & Bain, 2001	X		
Shadle, Marker, & Earl, 2017	X	X	X
Sunal, D. W., Hodges, Sunal, C. S., Whitaker, Freeman, Edwards . . . Odell, 2001	X		
Walczyk, Ramsey, & Zha, 2007	X	X	

Personal Factors

Personal factors relate to the individual STEM faculty member and include the individual's self-efficacy for evidence-based teaching and attitudes about teaching and learning, including EBIPs.

Self-efficacy. Self-efficacy for evidence-based teaching is an individual STEM faculty member's self-appraisal of his or her ability to use EBIPs. A primary determinant of an individual's self-efficacy in a domain is his or her experience of mastery in that domain (Bandura, 2010). For the purpose of this review, mastery experiences refer to a STEM faculty member's experience of success using EBIPs. Although recent efforts have attempted to provide teaching training for graduate students and postdoctoral scholars (Derting et al., 2016; Ebert-May et al., 2015), Walczyk, Ramsey, and Zha (2007) found that most science and math faculty had received little or no pedagogical training. Owens et al. (2018) found that a lack of formal teaching training and a desire to improve teaching were motivators for biology faculty participation in a professional development program about EBIPs. STEM faculty are unlikely to have prior experience using EBIPs successfully, which negatively impacts their self-efficacy but can serve as motivation to learn more. A secondary influence on self-efficacy is social modeling, or vicarious experiences. When STEM faculty have models whom they view as similar to themselves and who are successfully using EBIPs, they are more likely to feel confident in their own abilities to use EBIPs (Bandura, 2010). In departments where there is a culture of collaboration, faculty can learn from other, more experienced instructors, reducing the likelihood of failure (Shadle, Marker, & Earl, 2017; Sunal et al., 2001). Additionally, when departments have an established culture of reflective teaching and experimentation with new teaching strategies is encouraged, faculty will learn how to deal with setbacks (Michael, 2007;

Shadle et al. 2017). Indeed, Andrews and Lemons (2015) found that resilience was a necessary trait for STEM faculty adopting EBIPs. Learning from mistakes is a powerful way to develop greater self-efficacy with the use of EBIPs through perseverant effort (Bandura, 2010). The effect of low self-efficacy in facilitating EBIPs affects teaching dramatically. Faculty who don't feel confident using EBIPs generally do not choose to use them.

Attitudes. Attitudes toward EBIPs are closely associated with attitudes about teaching and learning. Gess-Newsome, Southerland, Johnston, and Woodbury (2003) associated traditional instructional practices with the attitude that students must be told information, whereas they associated EBIPs with the attitude that teachers should facilitate meaningful experiences for students, who will construct their own knowledge by grappling with new ideas. These two views were labeled, respectively, as "transmissive" and "facilitative." The relationships between transmissive views of teaching and traditional instruction and between facilitative views of teaching and EBIPs have been seen repeatedly (Trigwell & Prosser, 2004). Pundak, Herscovitz, Shacham, and Wiser-Biton (2009) found that instructors who used traditional methods such as lecture tended to view themselves as knowledge deliverers, rather than as facilitators of learning. Samuelowicz and Bain (2001) concluded that a faculty member's transmissive or facilitative attitudes about teaching and learning could affect their willingness to adopt new technologies or teaching practices. Light, Calkins, Luna, and Drane (2009) found that faculty participants in a professional development program changed from transmissive to more facilitative views about teaching and that this affected their instructional decisions. When faculty view teaching as a facilitation of student learning, rather than a transmission of knowledge, they are more likely to choose EBIPs. STEM faculty attitudes about who can learn also influence their decisions about EBIPs. Sunal et al. (2001) investigated the process of EBIP adoption for faculty from 30 institutions with teams participating in NASA's NOVA project to improve undergraduate STEM teaching. They identified several attitudes that correlated with higher likelihood of implementing EBIPs. The belief that all students can learn had a statistically significant correlation with changes in classroom practice. This relationship was quite strong—most of the participants who believed that some students are incapable of success in science dropped out of the professional development program early in the process, prior to making changes to their instructional practices. A belief that not all students can learn STEM perpetuates the use of traditional instructional practices.

Beyond general attitudes about teaching and learning, faculty may have beliefs or attitudes about EBIPs specifically. Some portion of STEM faculty is wary of change in general and resists any effort to reform instruction (Shadle et al., 2017). Others dislike the idea that EBIPs tend to transfer some control of content and pacing to the students, or the feeling that the faculty member must somehow give up control over certain aspects of the learning environment (Michael, 2007; Shadle et al., 2017). Still other STEM faculty view EBIPs more as a form of entertainment or as strategies to keep students' attention, rather than as a way to address difficult issues like the varying educational backgrounds of their students (Henderson & Dancy, 2008; Michael, 2007). When faculty don't understand the power of EBIPs to address the needs of their students, they may be unlikely to modify their instruction.

Faculty may also view EBIPs as inappropriate for their classrooms. Henderson and Dancy (2008) identified a need for discipline-based education researchers to work with faculty in the development of new curricula, rather than expecting faculty to adopt curricula developed by others. They found that faculty were more likely to invent or reinvent solutions to their instructional problems than to adopt or adapt a given educational innovation, which confirmed the result from the single case study in Henderson (2005). This was in part because the faculty felt that discipline-based educational researchers were unaware of the unique circumstances of their classrooms or didn't respect the years of experience that informed faculty practice.

The personal factors of self-efficacy using EBIPs and attitudes toward EBIPs, including attitudes toward teaching and learning generally, strongly affect the instructional decisions of STEM faculty members. However, STEM faculty members do not operate in isolation, and social pressures from colleagues, students, and administrators also influence their decision-making process.

Social Factors

STEM faculty experience social pressures from all stakeholders in undergraduate STEM education: students, colleagues, and administrators, like department chairs and deans. Sociocultural factors can impact faculty decision-making about EBIPs even when they consist of unwritten rules, or tacit norms (Hora, 2012). Each of these groups has its own expectations around teaching that can influence a faculty member's instructional decisions about EBIPs.

Colleagues. The social norms that a faculty member learns from colleagues are often based in the culture of a department or college. Michael (2007) conducted focus groups with university faculty, including one group made up entirely of science faculty, in order to understand the perceived barriers to implementation of EBIPs. The faculty participants agreed that faculty expect colleagues to use traditional instruction in university courses and that those expectations are reinforced both by experience and current media. Shadle et al. (2017) identified collaboration with colleagues around teaching as an important driver for the adoption of EBIPs by STEM faculty. In a department-wide professional development program for EBIPs, biology faculty cited collegial interactions as an important aspect of their motivation for participation

(Owens et al., 2018). Furthermore, informal social interactions about EBIPs can be important factors in faculty decision-making (Andrews, Conaway, Zhao, & Dolan, 2016; Dancy, Henderson, & Turpen, 2016). Landrum et al. (2017) created a survey to assess instructional climate and EBIP adoption. They found that when faculty felt more connected to other teachers on campus, they also tended to have greater levels of EBIP adoption. Others have found that the motivation, support, and feedback provided by colleagues as part of a reflective teaching practice are essential for faculty to persist with EBIP adoption (Brickman, Gormally, & Martella, 2016).

General socialization within a field and via disciplinary professional societies can also influence faculty decision-making about EBIPs. Some faculty may feel these professional norms even more acutely than the pressures within their department. Brownell and Tanner (2012) claimed that the socialization of young scientists usually favors research practices over teaching practices. Furthermore, the social structures that create and sustain scientists' professional identities, including professional organizations, prioritize research over teaching in publications, conferences, and prestige. Lindblom-Ylänne, Trigwell, Nevgi, and Ashwin (2006) found that traditional, lecture-based teaching was more common among STEM disciplines than among humanities disciplines. Social pressure from colleagues, both near and far, can strongly influence STEM faculty instructional decision-making, including the adoption of EBIPs.

Administration. A primary concern for young faculty and those who have not yet achieved the rank of full professor is the way in which teaching is considered in the rank and status process, which is a strong indication of how administrators think about teaching quality. Walczyk et al. (2007) developed the Incentives and Supports for Instructional Innovation Survey (ISIIS) to investigate roadblocks to the use of student-centered teaching strategies in undergraduate STEM coursework. The survey was sent to all science and mathematics faculty in

Louisiana institutions of higher education and had a 28% response rate. The majority of faculty respondents indicated that teaching was not highly valued as part of important personnel decisions like tenure and rank advancement and that teaching was normally assessed primarily using student ratings.

Andrews et al. (2016) found that department leaders could influence STEM faculty decisions about EBIPs through a variety of means, including supporting professional development activities, providing resources for coteaching, prioritizing the hiring of discipline-based educational researchers, and ensuring that all faculty are exposed to high-quality educational research and its practical implications for teaching. Landrum et al. (2017) found that when faculty perceived more encouragement from administrators to use EBIPs, they were more likely to use them. Administrators communicate their values to STEM faculty through the departmental teaching efforts they support and the rank-and-status process. These social pressures inform STEM faculty instructional decision-making.

Students. In addition to social influences from colleagues and administrators, faculty experience social norms from students that influence their instructional decisions about EBIPs. Students arrive at the university with 12 years of school experiences and the expectation that college learning will be similar. This student expectation creates a subjective norm for faculty that discourages the use of EBIPs. Slater (2003) described student expectations for college science courses as a sort of “hidden contract” that outlines the professor’s responsibility to tell students what’s on the test and the students’ responsibility to memorize it. Violating the contract, by using EBIPs that require students to think deeply, can cause rebellion and anger from students who have a specific expectation about college coursework. This feedback loop acts as a deterrent for faculty to break out of traditional lecture instruction. Michael (2007) conducted focus groups with university faculty, including one group made up entirely of science faculty, in order to understand the perceived barriers to implementation of EBIPs. He found that STEM faculty perceived that their students expected traditional instruction. This negatively influenced the faculty members' adoption of EBIPs.

Students communicate their expectations about teaching to STEM faculty primarily through their in-class response to EBIPs and their student evaluations of teaching. Some students may apply negative pressure to faculty who attempt to use EBIPs in real time, by resisting increased demands for classroom participation (Michael, 2007; Shadle et al., 2017). Even if students don't resist EBIPs in real time, they may express their discontent on student evaluations. Student evaluations of teaching scores often go down when faculty implement EBIPs for the first time (Brickman et al., 2016). This effect can be especially problematic for pretenure faculty or faculty applying for a rank advancement because it is risky to try new methods, knowing that the effort may be punished instead of rewarded (Shadle et al., 2017). Social pressure from students to teach traditionally can discourage STEM faculty from adopting and using EBIPs.

Contextual Factors

STEM faculty make instructional decisions within a complex context, where their personal characteristics and social factors interact with the context of resources and materials that are available to them. The idea that many faculty members feel constrained by factors outside of their control is not new. Although their primary emphasis was on faculty beliefs, in the survey designed by Gibbons, Villafañe, Stains, Murphy, and Raker (2018), faculty were asked to respond while thinking about the course over which they have the most control. Dancy and Henderson (2008) conducted interviews with physics faculty members to better understand the process of learning about and experimenting with peer instruction and found that, even for faculty who had positive attitudes toward EBIPs, an environment conducive to the implementation of EBIPs was necessary for faculty to align their practices with their attitudes. One study, which evaluated the impact of professional development based on process-oriented guided-inquiry learning, found that faculty who were farther along in adopting and being committed to continued use of EBIPs also tended to focus on barriers that were within their control (Bunce, Havanki, & VandenPlas, 2008). Contextual factors, including time, resources, and student characteristics, were almost universally found to be barriers to the adoption of EBIPs.

Time. Time is a limited resource, both in and out of class. STEM faculty must balance a variety of responsibilities, including research, citizenship, and teaching. There is an opportunity cost when faculty choose to spend time improving their teaching—that time presumably would have been spent on research. The issue of time management and balancing responsibilities has been reported extensively in the literature (Dancy & Henderson, 2008; Ebert-May et al., 2011; Leslie, 2002; Michael, 2007; Pfund et al., 2009), although Colbeck (1998) argued that faculty can integrate research and teaching to save time. Shadle et al. (2017) reported that time constraints were one of the most commonly identified barriers to the adoption of EBIPs cited by the 169 faculty members in 12 STEM departments who participated in the survey.

Finding time outside of class to prepare for evidence-based instruction takes significant effort, but time inside of class can also be a limitation. EBIPs can be less efficient than lecture, so instructors choosing to use EBIPs must decrease the amount of material they cover in class, hopefully in exchange for deeper student understanding of the material they do cover (Marbach-Ad & Rietschel, 2016). Pundak et al. (2009) surveyed 153 faculty members about their attitudes toward active learning using a questionnaire that they designed for this purpose. They found that traditional faculty, who have not adopted EBIPs, were more likely to be concerned with content coverage than understanding. The need to reduce content coverage is a significant barrier because STEM faculty face a variety of pressures to cover content within the semester. This pressure may exist because the course they teach is a prerequisite for a more advanced course, because the department has established learning objectives for each course, because the course must prepare students for a standardized graduate entrance exam, or because an accreditation body has established guidelines for content coverage (Dancy & Henderson, 2008; Michael, 2007; Shadle et al., 2017). Time, both in class and out of class, factors into STEM faculty instructional decision-making about EBIPs.

Resources. Evidence-based instruction requires different resources than traditional instruction. Lecture halls with fixed seating are appropriate for lectures, which don't require audience participation. Flexible instructional spaces, in contrast, can better facilitate group interactions and dialogue. The lack of appropriate learning environments is frequently cited as a barrier to the use of EBIPs (Dancy & Henderson, 2008; Ebert-May et al., 2011; Pfund et al., 2009; Shadle et al., 2017). Michael (2007) concluded that the physical arrangement of classrooms is a universal barrier to the adoption of active learning. In contrast, Talanquer and Pollard (2017), describing the slow process of changing instruction within the chemistry department, claimed that the availability of a classroom designed for EBIPs was a major driver of change at their institution. When examining the impact of a physics EBIP at different institutions, Foote, Neumeyer, Henderson, Dancy, and Beichner (2014) found that having a specialized classroom compatible with that teaching strategy was likely to support continued use of EBIPs at student-centered active learning environment with upside-down pedagogies (SCALE-UP) sites.

Appropriate classroom space is an important resource barrier, but it is not the only resource barrier for STEM faculty attempting to adopt EBIPs. Training and course release time are two university resources that can support STEM faculty adoption and use of EBIPs (Sunal et al., 2001). Additionally, the use of EBIPs may require additional monetary support for teaching assistants to help facilitate EBIPs in class or grade evidence-based assessments out of class (Ebert-May et al., 2011; Shadle et al., 2017; Walczyk et al., 2007). Although standard dissemination activities can increase awareness of EBIPs, supporting faculty during implementation and continued use of EBIPs is necessary (Henderson, Dancy, & Niewiadomska-Bugaj, 2012).

Some resource barriers are related to the larger STEM education community. STEM faculty have difficulty finding high-quality instructional resources (Michael, 2007; Shadle et al., 2017). Even those resources developed by discipline-based educational researchers may not be viewed as appropriate for a specific college, course, or group of students. Instructors may feel the need to create their own or modify existing resources (Henderson & Dancy, 2008). This development effort requires a significant amount of faculty time and, because it is conducted by STEM faculty untrained in curriculum development, frequently results in a version of the course materials that removes the evidence-based qualities (Dancy & Henderson, 2008). When context-appropriate teaching materials, such as those generated by the On the Cutting Edge project in geosciences, are available, STEM faculty will use them to improve their teaching (Manduca et al., 2017). The availability or lack of appropriate material and pedagogical resources can influence STEM faculty adoption of EBIPs.

Student characteristics. Instructors do not have control over several student factors that influence their ability to use EBIPs. Large class sizes, heterogeneous student populations, poor student preparation for class, and lack of college readiness can affect instructional decisions. In large classes, faculty may not be able to monitor the work of all student groups to ensure that they are on task and making progress toward the desired learning objectives (Dancy & Henderson, 2008; Henderson & Dancy, 2008; Michael, 2007; Pundak et al., 2009; Shadle et al., 2017). This issue is exacerbated when class sections are composed of students with very different skill levels (Henderson & Dancy, 2008; Michael, 2007). Using EBIPs can be challenging when some students may not be able to participate productively. This can result from a lack of student preparation for class on any given day (Henderson & Dancy, 2008; Michael, 2007), for example, when a student does not complete the required reading or video viewing prior to class. Unproductive participation or nonparticipation in EBIPs can also result from the general lack of maturity or academic preparation of some students who may not be well prepared for college (Michael, 2007; Shadle et al., 2017). Marbach-Ad and Rietschel (2016) found that for EBIP adoptions to be successful, students must accept greater responsibility for their own learning. When students are unprepared, immature, or too heterogeneous in their abilities, that can act as a deterrent for STEM faculty to adopt and use EBIPs.

Discussion

Using an ecological model for STEM faculty instructional decision-making, we can begin to explore the complex interactions between individuals, their communities, and their environments. A few examples, drawn from case studies in the literature, will serve to illustrate this point.

One of the participants in the case studies presented by Gess-Newsome et al. (2003), Brian, eagerly embraced EBIPs in the creation of a new interdisciplinary course, which he accomplished collaboratively with three colleagues. Brian had positive attitudes toward EBIPs and had powerful mastery experiences using EBIPs in the classroom, so his personal characteristics were supportive of the use of EBIPs. During the study, he worked with the support of several colleagues, including both disciplinary experts and educational researchers, so he had significant social support for teaching improvement. However, when the researchers asked whether Brian would use EBIPs in other courses, he said he probably would not. In part, that decision was because he would not have the same social support in a different course. In this case, although Brian's personal characteristics are indicative of an individual who is likely to adopt EBIPs, the social factors related to collegial interactions were the determining factor in his decision to use EBIPs in different contexts. This example highlights the need to understand and address both personal and social factors when working to encourage adoption of EBIPs.

Albert, another participant in the Gess-Newsome et al. (2003) study, chose not to use EBIPs, instead relying on flashy, fun lessons that students found engaging but didn't challenge their thinking. He did this despite his firmly held belief that inquiry is essential to science learning. Although he had a facilitator attitude about learning, which would normally support better teaching, the social influence of student desires for easy coursework discouraged Albert from using EBIPs. Both Brian and Albert operated within the same university ecosystem, and both were foiled by social norms that discouraged the use of EBIPs, albeit from different sources. This fact highlights the idea that common social structures within university systems might affect individuals in similar ways.

Henderson and Dancy (2007) interviewed several physics faculty about their attitudes toward EBIPs and their current practices. One of those faculty members, Mary, had positive attitudes toward EBIPs and student-centered ideas about learning but did not use EBIPs in class very often because of unfavorable time limitations and the lack of departmental support for alternative teaching methods. She experienced positive personal factors but negative social and contextual factors. When the university received grant funding to support the implementation of EBIPs, Mary identified three factors that influenced her decision to adopt EBIPs, saying:

> It was the release of time so that I had more flexibility in how to cover a lesser amount of material more in depth. Two, that there is a group here doing it. And three, that I was exposed to more research on how cooperative learning works. (p. 10)

Mary identified the contextual factor of time, the social factor of collegial support, and the personal factor of knowledge about EBIPs as the three constraints that had prevented her from using EBIPs in the past. When these three factors were aligned in support of EBIP adoption, she adopted and used EBIPs.

These three examples from the literature illustrate the complex human decisions associated with the adoption of EBIPs in STEM classrooms. When personal, social, and contextual factors are all supportive of reform, faculty are likely to adopt and use EBIPs.

Conclusions

STEM faculty make instructional decisions about EBIPs while navigating a complex web of personal, social, and contextual factors that make up the STEM faculty ecosystem. To effect change in teaching practices, we must consider all parts of the ecosystem and work to align each part with factors that support the adoption and use of EBIPs. As Austin (2011) concluded, we must think about both bottom-up solutions that engage individual faculty members to improve their attitudes and self-efficacy and top-down solutions that transform the contextual and social factors that influence instructional decisions. More recently, others have advocated for a "middle-out" approach, focusing on department-level changes (Reinholz, Pilgrim, Corbo, & Finkelstein, 2019). There is great variation in the personal characteristics of individuals within departments and among different departments at the university (Lund & Stains, 2015; Shadle et al., 2017) which makes adoption of a single model of teaching reform challenging. However, within each context, interventions to encourage the adoption and use of EBIPs should be targeted to the personal, social, and contextual factors that are salient for a particular group.

One recent STEM faculty development effort, Faculty Explorations in Scientific Teaching (FEST), was successful at helping biology faculty change their teaching methods to include more EBIPs (Owens et al., 2018). Program elements were targeted to improve personal, social, and contextual factors. Personal factors were addressed by supporting STEM faculty's reflection on their attitudes toward teaching and providing focused instruction and opportunities to practice using EBIPs in order to develop self-efficacy. Social factors were addressed by organizing and supporting communities of practice, where small groups of faculty members would gather to discuss teaching, observe each other, and reflect on their own teaching. Additionally, the project moved forward with the strong support of administration, including explicit statements that biology education research publications would be viewed as equivalent to traditional biology research publications in tenure and promotion processes. To address contextual factors, the project leadership also considered the existing resources and chose EBIPs that could be carried out given the resources available at the department and university. The alignment of personal, social, and contextual factors supported the adoption of EBIPs.

Although an ecological model for STEM faculty instructional decision-making can account for personal, social, and contextual factors that influence STEM faculty instructional decisions, further work is needed to develop or adopt conceptual frameworks for understanding STEM faculty instructional decision-making.

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ARTICLE 2

Factors That Influence STEM Faculty Use of Evidence-Based Instructional Practices: An Ecological Model

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Introduction

There is a pressing national need for more highly qualified scientists and engineers to enter the workforce (President's Council of Advisors on Science and Technology, 2012), a need that has not been met with current practices in higher education (Baldwin, 2009b). About half of bachelor's degree students who declare a science, technology, engineering, or mathematics (STEM) major either switch to a different degree program or don't complete a degree at all within six years (Chen, 2013). Poor student performance in or withdrawal from introductory STEM coursework is highly predictive of a student's choice to leave a STEM major (Chen, 2013, p. 39). Among students who change majors from STEM subjects to non-STEM subjects, 90% cite poor teaching by STEM faculty as a concern and 36% cite low teaching quality as a deciding factor in their decision to switch fields (Seymour & Hewitt, 1997). Improving the quality of teaching at the undergraduate level with the goal of also improving student performance in introductory STEM courses will be necessary to meet the goal of one million more graduates qualified for work in STEM fields (President's Council of Advisors on Science and Technology, 2012).

The most effective way to improve undergraduate STEM teaching is to use instructional practices that have been studied and shown to affect student learning. While other terms such as active learning, student-centered learning, and learner-centered teaching describe reformed teaching methods that depart from tradition, we will use evidence-based instructional practices (EBIPs) for the purposes of this article. We define traditional practices as lecture with some opportunity for questions and answers. There is a spectrum of EBIPs that vary from simple, fast, formative assessments to full course redesign. Types of EBIPs and the evidence supporting their use have been extensively reviewed elsewhere (Cooper, 2014; National Research Council, 2012).

Notably, the use of EBIPs improves course completion rates and raises grades in introductory college coursework, including the gateway courses that often prevent students from continuing their studies in a STEM degree. After completing a meta-analysis of the research on active learning, Freeman et al. (2014) boldly claimed that if this were a medical trial on EBIPs with similar dramatic effects, it would be unethical to continue lecturing. These teaching strategies are robust and largely discipline independent, meaning that what works in one STEM discipline will work in any STEM discipline (Fairweather, 2008).

Stagnant Instructional Practices

Even though there is significant evidence to support the use of EBIPs, the majority of STEM faculty have not adopted these methods (Henderson & Dancy, 2007; Landrum, Viskupic, Shadle, & Bullock, 2017; Stains et al., 2018). This is true despite the significant investment of time, energy, and money in the improvement of STEM teaching at the undergraduate level (Executive Office of the President, 2011). Many of these funded projects were successful in helping individual faculty members change their practices, but very few projects succeeded at widespread adoption of EBIPs, either within the university or in the larger community (Fairweather, 2008).

Justification for Current Study

One possible explanation for stagnant instructional practices is a lack of understanding about the barriers and drivers for change. Faculty members themselves do not accurately predict which challenges they will face during implementation of EBIPs (Pfund et al., 2009). Austin (2011), in a report commissioned by the National Research Council, recommends that research efforts in this area focus not only on the effectiveness of strategies but also on the behaviors and instructional decisions of STEM faculty members. Others have also called for more research about the process of change for STEM faculty (Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Talanquer, 2014). Kezar and Gehrke (2015) advocate for investigations that shed light on both individual faculty member decision-making and the organizational structures that influence those decisions.

In this paper, we attempt to address these concerns of understanding the process of change for STEM faculty and finding conceptual frameworks to guide thinking in this area by studying the instructional decision-making process for STEM faculty.

Literature Review

A significant effort has been made to characterize the factors that influence STEM faculty adoption and use of EBIPs. Much as there are emergent properties in levels of biological organization—from individual, to population, to community and ecosystem—a careful consideration of the decision-making environment of STEM faculty members requires attention to these layers of complexity, recognizing the influence of personal, social, and contextual factors.

Personal Factors

With the exception of a few programs that specifically prepare graduate students and postdoctoral scholars for university teaching (Austin et al., 2009; Ebert-May et al., 2015), the majority of STEM faculty begin teaching without any training in pedagogy, much less the use of EBIPs (Walczyk, Ramsey, & Zha, 2007). Citing this lack of training, Baldwin (2009a) suggested that high-quality professional development about EBIPs could dramatically improve undergraduate STEM teaching and learning. It stands to reason that faculty who don't know how to use EBIPs will not use them.

In addition to pedagogical knowledge, faculty hold strong beliefs about teaching and learning that can influence their instructional choices. These beliefs are developed over a lifetime of experience as students and teachers. Gess-Newsome et al. (2003) found that traditional instructional practices were associated with the attitude that information must be transmitted or delivered to students, whereas EBIPs were associated with the attitude that teachers should facilitate meaningful experiences for students, who construct their own knowledge by grappling with new ideas. Pundak, Herscovitz, Shacham, and Wiser-Biton (2009) found that instructors who use traditional methods such as lecture tend to view themselves as a knowledge deliverer, rather than as a facilitator of learning. Sunal et al. (2001) found that the belief that all students can learn was significantly correlated with adoption of EBIPs. Samuelowicz and Bain (2001) concluded that a faculty member's attitudes about teaching and learning can affect their willingness to adopt new technologies or teaching practices, and interventions need to take into account faculty beliefs in order to have lasting benefits.

Social Factors

Faculty members operate within a complex social environment, interacting with students, colleagues from within their department or college, administrators within the university, and broadly with members of their academic disciplinary groups. These social interactions can affect STEM faculty instructional decision-making, including whether and how to adopt EBIPs.

Slater (2003) described student expectations for college science courses as a sort of "hidden contract" that outlines the professor's responsibility to tell students what's on the test and the students' responsibility to memorize it. Violating the contract, by using EBIPs that require students to think deeply, can cause rebellion and anger from students who have a specific expectation about college coursework. This feedback loop acts as a deterrent for faculty to break out of traditional lecture instruction. This student expectation is exacerbated by the significant role of student evaluations in faculty rank-and-status decisions (Walczyk et al., 2007), which can be especially problematic for pretenure faculty or faculty applying for a rank advancement. It is risky to try new methods like EBIPs, knowing that the effort may be punished instead of rewarded (Shadle, Marker, & Earl, 2017).

Interactions between colleagues within a department can also support or hinder the adoption and use of EBIPs. Shadle et al. (2017) identified collaboration with colleagues about teaching as an important driver for change. Michael (2007) found that department and university culture around teaching was a leverage point for change. The faculty participants in that study agreed that both students and colleagues expect traditional instruction in university courses and that those expectations are reinforced both by experience and current media. Socialization within a disciplinary field can extend beyond a department or university to professional societies. These social interactions are likely to prioritize research over teaching in publications, conferences, and prestige, affecting a STEM faculty member's professional identity (Brownell & Tanner, 2012).

The social interactions between STEM faculty and university administrators can also affect decisions to adopt or use EBIPs. Walczyk et al. (2007) developed the Incentives and Supports for Instructional Innovation Survey (ISIIS) to investigate roadblocks to the use of student-centered teaching strategies in undergraduate STEM coursework. The majority of faculty respondents indicated that teaching was not highly valued as part of important personnel decisions like tenure and rank advancement and that teaching was normally assessed primarily using student ratings. When administrators neither value nor support efforts to improve teaching, it acts as a disincentive to the adoption and use of EBIPs.

Contextual Factors

In addition to an individual STEM faculty member's personal characteristics and interactions with people, there are also interactions with the environment to consider. Even faculty with the best intentions and considerable social support might have difficulty overcoming time and resource constraints.

Time is a limited resource, both in and out of class. Shadle et al. (2017) reported that time constraints and instructional challenges were the two most commonly identified barriers to the adoption of EBIPs cited by the 169 faculty members in twelve STEM departments who participated in the survey. Regarding time in class, efficient use of instructional time can be a significant barrier to the adoption and use of EBIPs because STEM faculty face a variety of pressures to cover content within the semester. This pressure may exist because the course they teach is a prerequisite for a more advanced course, because the department has established learning objectives for each course, because the course must prepare students for a standardized graduate entrance exam, or because an accreditation body has established guidelines for content coverage (Dancy & Henderson, 2008; Michael, 2007; Shadle et al., 2017). The use of novel instructional strategies also requires preparation time outside of class. There is an opportunity cost when faculty choose to spend time improving their teaching—that time presumably would have been spent on research. The challenge of balancing responsibilities and its influence on STEM faculty instructional decision-making has been reported extensively in the literature (Dancy & Henderson, 2008; Ebert-May et al., 2011; Michael, 2007; Pfund et al., 2009).

Evidence-based instruction requires different resources than traditional instruction. Lecture halls with fixed seating are appropriate for lectures, which don't require audience participation. Flexible instructional spaces, in contrast, can facilitate group interactions and dialogue. The lack of appropriate learning environments is frequently cited as a barrier to the use of EBIPs (Dancy & Henderson, 2008; Ebert-May et al., 2011; Pfund et al., 2009; Shadle et al., 2017). Talanquer and Pollard (2017), describing the slow process of changing instruction within the chemistry department, claimed that the availability of a classroom designed for EBIPs was a major driver of change at their institution. Michael (2007) concluded that the physical arrangement of classrooms is a universal barrier to the adoption of EBIPs.

Conceptual and Methodological Frameworks

This work is guided by ecological models of human behavior (Sallis & Owen, 2015) and the methodological framework of hermeneutics (Shane, 2007). Ecological models of human behavior have been used extensively in public health research and interventions. This family of models is based on the levels of biological organization that make up ecosystems on Earth, with emergent properties at each level. For example, one level of organization is the atom, and the next level is the molecule. As atoms combine to form molecules, those molecules have properties and characteristics that are different from their constituent atoms and more complex than what would be predicted based solely on the properties of atoms. When modeling human behaviors, ecological models generally encompass levels of organization at or larger than the individual level. These include individual humans, with their unique personal characteristics; population dynamics comprising the social interactions between humans; and interactions with the material world at the ecosystem level. We framed our research by considering personal, social, and contextual characteristics that contribute to STEM faculty instructional decision-making. Figure 1 illustrates the embedded nature of humans within social and physical/material contexts.

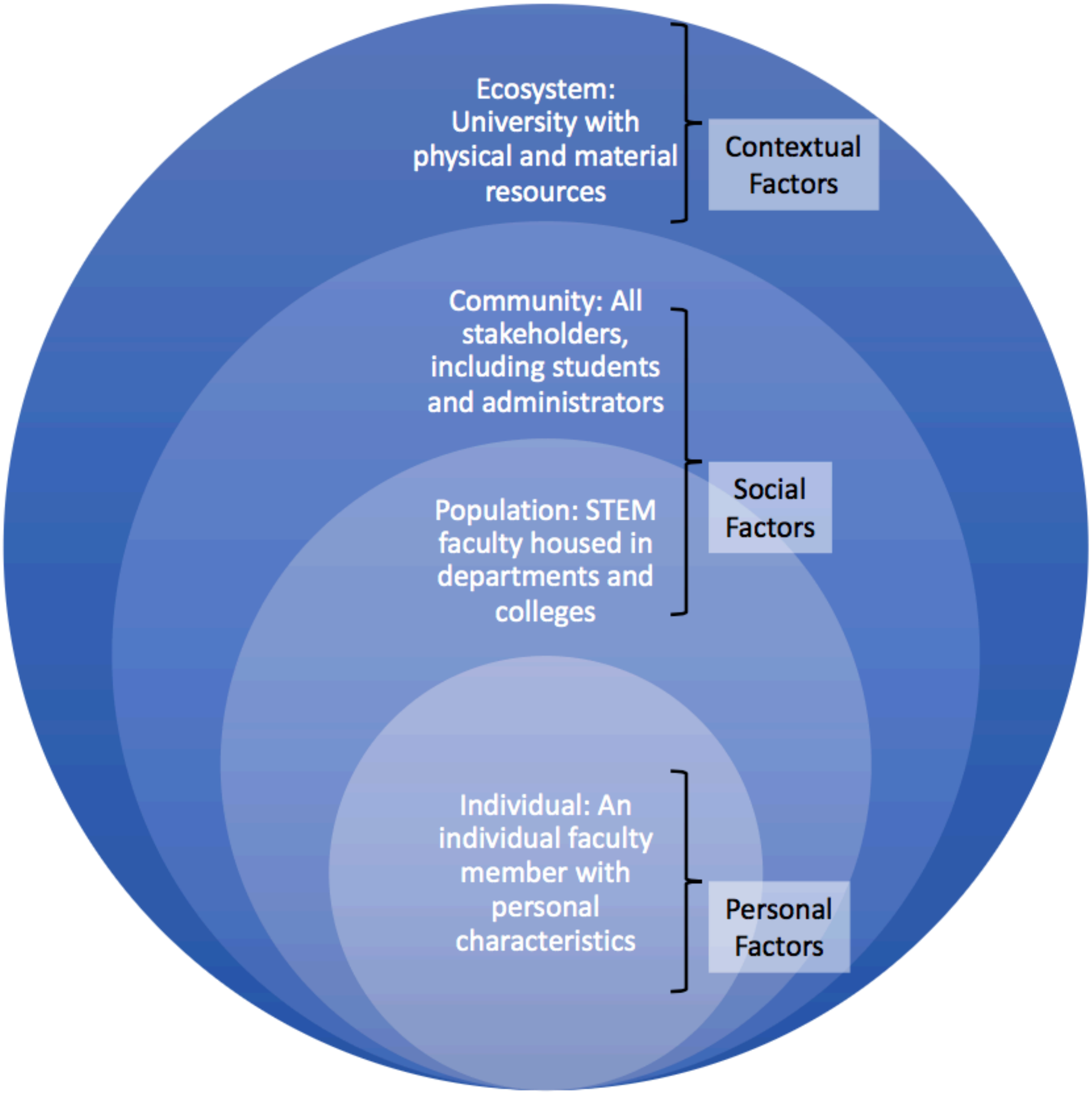

Figure 1. An ecological model of STEM faculty instructional decision-making. Individuals, with personal characteristics, are part of the population of STEM faculty within a department or college, who interact with other populations such as students and administrators to form the community. These living things interact with the nonliving parts of the environment, such as resources and classroom spaces, to form the ecosystem.

Hermeneutic philosophy also influenced this work, particularly in the ways we considered context while attempting to understand faculty members' beliefs, experiences, and perceptions (Shane, 2007). STEM Faculty Institute (STEMFI) participants were involved in a rich, yearlong professional learning program. Our engagement with participants included pre- and postinterviews, one-on-one work during the summer workshop, pre- and post-classroom observations, ongoing journal entries, cohort meetings (where they shared videos of their teaching), and many informal interactions on campus. Thus, the researchers were engaged in knowing and understanding the participants as individuals, including their social and environmental contexts. This work also takes place within a historical context, when STEM education reform is a national priority and STEM faculty have increased awareness of EBIPs compared to their predecessors.

Method

In this study, we addressed the research question: What factors influence STEM faculty decision-making about EBIPs?

Setting

This study took place at a large, private, doctoral-granting university in the western United States. The university may be unique compared to universities of similar size because of its emphasis on undergraduate teaching, because of the high academic preparation of its students, and because of its relatively homogeneous student population. Although the university grants some doctoral degrees, these programs are relatively rare, and there are approximately 10 times as many undergraduates as graduate students on campus. The mission of the university is focused on high-quality undergraduate education. The students that attend this university are academically talented. The average ACT score for entering freshmen in 2018 was 29/36, whereas the national average is only 22. Additionally, the high school grade point average for entering freshmen was about 3.85/4.0. Although the university has students from all 50 U.S. states and from more than 100 foreign countries, most students identify as Caucasian (~85%). These characteristics may make the study population unique, and our findings may not be fully transferrable to universities with different characteristics.

Participants

Participants were chosen based on their participation in the STEMFI program at Brigham Young University. Fifteen full-time, tenure-track faculty members from the Colleges of Engineering, Life Sciences, and Physical and Mathematical Sciences volunteered to participate in this program and received approval from their department chairs to participate. All 15 STEMFI participants agreed to participate in this research project, Which was approved by the institution's Institutional Review Board for human subjects research. STEMFI included a summer workshop on EBIPs followed by a year-long mentored implementation, during which participants used EBIPs in an undergraduate STEM course of their choosing, received mentoring from a peer, reflected on the changes they made, and collaborated in cohort meetings. Participants received a small stipend for their participation.

Data Collection

In order to understand the participants' teaching background and attitudes, current teaching practices, and knowledge of and attitude toward student-centered teaching, we conducted an initial interview with each of the 15 STEMFI participants, which lasted about 45 minutes. Semi-structured interviews explored three primary areas: (a) participant beliefs about teaching and learning (e.g., How do you think students learn best?), (b) current teaching practices (e.g., Describe a typical day in your classroom), and (c) motivation to change (e.g., What barriers keep you from using more EBIPs?). Two researchers conducted the interviews together, taking turns alternately conducting and observing.

Data Analysis

We have followed the guidelines for qualitative data analysis described by Miles and Huberman (1994) with some variations. Prior to and during the study, the primary researchers recorded evolving thoughts in a reflexive journal. Then we conducted the interviews as described in the data collection section. Immediately after the interviews, we discussed any noteworthy ideas or items that we wanted to explore further and we individually recorded our thoughts in the reflexive journal. The interviews were audio recorded and transcribed verbatim.

To protect the anonymity of study participants, all quotes and descriptions use gender-neutral pronouns (*they/their* instead of *he/his* or *she/hers*). Additionally, information that could identify the specific course they teach has been removed (e.g., replacing Physical Science 100 with a general education science course). Quotes were adjusted slightly for clarity by removing stutters and speech disfluencies (e.g., "like," "you know," "um," etc.) and expanding reductions (e.g., "gonna," "wanna," "kinda," etc.).

We each used our thoughts about the interviews to form a sense of the whole meaning, then analyzed the transcript sentence by sentence, asking at each sentence whether the participant had communicated something about why they made instructional decisions. We organized themes within the main structure of personal, social, and contextual influences (see the ecological model discussed previously). After we had analyzed the transcripts individually, we met to discuss our interpretation of the interviews and the emerging themes. Together, we created participant profiles, which are two-page summaries of the key characteristics of each participant, organized according to an ecological model with personal, social, and contextual factors. Each profile briefly described the participant's current teaching practices; summarized the personal, social, and contextual factors that influenced their decisions about EBIPs; and identified major conflicts or challenges that prevented them from utilizing EBIPs more frequently. The participant profile was designed to give an overall sense of the participant's intention to adopt EBIPs prior to their participation in the STEMFI workshop. This method emphasizes the hermeneutic circle—that the whole gives meaning to the parts and the parts to the whole.

After this primary analysis, we created a codebook with themes that emerged from the interviews and applied it to a separate data set (from the second cohort of participants) to ensure that we were able to capture the nuances in the data using the codes. We used a constant comparison method, actively searching for ideas that were not described by the existing codes, and where patterns emerged, we added additional codes to the codebook (Glaser & Strauss, 1967). This revised codebook was used to analyze the data for this article, and as we analyzed, we proceeded with the same attention to ideas not previously identified. Ultimately, we developed 57 unique codes and 10 metacodes, which we report in the results. Finally, we selected representative passages to include in the research report. Due to space, we are unable to describe all of the themes we identified, but we included those that stood out as the most important factors influencing instructional decision-making. We also highlight the ways that participants experience conflict between different beliefs and the nuanced ways that a single theme might show up differently for different people.

Trustworthiness

We used reflexive journaling, peer debriefing, member checking, and prolonged engagement to address issues of trustworthiness. The reflexive journal was maintained as described above as a place to record all research activities and evolving thoughts over the course of the study. We engaged in regular (weekly) debriefing with another member of the research team, checking that our analyses made sense and were consistent with the data. This manuscript was also sent to the participants for a member check, and they agreed that their thoughts were analyzed and communicated accurately. Additionally, this work is part of an ongoing professional learning opportunity for the participants, so researchers engaged individuals in a variety of ways, including interviews, classroom observations, self-reflection through journals and video recordings of classes, and a variety of informal interactions over the course of a year.

Limitations

This study population is not representative of all STEM faculty at all institutions. The institution, while it offers master's and doctoral programs in STEM fields, has a mission that is focused on undergraduate education. The total number of undergraduates at the university is approximately 10 times as many as the number of graduate students. This fact influences expectations about research and teaching within the university community. The student population at this university is also unique. Students tend to be highly academically qualified, with an average entering ACT score of 29 (out of 36, with a national average of 22) for the class of 2021. The student population is not very racially diverse, with 85% of students identifying as Caucasian.

All of the STEM faculty members who participated in this study were volunteers taking part in a professional development opportunity to support the adoption and use of EBIPs. Therefore, they represent a subset of all STEM faculty—those who have some desire to improve their teaching using EBIPs. While this may be viewed as a limitation, we chose to work with this population of willing participants because we believe that a large number of STEM faculty at a variety of institutions fall into this category. Any attempts at systemic change must reach a critical mass of faculty subscribing to the philosophy of evidence-based teaching. Thus, understanding the factors that influence the instructional decisions of STEM faculty who express some willingness to learn more about and use EBIPs will be an essential piece of change efforts.

Results

Results are organized according to the ecological model. The metathemes, themes, and subthemes we identified are presented in Table 1.

Personal Factors

STEM faculty have deeply held beliefs and attitudes about teaching and learning and about EBIPs, which influence their instructional decisions. In addition to attitudes, self-efficacy with the use of EBIPs was explored.

Beliefs about teaching and learning. Some beliefs expressed by participants in the study related to general beliefs about teaching and learning that affect the adoption of EBIPs.

Previous research has shown that faculty may hold beliefs along a facilitator-deliverer continuum, where facilitators tend to be more constructivist and view teaching as facilitating student learning and deliverers tend to be more traditional and view teaching as the delivery of information (Trigwell & Prosser, 2004). We found that our faculty participants often struggled with these beliefs, expressing a mixture of facilitator and deliverer attitudes.

The *facilitator* code was assigned when participants expressed a desire to create classroom environments that facilitate student learning or when they described classroom activities that provide evidence that they view teaching in this way. For example, one participant said, “Students learn best the things that they have some hand in figuring out. So . . . I have gone

Table 1

Themes About Instructional Decision-Making Identified During the Analysis of Interview Data

Metathemes	Themes	Subthemes
Personal factors	Beliefs about teaching and learning	Facilitator Deliverer Caring
	Attitudes about EBIPs	Learn more Engagement Uncomfortable Context
	Self-efficacy	Knowledge and training Professional development Yes, I can Management
Social factors	Colleagues	Collaboration Canon
	Students	Like Prefer lecture
	Administration	Valued Initiatives
	Student evaluations of teaching	Meet the bar Negative Only measure
Contextual factors	Time	In class Out of class Balancing responsibilities
	Resources	Materials
	Student characteristics	College readiness Unprepared for class Heterogeneity

more and more away from 'I am going to lecture you and tell you stuff.'" Another participant described a classroom activity that suggested a facilitator teaching style, saying:

> I can tell them about cholera and then we say okay now you're presented with this problem. Is cholera caused by tainted water or tainted air? Right, everybody thought it was air because it's found in places that are stinky. How would you distinguish between those things? How would you think logically about those? What would the data look like in order for you to assess one vs. the other? And then we say, "Here's an interesting data set that was collected in the 1850s. What does this show you? Does this support one vs. the other?"

All of the participants exhibited some degree of disposition toward facilitation, as manifest in their espoused and enacted beliefs.

The *deliverer* code indicated that the participant viewed teaching as delivering information to students. One participant explained, "I mean, that's the goal of teaching. You take what you know and give that to the people you are teaching, that's the definition of teaching, right?" Others highlighted the efficiency and clarity of lecture, saying, "In some cases, that's the way that knowledge has to be transmitted" and it allows you "to introduce the content so it's clear to the student." For some faculty, lecture is the default, even when they attempt to use a more student-centered strategy. One participant described what happened when students were asked to report to the class on journal articles, saying, "It was really a student lecturing, and then we tagged out and I lectured for the rest of the time." Interestingly, when asked to describe a powerful learning experience from when they were students, many faculty members described a good lecture. One said of their favorite professor in graduate school, "he explained things really well . . . it made sense to listen." Highlighting the sometimes-disconnect between their attitudes and behaviors, one participant acknowledged that they primarily lecture, even when students can't keep up with the deluge of information. They said:

> Philosophically, I would really like all of those problems to be worked live on the chalkboard. And the reason is that it slows me down enough that the students have a hope of keeping up. . . . So I try at least once in a class to actually get down to chalk.

That the deliverer attitude appeared so often, even though most faculty participants viewed themselves as facilitators, is evidence of the persistent struggle to move toward student-centered teaching.

Beliefs about teaching as an important endeavor were coded as *caring*. This code was assigned when participants described their own efforts to be the best teachers they could be, often manifested in spending extra time or effort to get to know students, help struggling students, and make the content relevant. One participant said plainly, "I'd like to improve. . . . I want to be a better educator . . . I'd like to have more skills, and more students that are learning." Another commented that even though their student evaluations have been good, they still saw ways to improve their teaching, saying, "How [do I] not continuously just say, 'OK, I have this class where I want it' and just teach it for the next 30 years but always try to say, 'How can I do this better?' That's motivating for me." Finally, several participants discussed learning students' names and trying to build a safe community in class, where everyone could participate. One participant said, "I think creating those environments of vulnerability, where they're safe and they'll be respected, is really valuable for learning." Another added, "I learn all their names in all the classes that I have so they can feel comfortable talking to me and approaching me." One participant described the ways that they reach out to overwhelmed students, saying they "invite students that [they] see really struggling and say, 'Hey, I can see you're slipping behind here; why don't you come talk to me?' and set up appointments outside office hours." Another participant talked about how they tailor their course to the students' interests. Recognizing that many of their students plan to pursue careers in medicine and dentistry, this instructor said, "Why are they taking the class? . . . Most of them are MCAT and DAT people. . . . So I spend a lot of time finding new materials . . . that are medicinally relevant or even dentistry related." Each of these actions demonstrates the care with which the participants approach teaching and the effort they are willing to make to become better teachers.

Attitudes about EBIPs. Participants also expressed attitudes directly related to EBIPs, based on what they had seen, heard, observed, or experienced.

Faculty participants generally believed students *learn more* (which was one of our codes) or engage in more *complex thinking* (another code) when taught using EBIPs. One participant described a quadrant with engaging vs. boring and active vs. passive learning experiences and said, "Engaging and active is sort of the corner of that matrix that I think most quality learning occurs in." Another participant, who had recently tried encouraging more student-student discussions in class noticed that "once they get to participate, we can see big improvements in learning. . . . When they were reading the material in the textbook, they didn't fully understand until we discussed it in the classroom."

EBIPs are also perceived as useful for improving retention of learning, with one participant saying that when they use EBIPs, they predict that "six months later, [the students] would've retained more of a conceptual understanding of things." Using EBIPs to support deeper student learning can sometimes cause students to feel uncomfortable, leading one participant to say, "I've had a couple student evaluations that were like, 'I had to teach myself everything!' And I thought, 'Good! That's great.' That's what I want." Emphasizing complex thinking over recall, one participant commented that they wanted to "get to the higher-level thinking skills and have time to really see how to develop and apply those problem-solving strategies to interesting problems and not superficial ones." The expression of positive attitudes about EBIPs was most often related to their ability to help students learn more or think more deeply, which suggests that faculty are aware of some of the evidence base that supports their use.

Beyond learning more, faculty perceive EBIPs as encouraging student *engagement*, recognizing that EBIPs help students stay awake, attentive, and entertained in class by providing variety. One participant claimed that "there needs to be an active component. . . . There needs to be something that forces them to engage every five to 10 minutes." They went on to describe one of the major challenges of university teaching as "learning how to manage attention spans, learning how to mix up activities to keep people interested," joking that they're "up tap dancing on the front counter to keep them entertained long enough that they'll go back and actually do the work." Another participant said that using EBIPs was one way that they tried to keep all students engaged in class, saying, "I try to teach from different learning styles and perspectives and do different, really varied kinds of activities." Engaging students was perceived as a major benefit of EBIPs, even when faculty did not see EBIPs as a means to improve student learning.

One concern with the use of EBIPs was that they were perceived as not fitting the personality of the instructor, causing the instructor to lose control of the class or being *uncomfortable* in comparison to lecture. One participant noted that because lecture is the academic tradition of universities, "the lecture is really easy to figure out for professors. I understand the material so I'm going to stand up and expound. . . . We do it a lot because it's so much easier." Another participant explained that lecture is an easy pattern to fall into, saying, "I fall back to what I'm comfortable doing, and we love that control when you know the pace, you know the content. . . . You know how it will be presented, and lecturing is a really good way to do that." Other participants felt that the EBIPs they had tried "didn't work with [their] personality," "screwed up [their] flow," were "scary," or "felt forced and awkward," causing them to avoid using those strategies more often. One participant cited the flipped classroom as an example that wouldn't work for them because they would both lose control of the classroom and feel uncomfortable, saying, "It's a popular thing to do and also chaotic. The chaos is that you might totally miss some students or you might not cover the material you want or you might not feel confident in your teaching." The sense that EBIPs are uncomfortable for the instructor may be a result of limited knowledge of EBIPs or the instructor's lack of awareness of a variety of strategies that are good pedagogically for them.

Many faculty members expressed concern that EBIPs might be appropriate in some situations but not in the *context* of their specific course or STEM content. Some participants reported that for certain material lecturing just made the most sense, saying, "Some days end up a little more back towards the traditional lecture style just because of what the topics are," and "There was some material . . . [that] was difficult enough. . . . I felt like I had to lecture and explain what was going on." Others noted differences between types of classes—general education vs. majors, lower division vs. upper division, and required vs. elective. One participant said they use fewer EBIPs in upper-division courses, noting that "for an upper division class, I spend more time on concepts and less time on examples." Similarly, one faculty member felt that EBIPs weren't appropriate for use in upper-level courses, saying, "I didn't see how a quick two-minute clicker question could necessarily help in an advanced class." Another participant did the opposite, taking advantage of smaller class sizes in more advanced classes, saying, "In my advanced class where I only have six students, I had more than half a mind to put all the chairs at a table and just talk about stuff and totally changed the method for that class."

Faculty also expressed divergent views about when learning happens, indicating that the real learning doesn't happen during the regular class time but rather as students work on problems in recitation and at home. One participant expressed that problem-solving work is "so much more efficiently done in recitation and in homework, so [they prefer to] push that as much as possible to where it is most effective," meaning out of class. These beliefs about EBIPs demonstrate an understanding of the limitations and affordances of the strategies and are highly influenced by the types of EBIPs faculty participants are familiar with.

Self-efficacy. An individual's sense of their own capability to use EBIPs is encompassed by the construct of self-efficacy (Bandura, 2010).

One factor that influenced participants' self-efficacy with the use of EBIPs was *knowledge and training*. Some of the study participants had formal training in education. One earned a master's of education degree and taught high school prior to returning to graduate school and pursuing a career at the university. When describing their confidence with using EBIPs, they said, "I went through an education degree, which helps. . . . I did get some learning there." Two others had participated extensively in training or mentorship related to science pedagogy and active learning. One said of his experience as a graduate student:

> I worked with a program . . . and part of it was developing inquiry-based learning strategies for junior high and high school teachers . . . and it made me think about all the ways we were teaching effectively and how we could potentially improve it.

The other observed his postdoctoral advisor using active learning, commenting that "my advisor there was pretty progressive in her approach to teaching. Nothing was formal; there wasn't any sort of formal training. But I observed her as she tried to do more active learning in her own introductory classes." These examples don't apply to most participants, who received no training in pedagogy. Many described the process of learning to teach at the university as a sort of trial-by-fire experience. They commented, "You're an expert on something, and suddenly it's like, 'We are going to throw you in [to the classroom].'" "You get hired here, and it's like, 'Teach away!'" And "It's pretty much been learning on the job."

Although a few participants had some required teaching training as graduate students, most described it as minimal or insignificant. For example, one participant said:

> During my PhD, I taught one lecture. You taught one lecture, you wrote the test questions, and you met with the professor a few times and kind of walked through it. So, I did that once, and that was my teaching experience before [being hired].

Another described the teaching requirement for their PhD program:

> One of the requirements was to teach a college course and that was called your teaching practicum. But there wasn't training before you did. . . . It was just like, "Okay, go teach this class, and then you're done with your teaching practicum."

Faculty participants also recognized that, in the absence of training, they patterned their teaching on what they had experienced as students. One participant shared that, "as an assistant professor, I just started teaching. And I based most of it off what I'd observed in classes I had taken before." Another said succinctly, "The only way I know how to teach is how I was taught, which a generation ago was pretty much a teacher lecture." Lacking formal training, or minimal training experiences, caused faculty to rely on their experiences as students, which are usually traditional, not evidence based.

Although most faculty had little or no formal training in pedagogy, many of them were familiar with a variety of evidence-based practices, including the use of student response systems, dialoguing strategies, group work, and the flipped classroom. They knew about these strategies because they sought *professional development* for teaching. They described reading journal articles and books about teaching, attending teaching workshops in their college and elsewhere on campus, working with consultants at the Center for Teaching and Learning, and attending new faculty programs at the university or hosted by professional societies. One commented that their "work to become a better teacher has been mostly proactive," while another shared that they "attend [teaching workshops] whenever [they] can" and find them "extremely beneficial."

Faculty participated in these professional development activities because they wanted a sense of accountability and dedicated time for improving their teaching. One commented that they saw participating in STEMFI as an opportunity to refine their teaching because they knew they "would not do it otherwise." Another faculty member described their participation as "a good opportunity to kick myself in the pants and try some new, different things." The participants in our study were proactive in seeking opportunities to think about and improve their teaching.

One reason why participants seek professional development is because they believe they can learn to teach better, a sentiment we coded as *yes*, *I can*. In some sense, this confidence was surprising, because they also expressed a lack of knowledge about EBIPs and pedagogy generally. One participant shared, "I honestly don't know how to improve or where to improve. But I know I can, so that's one of my motivations for doing this workshop." Many participants described a willingness to try new teaching strategies, saying, "I experiment a lot," "Every semester I try something different," and "I have the confidence to try stuff." In describing their process of continual reflection and improvement, one participant said, "I hope I'm open to change . . . willing enough to say this isn't working, and . . . if this isn't working for the students, then I have got to rethink it." Acknowledging their own unfamiliarity with EBIPs and simultaneously expressing their confidence in their ability to use new strategies, one participant said, "I am sure that there are other strategies that I could incorporate that I just haven't ever witnessed. So, I'll see it and say, 'That's a great idea!' and I see how I could totally use that" in class. Participants expressed confidence that yes, they can learn and implement new teaching strategies, and this enthusiasm was not dampened by a lack of training or knowledge.

Participants were also perceptive enough to identify situations where they had attempted, unsuccessfully, to use EBIPs, failing because their *management* was insufficient. One participant said, "Sometimes when I implement it, it just doesn't seem to go well," elaborating, "It's probably honestly I just didn't implement it right, or maybe I misinterpreted how to do . . . it didn't work out really well." Others commented, "I feel like I've still got work to do to get a bit more engagement in class," "It would be great if I could learn how to do it in a way that doesn't cause chaos," and "Sometimes it works really nicely, and sometimes it doesn't."

To clarify that the issue is not with the strategy itself, but rather with the instructor's management of the strategy in class, other participants added, "When they're not successful, it's mostly either lack of planning or lack of a good explanation or 'Oh, I didn't know this thing would happen,'" and "I think it's squarely on me just [not being able to] figure out how to do it." Another participant commented on research they read, saying, "If I interpret one of the studies I read correctly, it works well if the instructor knows what they're doing, but it works really poorly if the instructor doesn't know what they're doing. . . . I think you've got to learn the approaches that work with your skill set and then really understand how to implement them to be successful using active learning strategies in the classroom." Issues with instructor management of EBIPs also centered on ensuring that all students were actively engaged. Participants explained, "It's hard to figure out how to make that work . . . and really get the students to do what you need them to do" and asked "How do you change the power structure so everybody has a more equal voice in these active learning strategies?" Classroom management while using EBIPs was universally challenging for the study participants, who worried that their ineffective management might cause students to disengage in class.

Social Factors

Participants reported expectations about teaching from colleagues, students, and administrators that fall in the social parts of the ecosystem model.

Colleagues. Treating STEM faculty as members of the same species, the population level of the ecological model dictates that collegial interactions among STEM faculty should be highly influential for teaching practice.

One repeated theme in this category related to cultures of *collaboration*, or lack thereof, around teaching within departments. For some faculty, there were opportunities for collaboration with colleagues teaching the same course. One participant remarked that they have "done a fair amount of joint teaching. So, for our honors freshman course, we specifically have our two or three instructors working very closely together. . . . So we're doing a lot of sort of peer-to-peer development." For other faculty members, coteaching was not possible, either because they were the only person teaching a course or because they were excluded from that opportunity. One participant remarked that they have "felt quite lonely as a faculty member here," explaining that they have "seen other faculty members doing coteaching. . . . It sounded like this was a positive, constructive experience, and I've never had the opportunity to do that with anyone." In one of the colleges, peer-teaching evaluations are relatively common. One participant shared that the peer would "come to your class for two lectures and you'll come to mine and we'll go to lunch and talk about" the teaching to learn from each other. For others, these collaborations were limited in scope to deciding on learning objectives or content goals, rather than sharing teaching methods. One participant said, "We're in a sense almost synced, what we teach." Another commented that their department has "come up with learning outcomes together."

Many participants expressed that one of the reasons they wanted to participate in STEMFI was the opportunity to collaborate, indicating a lack of collaboration within their departments. One expressed that nobody in their department talked about teaching, and "with colleagues, it's 'your class is your class' and you do your stuff." One participant, who sought feedback on using EBIPs from colleagues, was strongly discouraged from trying anything new, with colleagues who said, "That's really dumb," and "No, that's not even possible." Collaboration around teaching creates cultural norms that can encourage the use of EBIPs, while a lack of collaboration can be isolating and discourage the use of EBIPs. One participant, who was farther along in the EBIP adoption process, felt that there was nobody in their department from whom to learn. They were the most advanced teacher, so they felt isolated. Many participants expressed that part of their desire to participate in the STEMFI program was to meet other faculty who were interested in teaching so they could learn from each other.

Despite minimal expectations from colleagues about how to teach, there were strong expectations about what to teach, which included the *canon* of the discipline. Some departments have established curriculum committees that delineate specific learning outcomes for each course. One participant remarked that "because the learning outcomes were set up by a committee in the department, you don't feel like you can really vary all that much."

These expectations were more pronounced for courses intended for students majoring in the discipline, for courses that serve as prerequisites for later courses, and when the course content is perceived as required by disciplinary accreditation organizations or for graduate entrance exams. One participant explained:

> We are kind of restricted by the [professional association accreditation requirements] and the [graduate entrance exam] content. We've got to go through enough topics. And then there's the issue if it's [the first semester in a two-semester sequence], you've got to finish a certain chapter before you pass the kids off to [the second semester course]. So, we try to keep them on schedule there.

A sense of the established canon in the field can also be influenced by commonly used textbooks. One participant described feeling constrained by the content requirements in this way: "If you look at most biology textbooks, they sort of start at biochemistry and they end at ecosystems and there's 37 chapters and it's like, Oh, there's about 37 lectures, and that's about a chapter a day, and it sort of forces you into a structure." Another participant felt pressured to use a textbook commonly used elsewhere as a way of ensuring that graduates from the program here would be competitive with graduates from other universities. They said, "I try and stay . . . close to the textbook. . . . I know that most other programs in the country use this textbook, and so it's got a lot of the definitions that they need to know. I stay close to it." Faculty participants feel a sense of responsibility to their community of colleagues and to the students to ensure that courses teach all aspects of accepted knowledge in the field.

Students. Participants experienced mixed subjective norms from students, who sometimes enjoy EBIPs and sometimes prefer lecture.

There is the general perception by faculty that students *like* EBIPs. Whether students enjoy an experience can be an important measure of success for faculty. When describing their past experiences using EBIPs, they said, "The students generally liked it a lot," "The students seem to enjoy it," and "I've gotten a lot of good feedback on it." There is some indication that student enjoyment goes beyond having fun to feeling that EBIPs are more effective for their learning. One participant was unsure how their class felt about explaining concepts to partners but got positive feedback from the students. "I would ask them a couple of times, is this helpful? They would all say yes." Another participant described a student who learned more after working through a group problem-solving activity:

> I have one of those students who is not always super engaged in class. This student was like, "That was super helpful! That made so much more sense! Because at the end of the class, it was like, just multiply everything together and add them up! And now I get why we're multiplying and adding." And I was like, "Yay! You just made my day!" So anyway, I guess that was a moment where I felt like, "Oh, good, success! You did something good."

Faculty participants felt that students like EBIPs that are engaging and help them learn more.

This student expectation for EBIPs was not universal. Some faculty perceive students as *preferring lecture*, because they are accustomed to it or it requires less effort. Students are taught the norms of college life early on, so it can be challenging to teach advanced students using EBIPs. One participant said, "They're seniors by the time we get them, and so they've already had a lot of exposure to college classes and they have expectations for what it's going to be like, and so when you vary from those expectations, I think they go, 'Hey, wait, I'm really good at this other way. Why aren't we still doing this other way?'" Another participant explained, “They want the passive experience. I, as the authority figure, tell them what they need to know for the test. They parrot back what I told them they needed to know for the test, and I put a gold star on their forehead.” When faculty perceive that students want traditional lecture instruction, it can be challenging for them to go against student expectations and use EBIPs.

Administration. The expectations of university administrators can influence the instructional decisions of STEM faculty.

Most faculty participants agreed that *teaching is valued* at the university. They said the university is “generally so supportive of teaching,” that their departments put “a decent amount of emphasis on being good teachers,” and that “teaching is highly, highly valued.” One participant commented that during the new faculty seminar series, which is required for all new faculty, “they talked a lot about teaching.” Another, when asked about how their department chair would respond if they changed their teaching by incorporating more student-centered activities, said, “I think it would be positively viewed.” That teaching is perceived as valued is not surprising given the institution’s emphasis on undergraduate education as its primary mission.

The importance of good teaching is also communicated to faculty via *initiatives*, led by departments, colleges, and the university, that support and invest in teaching. This emphasis on good teaching was communicated primarily by faculty from one college. They noted “regular teaching seminars, almost on a monthly basis.” One further described this initiative from the department and the college. “Our department spends a lot of time talking about [teaching] in faculty meetings. We talk about it in our college a lot, and we have teaching-learning seminars where we discuss techniques and strategies that work.” Faculty outside of that college rarely commented on teaching initiatives, but when they did, they spoke of STEMFI as a campus-wide program for improving teaching and referenced a speech at university conference about expecting more out of our students. The presence of administration-supported initiatives to improve teaching can encourage collaboration, sharing of ideas, and support faculty use of EBIPs.

Student evaluations of teaching. Student evaluations of teaching, or SET, were a unique aspect of the faculty experience and manifested in a variety of ways depending on who faculty interacted with.

Most faculty participants acknowledged that colleagues expected them to be good teachers, as measured by the code *meeting the bar* on student evaluations of teaching. If their student evaluation scores were high enough, colleagues wouldn't have anything else to say about their teaching. One participant remarked that "departmental teaching expectations [are to] get good ratings! . . . When it's all said and done, that's how you get measured." Another participant, who teaches using a hybrid in-person/online format, commented that they had "concluded that [their] student evaluations are there within a range that's accepted, so there is nothing [that colleagues] can say" to discredit their alternative teaching format. A third said, "The main thing that we get as far as faculty discussions is just to make sure GPAs are in a certain range and that you get good student ratings. I mean, that's kind of it; there's not a lot of other discussion about it." Collegial expectations about teaching suggest a minimum standard of acceptable SET scores, often with no consideration of teaching methods or evidence-based practice.

Worries about SET can be a significant disincentive to faculty deciding to use or continue using EBIPs. Several participants described the *negative* impacts to SET when they changed their teaching methods. One, who used a just-in-time teaching approach that was responsive to student questions submitted prior to class, observed, “My student ratings actually went down that semester. . . . Students commented on disorganization.” Another, who attempted to flip the class, said, “My student ratings were really bad that year. . . . part of my apprehension [going into STEMFI] is . . . that backfired. So, I can’t necessarily get those kinds of student ratings again.” In addition to having experienced lower student ratings in response to an EBIP implementation, some participants preemptively assumed that their SET scores would go down, even though they hadn’t yet made instructional changes. “Every time you try to slip in something that’s really different, your ratings are probably going to take a little bit of a dive. It’s unfortunate that that’s the case, . . . but I think we’re always thinking about these things.” SET are one of the primary ways that students communicate to faculty what their expectations are for the course and can be negatively affected when students don’t understand EBIPs or if faculty implement EBIPs imperfectly.

An additional impact of SET was in relation to the rank-and-status requirements, especially that student ratings are essentially the *only measure* of teaching quality even though they are ineffective for that purpose (Boring, Ottoboni, & Stark, 2016). Put simply, one assistant professor commented that they need to “get [their] scores up for when [they] go up for tenure.” Describing the outsized role of student ratings in rank-and-status decisions, another participant said, “I’ve got to have good ratings because if I don’t get good ratings, then I may not keep my job or not get my promotion.” Some participants expressed frustration at the system, saying:

> I can’t stand student ratings. . . . Those surveys don’t judge learning, in my opinion. They judge how much they [i.e., students] like the class, how much they like the

> professor. . . . That's the thing about student ratings—like it or not, it's one of the few metrics we have.

One participant acknowledged that peer reviews of teaching do occur but felt that they were not systematic and not taken seriously.

> I mean, we'll have faculty go in and do peer reviews. There's no real process for that, so most of the faculty are like, "What am I doing? What do you want me to review?" And it's been a lot of just go in and see how they're doing and write some stuff down and tell us what you think. So, it's really very loose.

The metrics used by administration to measure teaching quality show faculty what is important.

Contextual Factors

STEMFI participants identified several contextual factors that influenced their decisions about whether or when to use these strategies.

Time. Time is a precious commodity, both for the faculty member balancing responsibilities outside of class and the instructional time in class.

A primary concern for participants was the issue of *time in class*. One participant stated simply, "We have this limitation. We have 150 minutes a week." Another participant, when asked about constraints that limit their use of EBIPs, said, "The biggest one I'd say is Do I have enough time to cover the material that I feel is essential?" They elaborated:

> Because I've got this set of things that I think are critical for all my students to know. And for me to have more active learning, I feel like I have to shave off. . . . What fraction am I going to have to shave off so I have this chunk of time in class to be able to do active learning?

Other participants who had attempted to use a variety of EBIPs commented on how time intensive they were. One said, “Well, we would have gotten through one tenth of the lecture, so I can’t do that. I can’t afford to spend that much time on a good activity if it’s only a small piece of what we need to do.” Another commented that they consistently underestimate the amount of class time needed for student-centered activities, saying, “I always think they’re going to take 15 minutes; they take 30.” This time pressure is largely centered around ideas about content coverage. Faculty participants shared, “We’ve got to plow through a certain amount of material. . . . Here’s all our reactions we’re going to cover, and that’s it,” “You feel constrained by a big list of things we have to do,” and “It’s hard to increase this interactive part while still covering all the material.”

Even when faculty recognized that delivering more content was not effective, they still felt pressure to cover all the material. One participant said, “I think for me the balance of helping students learn and then just trying to give them more and more and more . . . and it’s easy to want to give them more and more and more, and they’re not learning.” Surprisingly, two participants chose, after teaching a course, to remove content to improve learning. One shared, “When I teach a class for five years, every year it gets a little easier, and every year I spend a little more time discussing topics, and every year I take a little bit of stuff out.” The other explained, “I got rid of some material, not because it was bad material but because I was spending too much time on it and rushing other things.” While some faculty found ways to reduce course content, the need to cover material and the limited amount of time in class were significant hurdles for most faculty participants using EBIPs.

In addition to the constraints posed by limited amounts of time in class, faculty frequently noted that *time out of class* to find, create, or refine class materials or respond to student work was a challenge to teaching innovation and the use of EBIPs. This concern was a universal challenge for faculty. Describing past efforts to implement EBIPs, they shared, "I haven't had the time to integrate all these things," "It took a lot of time and effort," and "It's a ton of work to set that up."

The finite number of hours in the day combined with *balancing responsibilities* of teaching, research, and citizenship meant faculty had to prioritize, sometimes choosing other activities over teaching. One participant asked:

> How much time can I put into this? I teach two classes a semester typically, I have administrative obligations, and I have a really ambitious research agenda. [Our institution] kind of straddles this fence of trying to be a really good teacher and a really good researcher, and sometimes it's hard to do both really well, so there are all these trade-offs.

Time outside of class to prepare class activities and assessments and give feedback to students, while managing a variety of other responsibilities, was a significant barrier to the adoption and use of EBIPs.

Resources. For participants who were just beginning to experiment with EBIPs, the most common concern was the lack of available, high-quality *materials* appropriate for their courses. One participant commented that they needed "time to develop the material. To come up with good activities that are not going to be busy work, that are going to be possible and doable, and you know will engage the student and help them understand." Sometimes, participants were able to find appropriate resources for their courses, but often they felt they had to create the materials themselves, which required a significant investment of preparation time.

For faculty further along in the adoption and use of EBIPs, a common concern was the lack of available assessment materials that aligned with the new classroom activities they were doing, including the perception that any assessment of learning by EBIPs would take longer to grade. One participant shared, "Ideally, we do these activities and they write about them. But then I have to grade that. . . . I don't have time to grade all that stuff!" Another participant explained the challenge of "trying to find that balance of meaningful assessment but not overwhelming in how much time it takes me to work through it."

Student characteristics. Student characteristics, including college readiness, preparation for class, and heterogeneity, influence the instructional decisions of STEM faculty.

Some study participants felt that students are generally not *college ready*, or mature enough for college-level work, and that their lack of maturity can make it challenging to use EBIPs. They commented, "The students are coming in more and more afraid of failure," "At some point, [they] have to transition to a self-motivated learning style," and "I don't know how to get them to class without being like their dad. In college, you should be able to handle your life without someone telling you how to do it."

Faculty also found it challenging to use EBIPs when students came *unprepared for class*, having not completed reading or other preparatory assignments or having done those assignments perfunctorily. One participant described a particularly challenging group of students as follows: "I would ask questions and they would just sit there, and they didn't read or prepare. I would ask, 'Is this read?' Or I would ask a few questions, and there would just be blank looks." When this instructor moved to a just-in-time teaching model, asking students to submit questions about the readings before class to encourage better preparation, students performed poorly. They said, “If you require the students to submit a question, you typically get someone who just kind of dashes off something to fulfill the assignment. They don’t care.”

Finally, instructors across all three colleges struggle to adapt to *heterogeneity* within student populations—with a variety of academic backgrounds and no consensus on prerequisites for their courses. One participant described the situation in a programming-intensive course:

> We have a pretty wide range of student abilities coming into the course. Some have never seen programming at all, and they’re clueless. Whatever speed I go is going to be too fast. Other students have seen this before, and they’re not necessarily engaged.

Another instructor spoke of the varied interests of their students, who come from a variety of majors, saying, “You have 50 completely different individuals, and sometimes there are things that they might share, but there are also lots of things that they do differently and think differently.” Unpreparedness, immaturity, and heterogeneity in the student population can make it challenging to target classroom activities at the right level so that all students are engaged.

Discussion

As we sought to understand participants’ experiences, we found that an ecological model can be a useful conceptual framework for understanding the complexity of STEM faculty instructional decisions about EBIPs. This framework allowed us to understand individuals’ personal, social, and contextual factors and thus target interventions to their specific needs. It also helped to expose the complex interactions and feedback loops that influence faculty practice. Together, we can use this information to identify appropriate supports that will encourage the adoption and use of EBIPs.

Importance of Individual Contexts

While we know that social factors can vary dramatically between departments (Lund & Stains, 2015; Shadle et al., 2017), this study exposed the fact that social factors also vary dramatically among individual faculty members within the same department. Six of the participants in this study came in pairs from three departments. In all three cases, they described very different social contexts, even though they came from the same department. In Department A, two faculty participants both taught the same course. One participant described their isolation from colleagues, having never had an opportunity to coteach. The other participant described sitting in on a colleague's class and the colleague sharing all their instructional materials. In Department B, a similar situation occurred, where one participant had worked with colleagues over several years to develop the curriculum for the freshman course for majors. The other participant said that in their area each faculty member decides what they want to do individually, and they don't even agree on what content to teach. A third pair, from Department C, teach the same course, but one does it in relative isolation while the other regularly collaborates with a colleague to develop learning activities.

Based on these examples, it would be inappropriate to assume that all members of a department or even those faculty who teach the same course experience similar social contexts. In addition to the unique personal contexts that individuals bring to the table, including their attitudes, experiences, and self-efficacy, we should also consider the unique social contexts that influence their decision-making about EBIPs.

Importance of Positive Feedback

Attitudes toward EBIPs change over time and are influenced by the experiences STEM faculty have while teaching and the feedback they receive from students and colleagues. When faculty are isolated or lack social supports that encourage the use of EBIPs, they base their decisions solely on the feedback they get from students.

In one situation, a faculty member had grown exasperated at their students' lack of preparation for class. They decided to use a guided worksheet and make students work in groups, not because they thought it would be more effective but as a punishment for coming unprepared to class:

> I would ask a few questions, and there would just be blank looks, and I just kind of got frustrated with them. I'm like, "OK, I'm just going to make you do worksheets in class if you're not going to prepare." . . . So I made a lot of my own little one-, two-sheet tutorial things where I . . . would force them to graph it . . . and explain it in a qualitative [way and] process that information. And I thought it worked really well. The people who would sit there on their phones suddenly had to talk to their neighbor. They had to pay attention, they had to interact, they had to think about the material, and the class enjoyed it too.

The positive response from students, coupled with the participant's sense that students were learning more, changed their attitudes about EBIPs. Rather than viewing EBIPs as a punishment, they came to view EBIPs as a useful learning tool.

This example is a bit of an exception more than a rule. Every participant described at least one situation where they attempted to use an EBIP and failed to facilitate it in the most effective way. These situations were often met with negative feedback from students, which discouraged faculty from trying new strategies or continuing to use the same ones. A more typical comment was

> I can totally envision a scenario where I . . . try and incorporate [EBIPs] this first semester, and I perceive from the students, like, “Meh.” If they’re not loving it or totally engaged in it, then am I really going to try and continue? How many semesters am I going to keep on trying this until I say, “I don’t know if this is working out that well.”

In this instance, the faculty member potentially decides to discontinue the use of EBIPs in the face of negative feedback from students and the absence of any feedback from colleagues.

One participant was discouraged after using EBIPs throughout their course and seeing student evaluation scores go down. Fortunately, they had a contact at the Center for Teaching and Learning and they reached out to get advice. The consultant was able to offer enough encouragement to convince the participant to persist:

> I met with [the consultant from the CTL] and I was like, “I don’t know what I should do with this because [my student evaluations] went down.” . . . And he said that often happens and then they start to come back up, and . . . you work through these things, and they’ll come back up. So I was like, “Alright! I’m going to do it!”

Imagine that this participant had experienced the same phenomenon in isolation. They likely would not have continued using EBIPs. Faculty will receive feedback from students, but the difference between persistence and resignation may be whether they also receive feedback from supportive colleagues.

Importance of Administrative Support

Consistent with the two-pronged approach of bottom-up and top-down efforts (Austin, 2011), we should not neglect the importance of structural changes at the university that can support high-quality teaching. For example, at our institution, SET are the primary measure of teaching quality, even though we know they don’t really measure teaching quality (Stark &

Freishtat, 2014). This can create a system of double jeopardy, where a faculty member might put effort into improving their teaching, taking time away from research, and be punished with lower student evaluation scores. Thus, their sincere efforts to improve harm them on both the research and teaching fronts. One participant described it this way:

> Because we are evaluated for rank and status using [student evaluations], that is a risk I take. By trying to change my teaching, it may not go super well, and then I may have this dip in my [student evaluations] for a semester, maybe two. . . . It's a buy-in of my time, and then I don't know what the reward is.

The outsized impact of student evaluations on the rank-and-status process can be buffered by institutional policies that encourage multiple measures of teaching quality and support experimentation and continuous reflection on teaching.

Conclusion

In this paper, we report our findings from semistructured interviews with 15 STEM faculty members who volunteered to participate in a professional development program supporting evidence-based instructional practices. We found that personal, social, and contextual factors all influenced faculty decision-making for what teaching methods to utilize. Personal factors included beliefs about teaching and learning, attitudes about EBIPs, and self-efficacy with the use of EBIPs. Social factors included expectations from colleagues, students, and administrators, which manifested in the complex ways faculty participants viewed student evaluations of teaching. Contextual factors included time, resources, and student characteristics.

These factors interact in multifaceted ways, and STEM faculty make instructional decisions, including whether to use EBIPs, in complex environments that encompass personal, social, and contextual factors. An ecological model for STEM faculty decision-making can help frame thinking about the factors that are most relevant to an individual faculty member's instructional decisions, allowing targeted interventions that provide individualized support. As there is so much variation among faculty members, even within the same department, this individualized approach is a necessary consideration for any systemic change efforts. Areas of focus for change efforts should also include providing supportive, collegial environments that will provide positive feedback and encouragement, even (and especially) when students don't provide that feedback. Institutional policies that minimize the risk of trying new teaching strategies by identifying multiple measures of teaching quality can also be supportive of faculty adoption of EBIPs.

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ARTICLE 3

Linking Theory and Action: Predicting Teaching Behaviors Based on an Ecological Model of STEM Faculty Instructional Decision-Making

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Introduction

To ensure that workforce needs for scientists and engineers are met, undergraduate science, technology, engineering, and mathematics (STEM) education must be improved (President's Council of Advisors on Science and Technology, 2012). Currently, up to two thirds of students who begin college intending to major in STEM fields either switch to other majors or exit college without a degree (Chen, 2013). The landmark *Talking About Leaving* study involved (Seymour & Hewitt, 1997) interviewing hundreds of students who left STEM majors and found that poor quality teaching in their STEM courses was a major reason for attrition. A more recent follow-up study confirmed that poor classroom experiences continue to be a driving force for attrition (Hunter, Thiry, Holland, Harper, & Seymour, n.d.). This is despite the fact that discipline-based educational research has helped us understand effective teaching strategies for undergraduate STEM courses (National Research Council, 2012). A recent meta-analysis by Freeman et al. (2014) found that studies have repeatedly and consistently shown that evidence-based instructional practices (EBIPs) have improved learning outcomes and persistence rates for STEM students in introductory courses. Even though the evidence base for EBIPs has continued to grow, faculty adoption of EBIPs has been slow. A recent large-scale observational study of more than 2,000 STEM classes taught by more than 500 faculty across 25 institutions in the United States found that for students 87% of class time is spent listening (Stains et al., 2018).

To reverse this trend, a variety of faculty development programs have attempted to support STEM faculty adoption of EBIPs, with varying degrees of success (Baker et al., 2014; Henderson, 2008; Pfund et al., 2009). Unfortunately, even though summer workshops for biology faculty sponsored by the Howard Hughes Medical Institute resulted in high rates of self-reported adoption of EBIPs (Pfund et al., 2009), they did not result in high rates of changed classroom practice based on observations (Ebert-May et al., 2011). In order to more effectively promote faculty change in the future, there are three fundamental questions we must answer: *What* are faculty members doing? *Why* are they doing it? And *how* can we help them change?

At this point, there has been considerable work related to the first question by characterizing STEM teaching practices. Several studies have used variations of Rogers' diffusion of innovation theory to characterize the degree to which faculty have adopted EBIPs (e.g., Henderson, 2005). Survey instruments have been created to measure self-reported instructional practices (Walter, Henderson, Beach, & Williams, 2016). Others have developed observation tools such as the Reformed Teaching Observation Protocol (RTOP) and the Classroom Observation Protocol for Undergraduate STEM (COPUS) that facilitate this characterization (Sawada et al., 2002; Smith, Jones, Gilbert, & Wieman, 2013). These surveys and observational tools have been used in cluster analysis to characterize instructor styles, such as didactic, interactive, and group work (Gibbons, Villafañe, Stains, Murphy, & Raker, 2017; Stains et al., 2018). Together, this work has helped us understand *what* STEM faculty do in their classrooms.

However, we still lack understanding of *why* STEM faculty make these instructional decisions. And until we understand why STEM faculty make instructional decisions, we are unlikely to make progress on *how* to support meaningful change. We have previously reported on qualitative work to understand STEM faculty instructional decisions about EBIPs (Sansom, 2019), which resulted in an ecological model of STEM faculty instructional decision-making. This model frames STEM faculty as complex individuals with their own experiences, attitudes, and beliefs. These personal factors interact with the social factors created by disciplinary and university colleagues, students, and administrators. Additionally, there are a variety of contextual factors, including time, resources, and student characteristics, which influence instructional decisions (Sansom, 2019).

Literature Review

To address our question about the relationship between an ecological model of STEM faculty instructional decision-making and teaching practice, we will review what we know from past research on faculty teaching practices and the links between personal, social, and contextual factors and teaching practices, concluding with a brief review of the conceptual model that frames this study.

Characterizing Teaching Practices

Over the last two decades, considerable effort has gone into developing tools to measure teaching quality for evidence-based, or reformed, teaching. Two instruments that have come to be used extensively for undergraduate STEM courses because of their high interrater reliability and ease of use are RTOP and COPUS. The RTOP (Sawada et al., 2002) measures reformed, student-centered teaching holistically across three scales: lesson design and implementation, content, and classroom culture. RTOP scores for teachers and faculty were correlated with improved student learning across disciplines in science and mathematics and across grade levels from elementary through college (Sawada et al., 2002). COPUS observers code both faculty and student behaviors at two-minute intervals throughout a lesson. There are 25 unique codes for faculty and student behaviors that span traditional activities, such as lecturing and writing on the board, to more student-centered and evidence-based activities, such as moving through the class, guiding ongoing student work, and asking clicker questions (Smith et al., 2013). Reports from this instrument characterize both faculty and student activities as either teacher centered or student centered. Further research in this area has resulted in the definition of instructional styles like lecture, Socratic, peer instruction, and collaborative learning (Lund & Stains, 2015) based on the combination of COPUS and RTOP data. These instruments allow us to characterize and understand teaching behaviors in undergraduate STEM classrooms.

In addition to observation protocols, survey instruments have been developed that allow faculty to self-report EBIP usage or students to report on the activities they do in class. The Teaching Practices Inventory (TPI) was developed as a measure of the teaching strategies that instructors use in science and math courses (Wieman & Gilbert, 2014). The TPI measures eight dimensions of teacher practice, five of which concern in-class activities and three of which address continuous improvement and faculty reflection. Although the TPI does not focus on the use of EBIPs, elements of the survey do inquire about those classroom practices. The Postsecondary Instructional Practices Survey (PIPS) is a self-report instructor survey that measures instructor-student, student-content, and student-student interactions, as well as formative and summative assessment practices, and is focused on the adoption and use of EBIPs (Walter et al., 2016). The Measurement Instrument for Scientific Teaching (MIST) is a student survey that measures student perceptions of their instruction, including the instructor's use of active-learning strategies, learning objectives and feedback, inclusivity, and responsiveness. Students also score the degree to which they engage in science practices such as experimental design, data analysis, and advanced cognitive skills (Durham, Knight, & Couch, 2017). These survey instruments allow researchers to more easily assess the instructional practices utilized by STEM faculty.

Knowing what instructional strategies STEM faculty use also allows researchers to characterize the degree to which faculty have adopted EBIPs. A version of diffusion of innovations (Rogers, 1995) has been extensively utilized to understand the process of faculty change. Using this theory, faculty can be categorized based on the degree to which they have adopted EBIPs. Acknowledging prior conditions, the first stage of adoption is knowledge of the innovation, then persuasion, leading to a decision to adopt the practice. This is followed by implementation and a reflective confirmation that the adopted practice worked as expected. This process can be leaky, meaning that faculty may have knowledge but not be persuaded to adopt an EBIP or they may adopt an EBIP but later discontinue use (Henderson, 2005). Many researchers studying STEM faculty change have utilized this framework (e.g., Andrews & Lemons, 2015; Bunce, Havanki, & VandenPlas, 2008; Marbach-Ad & Rietschel, 2016) to classify instructors according to their instructional practices.

These efforts to both understand and characterize *what* STEM faculty do, based on innovation and change models and through observation protocols have increased our understanding of STEM faculty teaching practices and the stages faculty move through as their practice changes. However, these models fail to fully describe why faculty have these practices.

Evidence for Links Between Attitudes and Teaching Behaviors

Understanding *why* STEM faculty make these instructional choices has been more challenging. Pundak, Herscovitz, Shacham, and Wiser-Biton (2009) identified instructors who were in the process of adopting active learning and interviewed them repeatedly over a five-year change process. They used these interviews to create a questionnaire that assessed faculty attitudes across six domains: (a) activation of large classes, (b) student involvement, (c) independent learning, (d) development of knowledge, (e) quantity vs. understanding, and (f) function of the instructor. Comparing the responses of the active-learning adopters and traditional faculty, they found that active instructors had significantly different attitudes from traditional instructors across all six domains.

Similarly, Gibbons et al. (2017) investigated the connection between beliefs about learning and enacted instructional practices among chemistry faculty. Their work was based on the teacher-centered systemic reform model first proposed by Gess-Newsome, Southerland, Johnston, and Woodbury (2003). Gibbons et al. (2017) created a survey to measure beliefs about teaching and learning and self-efficacy with pedagogy and content, along with a self-reported measure of adopted instructional strategies. They showed small- to medium-effect sizes when comparing attitudes across instructional styles. Their results demonstrate a link between attitudes and practices. However, this study examined only two affective ideas: self-efficacy and placement along a teacher-centered to student-centered continuum. Further research should also investigate sociocultural issues and contextual factors.

Evidence for Links Between Social Factors, External Factors, and Teaching Behaviors

Separately, other studies have investigated the social factors that prevent STEM faculty from adopting EBIPs. These social factors may include influences from the students they teach, the peers they interact with, or the administrators they seek to please within their colleges and universities. Students may expect STEM faculty to teach traditionally because of their own experiences or ideas perpetuated in the media (Dancy & Henderson, 2008; Michael, 2007; Shadle, Marker, & Earl, 2017). Furthermore, students may express their displeasure with instructors who use EBIPs through student evaluations of teaching, which influence rank and status decisions at the university (Michael, 2007; Shadle et al., 2017; Walczyk, Ramsey, & Zha, 2007). These social influences extend to peer interactions with colleagues, which can support or hinder the adoption of EBIPs (Michael, 2007; Sunal et al., 2001). Pressure from administrators to improve teaching or, conversely, to focus on research can also influence STEM faculty members' instructional decisions (Michael, 2007; Shadle et al., 2017; Sunal et al., 2001;

Walczyk et al., 2007). Each of these studies gathered data about STEM faculty members' perceived barriers to the adoption of EBIPs but did not investigate the relationship between these perceptions and faculty teaching behaviors. So although STEM faculty indicate that social norms affect their behavior, there has not yet been empirical evidence to support their claims.

In addition to social factors, many studies have identified external or contextual factors that STEM faculty perceive as barriers to adoption of EBIPs. One significant barrier is the lack of time to create or plan lessons designed using EBIPs (Dancy & Henderson, 2008; Michael, 2007; Shadle et al., 2017). Another challenge is the limited amount of class time to cover the required course content, which may be determined by accreditation or professional organizations or be related to graduate entrance exams (Dancy & Henderson, 2008; Michael, 2007; Shadle et al., 2017). Student characteristics have also been perceived as challenging to faculty who want to adopt EBIPs. Heterogeneity of preparation, poor preparation for college, and poor preparation for a particular lesson have all been cited as difficulties to be overcome (Dancy & Henderson, 2008; Henderson & Dancy, 2008; Michael, 2007; Shadle et al., 2017). The availability of resources, such as lesson plans designed for a particular STEM course, funding for additional TA support, and flexible classroom spaces, can also be problematic (Dancy & Henderson, 2008; Henderson & Dancy, 2008; Michael, 2007; Shadle et al., 2017; Walczyk et al., 2007). Although each of these studies identified external factors that acted as barriers to change, they did not investigate the relationship between STEM faculty perceptions of these barriers and their enacted teaching practices.

An Ecological Model of STEM Faculty Instructional Decision-Making

In our previous work (Sansom, 2019), we described an ecological model for STEM faculty instructional decision-making, which frames instructional decisions as taking place within a complex material and social environment and influenced by personal or individual characteristics. Although ecological models have been used in a variety of public health situations (Sallis & Owen, 2015), to our knowledge they have not yet been applied in the context of STEM faculty instructional decision-making. However, similar theories from the public health literature, such as the theory of planned behavior (Ajzen, 1991), have been used in this arena.

As an example, Bunce et al. (2008) performed an evaluation of workshops for the process-oriented guided inquiry learning (POGIL) project. In this evaluation, instructors were classified according to the degree to which they had adopted the reformed pedagogy advocated for by the POGIL project using Rogers's theory of diffusion of innovations using a self-reported measure. Additionally, the theory of planned behavior (TPB) was used to analyze individual's attitudes (personal factors), subjective norms (social factors), and perceived behavioral control (self-efficacy and contextual factors) with regard to adopting POGIL strategies. They found that instructors who were farther along in the process of adopting POGIL teaching strategies tended to have more positive attitudes toward student-centered teaching (personal factors) and more support from peers (social factors). While they acknowledged many of the same contextual factors affecting their perceived behavioral control, the advanced adopters chose to focus on those contextual factors that were within their control. This study provides evidence that personal, social, and contextual factors can be related to teacher behaviors. However, this study used self-reported teaching behaviors rather than observed teaching behaviors, and self-reported teaching behaviors for faculty who participate in teaching professional development have been shown to be unreliable measures of their actual teaching practices (Dancy, Henderson, & Turpen, 2016; Ebert-May et al., 2011; Pfund et al., 2009).

To date, the scholarly literature provides insight into what STEM faculty are doing in the classroom and which teaching practices work best. We also understand the general process for faculty change toward more innovative teaching and how to measure transitions along that continuum using observation protocols. However, what is lacking is a more rigorous understanding of how various internal and external factors influence the faculty change process. In short, we need to know *why* faculty change.

Based on our previous work, we hypothesize that the constructs of personal, social, and contextual factors, as described by an ecological model for STEM faculty instructional decision-making (Sansom, 2019), will explain some of the variation in observed teaching practices. According to this model, individual STEM faculty members have relevant personal characteristics that depend on their life experiences. These include beliefs about teaching and learning, attitudes about EBIPs, and self-efficacy with the use of EBIPs. Faculty are situated socially within the population of other STEM faculty, both at their university and within professional organizations. These colleagues influence perceptions of the required body of knowledge that should be taught in a course, and interactions with colleagues can provide opportunities for teaching collaboration or result in relative isolation. Students and administrators make up the community of stakeholders who also influence faculty teaching behaviors by communicating their like or dislike of EBIPs (students) and their support for high quality teaching (administrators). Student Evaluations of Teaching (SET) are a unique aspect of the population and community interactions and can manifest as a social influence by colleagues, students, and administrators. The ecosystem also includes contextual factors such as time (both in and out of class), resources, and student characteristics. Together, these personal, social, and contextual factors create a complex ecosystem with multiple types of interactions and feedback loops that influence STEM faculty members' instructional decisions.

More research is needed to explore the potential of an ecological model for STEM faculty instructional decision-making to explain why faculty make the teaching decisions they do. To that end, our research question is To what degree do personal, social, and contextual factors predict teaching behaviors measured by COPUS?

Method

For this study, we rated each participant using interview data to measure the components of an ecological model for STEM faculty instructional decision-making and COPUS data to measure classroom practices. If the personal, social, and contextual factors described by the ecological model were indeed explanatory, we expected that variation in those factors would explain variation in classroom practices as analyzed by multiple linear regression. We attempted to link the personal, social, and contextual factors to teaching behaviors and to better understand the relationship between affect and action.

This study uses a convergent mixed methods design (Creswell & Plano-Clark, 2017), where qualitative data from interviews and quantitative data from classroom observations are combined to form a more complete understanding of STEM faculty instructional decision-making. This allows us to explore potential links between personal, social, and contextual factors and the observed behaviors of STEM faculty.

Limitations

We are limited in the conclusions that we can draw because we only had 30 participants, so we did not have sufficient data to perform confirmatory factor analysis on the latent variable scores. Additionally, there was considerable missingness in the data because the rubric codes were based on interviews and not all participants discussed all 21 rubric topics in their interviews. For personal factors, the average missingness was about 14%. For social factors, the average missingness was about 32%. And for contextual factors, the average missingness was about 23%. Because we calculated an average score for each individual for each category, we were able to calculate a score for all participants. But when a participant did not discuss several aspects of one factor, their score is a less complete summary of their experience. This was particularly problematic for social factors, which we attribute to participants' general inability to articulate the nature of their social experiences about teaching. Individual missingness ranged from 0% to 52%, with an average of 21% (about four of the 21 rubric codes).

Despite these limitations, this study is intended to serve as an exploration of how an ecological model of STEM faculty instructional decision-making may explain some variance in faculty behavior and indicate whether it would be reasonable to invest in the full-scale development of a survey instrument.

Participants

Participants for this study are drawn from STEM faculty who have participated in the STEM Faculty Institute (STEMFI) professional development program. This program was a grant-funded professional development series at our university, where faculty attended a weeklong training on evidence-based instructional practices (EBIPs). They were then paired with a mentor who embodied these teaching strategies and ideals and worked with the mentor to identify aspects of their course that could be revised. Participants implemented these changes in the following semester and received ongoing support through mentoring and cohort meetings. These faculty were all full-time, tenure-track faculty, and represented the three STEM colleges on campus: physical and mathematical sciences, life sciences, and engineering. They ranged from assistant to full professors, and all taught undergraduate courses. Fifteen participants were included in each cohort, and this article includes data from the first two cohorts, for a total of 30 participants. Each individual volunteered to participate in the STEMFI program and was approved by their department chair.

Setting

This research occurred at a large, private, doctoral-granting university in the western United States. The university may be unique compared to universities of similar size because of its emphasis on undergraduate teaching, because of the high academic preparation of its students, and because of its relatively homogeneous student population. Although the university grants some doctoral degrees, these programs are relatively rare, and there are approximately 10 times as many undergraduates as graduate students on campus. The mission of the university is focused on high-quality undergraduate education. The students who attend this university are academically talented. The average ACT score for entering freshmen in 2018 was 29 out of 36, whereas the national average is only 22. Additionally, the high school grade point average for entering freshmen was about 3.85 out of 4. Although the university has students from all 50 U.S. states and from more than 100 foreign countries, most students identify as Caucasian (~85%). These characteristics may make the study population unique, and our findings may not be fully transferrable to universities with different characteristics.

Instruments and Data Collection

This mixed-methods study used qualitative data from interviews, transforming it into quantitative data using a rubric. The rubric scores were used in linear regression with additional scores from an observation protocol.

Interviews. In a previous study (Sansom, 2019), each of 15 participants in the first STEMFI cohort was interviewed prior to their participation in the program. In the current study, we utilized the original 15 interviews and added data from the second cohort of 15 additional participants. During these semistructured interviews, faculty were asked questions about their attitudes, current teaching practices, and goals for participation in the program. Each interview was transcribed verbatim and analyzed independently by two researchers to apply thematic codes. While we were interested in ideas related to our ecological model for STEM faculty instructional decision-making, the specific codes emerged from the data in the study (Sansom, 2019). Where there was disagreement, the two researchers discussed the issue and came to a consensus.

Rubric scoring. The interview codes were then evaluated with a scoring rubric that rates each participant holistically on 21 traits related to personal, social, and contextual factors. For each trait, the rating scale used a semantic differential, placing two opposite words at either end of the scale, one which would hinder the adoption of EBIPs and one which would support the adoption of EBIPs. Each trait was scored on a scale of −3 to 3, with 0 indicating a mixed or neutral position. Where data about a particular trait were not available in the interview, the rubric score was marked as missing. Scores of +/−1 indicate a minor influence, +/−2 indicates a major influence, and +/−3 indicates a primary influence.

Each participant's evaluation was double coded with the same rubric. Two researchers scored each faculty participant, compared their scores, and when they disagreed, discussed each trait until they reached consensus.

Description of rubric codes. Frequency codes (*neutral/minor/major/primary*) indicate the degree to which we judged the faculty member considers this factor when making instructional decisions. *Neutral* (0) means that they expressed thoughts about both sides of the continuum and are best considered as neutral or with mixed views. If the factor was not mentioned during the interview (which we acknowledge as a limitation), it was marked as missing. *Minor* (+/−1) factors were mentioned in passing or with little detail. *Major* (+/−2) factors were mentioned multiple times or with some explanatory detail. *Primary* (+/−3) factors were among the most significant concerns of the faculty member and came up repeatedly during the interview or were emphasized as primary by the participant.

Personal factors. These codes were used to score faculty participants' attitudes and self-efficacy with the use of EBIPs.

Deliverer/facilitator. The degree to which the faculty member believes that teaching is primarily about delivery of information (deliverer) or about facilitating student learning (facilitator). Rated based on both expressed attitudes and described characteristics of teaching, either their own or teaching they admire.

Indifferent/caring. The degree to which the faculty member cares about being a good teacher or feels indifferent to this role. *Caring* was applied when faculty described the extra efforts they make to improve their own teaching by helping individual students, tailoring instruction to the interests of the class, or putting in effort to improve generally. Indifference was applied when faculty expressed a primary professional identity as a researcher.

Satisfied/dissatisfied. The degree to which the faculty member felt satisfied or dissatisfied with their current teaching methods. Expressions of dissatisfaction include feeling that what they are doing isn't working, isn't meeting the needs of students, and feeling like it is time for change. Expressions of satisfaction would include feeling that what they are doing is effective or being resistant to the idea of change.

No better/students learn more. The degree to which the faculty member viewed EBIPs as unverified or no better than traditional instruction vs. the view that students will learn more information, retain the information longer, or think more deeply and access higher levels of Bloom's taxonomy when EBIPs are employed.

Boring/engaging. The degree to which the faculty member believed that EBIPs are boring or engaging for students in class. Expressions of engagement include that students will be more awake, paying better attention, or have more fun when EBIPs are used. This code does not include the expressed opinions of students, which are classified among social factors.

Uncomfortable/comfortable. The degree to which the faculty member felt that traditional (uncomfortable) or evidence-based (comfortable) teaching strategies are more comfortable for them personally. This could include aspects of fit with the instructor's personality, a sense of control over what happens in class, and preferences for public speaking.

Inappropriate/appropriate. The degree to which the faculty member viewed EBIPs as appropriate or inappropriate for the specific context of their course. Expressions of inappropriate fit might include acknowledging that EBIPs work for someone else but that they would not work in this class because it is unique.

Negative experiences/positive experience. The degree to which the faculty member had positive mastery experiences using EBIPs, where they successfully facilitated student learning, or had negative experiences, where the new strategy failed or didn't work the way they hoped it would.

Naivety/knowledge. The degree to which the faculty member had knowledge or training in pedagogy generally or specifically with the use of EBIPs. Knowledge may be expressed either as a description of training they have received or by their use or description of EBIPs that they are familiar with.

No, *I can't/yes*, *I can.* The degree to which the faculty member expressed confidence that they will be able to learn new evidence-based teaching strategies and use them in their course or uncertainty of their ability to use EBIPs.

Social factors. The following codes were used to score participants on their perceived social influences from colleagues, students, and administrators.

Isolation/collaboration. The degree to which the faculty member regularly collaborated (about teaching) with colleagues in their department or who teach similar classes. Collaboration would be indicated by the presence of someone that they talk to about teaching, a department culture of teaching experimentation and improvement, or their knowledge about what others are doing or that others know or care what they do. Isolation is expressed as the absence of these factors.

Dislike/like. The degree to which the participant perceived that students like or dislike EBIPs, as expressed to faculty. When faculty perceive that students dislike EBIPs, they may express it as students preferring lecture or passive experiences.

Not valued/valued. The degree to which the faculty member perceived that teaching is valued or not valued at the university or by administration at the department, college, or university level. Value may be expressed either as related to the mission or core values of the university or through initiatives that show material support for teaching improvements.

Ratings drop/ratings rise. The degree to which the faculty member predicts that their student evaluations of teaching will go down or go up when they use EBIPs. This may also include their assessment of past experiences when they used EBIPs and had ratings go down or up.

Primary measure/multiple evaluation measures. The degree to which the faculty member perceived that student evaluations of teaching are the primary or only source for administrative (i.e., rank and status) judgments of teaching quality. There may be other meaningful measures, such as peer evaluations, that lessen the impact of student ratings.

Meet the bar/keep going. The degree to which the faculty member perceived that colleagues would encourage them to work on teaching only until their student evaluation scores are good enough (*meet the bar*) or encourage continual self-reflection and improvement, even when there may not be a payoff in terms of student ratings.

Contextual factors. The following codes were used to score participants' contextual environment, including the time, material, and human resources on which they could draw.

Coverage/flexibility. The degree to which the faculty member felt that content coverage was a barrier to the use of EBIPs or that there is enough flexibility in the curriculum that they could cut out certain topics to work more deeply on the others. This may be expressed either as the need to cover content or the constraint of limited time in class.

Time constrained/time free. The degree to which the faculty member felt that their preparation time was constrained because of their other responsibilities at the university or that they have adequate time to make curricular changes. This may be expressed directly as the lack of time to engage in teaching improvements or as the difficulty of balancing diverse responsibilities at the university.

Students unprepared/students capable. The degree to which the faculty member felt that students are generally not college ready, come unprepared to class, or are so heterogeneous in preparation that it is difficult to use EBIPs. Or an expressed confidence in the students' ability to rise to the occasion when they ask them to do more.

University resources unavailable/available. The degree to which the faculty member was aware of or used university resources intended to improve teaching, including the Center for Teaching and Learning, teaching assistant resources, etc.

Materials unavailable/available. The degree to which the faculty member was aware of or used teaching materials that are aligned with EBIPs and appropriate for their course and content.

COPUS observations. Members of the research team used the COPUS (Smith et al., 2013) protocol to observe three to four class sessions taught by each faculty participant prior to their participation in the program. For the first cohort, we believed that three observations would be sufficient, but for the second cohort, we chose to observe four class sessions because a recent study demonstrated that four sessions are better for capturing the variety of instructional styles used by STEM faculty (Stains et al., 2018). During each two-minute interval of class, the observer recorded instructor and student actions. Instructor actions include activities such as lecturing, writing on the board, asking or answering questions, moving around the room, and guiding student work. Student actions included activities such as listening, asking and answering questions, and working in groups. For each participant, all observations were aggregated to find the average percentage of student-centered teaching. Student-centered teaching was defined as any faculty action other than lecturing, real-time writing, or video demonstration (Smith et al., 2013).

Data Analysis

We calculated an average score for personal, social, and contextual factors, according to an ecological model for STEM faculty instructional decision-making. We regressed the percentage of the student-centered COPUS scores on these three explanatory variables in a multiple linear regression analysis. To ensure that the model met the requirements of linear regression, we tested the data for linearity, normality of residuals, equality of variance, and multicollinearity. Multiple linear regression was an appropriate analytical strategy because we determined the percentage of variance in teaching behaviors that was explained by personal, social, and contextual factors using the R^2 value. We also determined the relative influence of the three factors on teaching behaviors using the standardized beta coefficients.

After completing the quantitative analysis, we revisited the interview data and described two individuals whose stories illustrated and explained the quantitative results. Thus, qualitative data were used both to explore the ecological model of STEM faculty instructional decision-making in the development of the rubric and scoring of participants and to explain the findings through these brief case studies.

Results

Rubric Scores

Figure 1 shows the mean scores on each dimension of the rubric. Most dimensions associated with personal factors are positive, while most dimensions associated with social and contextual factors are negative.

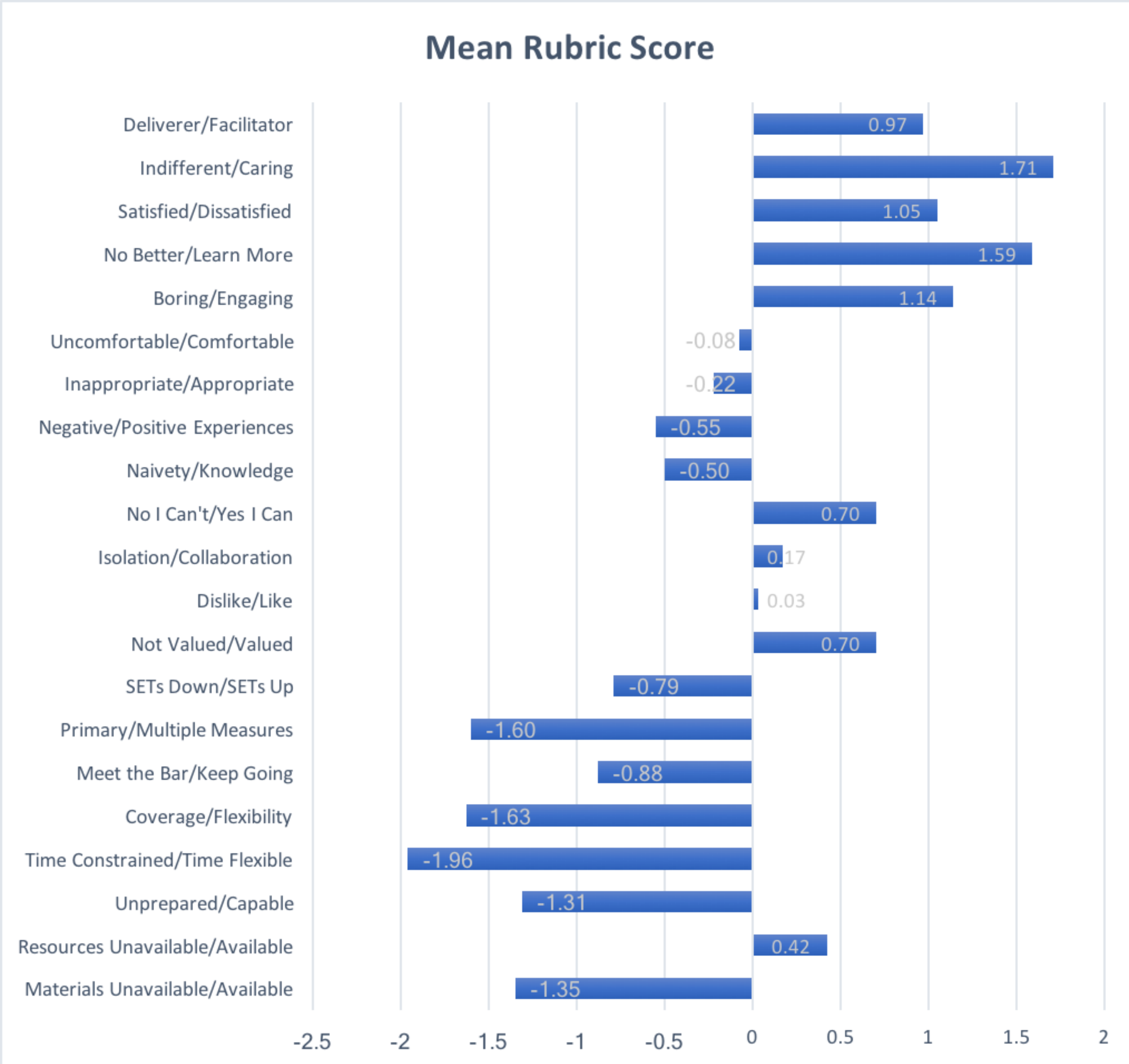

Figure 1. Descriptive statistics for each of the 21 rubric categories, organized by personal factors, social factors, and contextual factors.

Descriptive Statistics

Table 1 shows the descriptive statistics for the outcome variable, percentage of student-centered teaching, and the three predictor variables for personal, social, and contextual factors. All variables met the standard of the critical ratio test for normality.

Table 1

Descriptive Statistics for Outcome and Predictor Variables Used in the Linear Regression

Variable	Percentage of Student-Centered Teaching	Personal Factors	Social Factors	Contextual Factors
Mean	47.3501	0.5479	−0.0933	−1.2972
Median	50.3427	0.4722	−0.0833	−1.2250
Standard Deviation	15.4357	0.6557	0.6997	0.5487
Minimum	14.0619	−1.33	−1.50	−2.50
Maximum	82.2188	1.60	1.33	−0.50
Skewness	−0.131	−0.477	0.212	−0.410
Standard error of skewness	0.434	0.427	0.427	0.427
Kurtosis	0.062	0.878	−0.234	−0.739
Standard error of kurtosis	0.845	0.833	0.833	0.833

In addition to the descriptive statistics reported above, we performed a reliability analysis on each factor using Cronbach's alpha. The resulting alpha score was 0.708 for personal factors, but there was insufficient data to calculate reliability scores for the other two factors.

Linear Regression

The multiple linear regression model regressed percentage of student-centered teaching on three variables representing personal, social, and contextual factors. The model was significant [$F\ (3, 25) = 3.013$, $p = 0.049$] and predicted 26.6% of the variance in teaching behaviors, representing a large effect size ($f^2 = 0.36$). Participants' predicted percentage of student-centered teaching behaviors was equal to 28.239 + 10.152 P − 0.196 S − 10.169 C, where P, S, and C are the rubric scores for personal, social, and contextual factors respectively. Participants' percentage of student-centered teaching increased by about 10 percent for each unit increase in rubric score for personal factors ($p = 0.028$). The percentage of student-centered teaching decreased by about 0.2% for each unit increase in rubric score for social factors (p = 0.962) and by about 10% for each unit increase in rubric score for contextual factors (p = 0.053). Only personal factors were significant predictors of percentage of student-centered teaching.

Upon repeating the analysis, including only personal factors as a predictor variable, the model was significant [F (1, 27) = 4.384, p = 0.046] and predicted 14% of the variance in student-centered teaching behaviors, representing a medium effect size (f^2 = 0.16). Participants' predicted percentage of student-centered teaching behaviors was equal to 42.450 + 8.810 P, where P is the rubric score for personal factors. Participants' percentage of student-centered teaching increased by about 9% for each unit increase in rubric score for personal factors (p = 0.046).

Discussion

Based on this linear regression analysis, personal factors, including beliefs about teaching and learning, attitudes about EBIPs, and self-efficacy for the use of EBIPs, are a significant determinant of student-centered teaching behaviors. In contrast, neither social nor contextual factors significantly predict student-centered teaching. This finding is consistent with the qualitative data that we presented earlier (Sansom, 2019) and can be illustrated by examining two cases from among our participants.

Emma

In the first case, Emma, she had very positive attitudes about EBIPs. She believed that EBIPs were more engaging for students, helped students learn more and think more deeply, and were appropriate for her subject matter and course. She also believed that her role as an educator was to create an environment where students could grapple with ideas and make sense of new information and felt more comfortable working with smaller groups and individuals than standing in front of the whole class. Although she received very little training in pedagogy, she had become familiar with several EBIPs through teaching seminars and work with the university's Center for Teaching and Learning. She was very confident in her ability to learn and implement new strategies in her class. Like most faculty, Emma felt very pressed for time and found it challenging to set aside time to prepare for teaching. This challenge was exacerbated by the apparent lack of available evidence-based teaching materials for her subject. Emma experienced significant pushback from students, even causing her student evaluations of teaching scores to go down. Nevertheless, she persisted in using EBIPs because she felt so strongly that evidence-based strategies were better for student learning. She made this choice despite the sacrifice of time spent away from research and dealing with lower student evaluations of teaching scores. Eventually, her ratings improved and the effort was fruitful because she enjoyed teaching more and her students learned more. Emma had a higher-than-average COPUS percentage of student-centered teaching. In summary, Emma's strongly positive personal factors were sufficient to overcome the social and contextual barriers to the use of EBIPs.

Joseph

Our second case, Joseph, had mixed attitudes about EBIPs. While he recognized that students found these strategies engaging, he felt uncomfortable using them and preferred to lecture. While he saw some utility for EBIPs, he questioned whether they were appropriate for use during a large lecture class or better used in the accompanying small group recitation sections. Like most faculty, he lacked training about pedagogy. Joseph was aware of a few EBIPs and only a little bit confident that he could use them well, since he had seen others fail. While Joseph didn't experience as much pushback from students, he did experience some, and if he was ever aware of students not wanting to engage with EBIPs, he usually yielded to their desires. Although he didn't express the same concerns about preparation time, he was very concerned about time in class and needing to cover all the required content. Facing similar challenges, Joseph's personal characteristics were insufficient to overcome the barriers to the use of EBIPs and he had a very low COPUS percentage of student-centered teaching. Table 2 shows the average scores for Emma and Joseph for personal, social, and contextual factors, along with their average percentage for student-centered teaching.

Table 2

A Comparison of Two Cases

Case	Personal Factors	Social Factors	Contextual Factors	Percentage of Student-Centered Teaching
Emma	1.60	−0.67	−1.20	54.33
Joseph	0.40	0.67	−1.33	14.06

Acknowledging that individuals experience life within a complex social and material environment, these data support the notion that sufficient strength in one level of the ecosystem (in these cases, that level is personal or individual) can overcome some degree of opposition from other aspects of the system. Emma's significantly more positive personal factors allowed her to persevere despite the social and contextual challenges she experienced. In contrast, Joseph's less positive personal factors may not have been sufficient to support the use of EBIPs within a relatively negative context and with mediocre social support. Thus, one strategy to support the adoption and use of EBIPs may be to help STEM faculty change their beliefs and attitudes and improve their self-efficacy. Another strategy may be to reduce the social and contextual barriers to the use of EBIPs or transform the social and contextual factors into positive drivers for change.

Our finding that personal characteristics of STEM faculty, including attitudes and self-efficacy, can strongly influence adoption of EBIPs is consistent with other work in the field. Shadle et al. (2017) explored factors that could be considered barriers to the adoption of EBIPs as well as factors that could be drivers for the adoption of EBIPs. Examples of drivers included enhancing teaching satisfaction, aligning with faculty goals for student learning, and building on existing knowledge and experience with EBIPs, which are personal factors. Meanwhile, the barriers they uncovered included time constraints, content coverage, inadequate resources, and student resistance, which are contextual and social factors. As with any change to teaching practices, the adoption of EBIPs is an intensely personal action, so change efforts need to address individual attitudes and support individual self-efficacy with EBIPs.

Although our data about social and contextual factors were less robust than those about personal factors due to missingness, some discussion is warranted. We found that faculty were less likely to articulate clear ideas about social and contextual factors than about personal ones. Additionally, social factor scores tended to be clustered around the middle, indicating either conflicted or mild perceptions of social influences. About 20% of scores were zero, indicating that participants discussed social factors but that they experienced some positive and some negative influences that balanced out. Fifty-eight percent of scores were −1 or 1, which could indicate a mild influence or could indicate a mixture of positive and negative influences that result in an overall mildly positive or mildly negative social situation. For example, it was common for participants to indicate that teaching is highly valued at the university and to mention initiatives that they had participated in or were aware of that were designed to improve teaching quality.

It was also common for participants to indicate that student evaluations were the only real measurement of teaching quality for tenure and promotion decisions, so any action that might jeopardize student evaluation scores was discouraged. STEM faculty experience mixed messages about teaching, with some more local influences (such as from department colleagues) often contradicting the stated university goals and foci. Thus, one important consideration for social factors will be the alignment of the messages about teaching at different levels of organization within the university. One important way to do that is to ensure that the measures of teaching quality used for tenure and promotion decisions actually measure quality teaching, shifting the focus away from student evaluations of teaching and emphasizing evidence-based instructional practices.

With regard to contextual factors, the coefficient we found was large and negative. This indicates that faculty who feel less constrained by contextual factors are also less likely to use student-centered teaching, which is the opposite of what we might expect. However, it may be that faculty who are experimenting with EBIPs will have encountered contextual barriers and be able to articulate them in an interview. In contrast, those who have not experimented with EBIPs will not yet be aware of constraints because they have not yet pushed the boundaries of what is comfortable. This is consistent with findings from Pfund et al. (2009) that the challenges faculty actually face while implementing EBIPs are different than the challenges they anticipate prior to implementation.

Finally, it is clear that personal, social, and contextual factors can influence each other. For example, enterprising individual faculty members at the University of Arizona campaigned for remodeled classrooms with tables designed for group work. When the new classrooms were in place, other faculty members recognized the need to change their pedagogy to match the space

(Talanquer & Pollard, 2017). Thus, individuals can both influence and be influenced by their environments. Similarly, individuals have unique personality characteristics that interact differently with the same environment. For example, even within the same department, some faculty will be innovators, experimenting with EBIPs in their courses, while others may choose the status quo. Thus, for maximum effect, changes in social structures should be coupled with support for individual development of knowledge, self-efficacy, and positive attitudes about EBIPs.

Conclusion

Our findings suggest that personal factors, such as attitudes about teaching and learning, beliefs about EBIPs, and self-efficacy with EBIPs, were predictive of student-centered teaching behaviors, while social and contextual factors were not significant predictors of teaching behaviors. Further examination of our qualitative data suggests that when an individual has strongly positive personal factors, they will be able to overcome significant, unfavorable social and contextual factors. Thus, change efforts should provide opportunities for STEM faculty to examine their attitudes about teaching and learning, learn about the benefits of EBIPs so they develop more positive attitudes, and support self-efficacy with the use of EBIPs by providing training, practice, and support throughout the implementation process. These efforts, aimed at individual faculty members, should be supplemented with efforts to create supportive social environments and reduce contextual barriers to implementation of EBIPs.

Future research should continue to investigate the utility of ecological models of behavior for understanding and supporting STEM faculty adoption of EBIPs. This exploratory study provides some initial evidence that an ecological model for STEM faculty instructional decision-making could be useful for predicting faculty teaching behaviors. Future work may include the development or modification of surveys that will allow STEM faculty, administrators, and providers of professional development to assess the personal, social, and contextual factors that are most important for an individual or group of individuals and respond with appropriate supports.

One point for optimism is the idea of reciprocal transformation (Miles & Huberman, 1994, p. 58). That is, as STEM faculty change their practices, they will also change their social and contextual environments, and as social and contextual environments change, they will affect STEM faculty members' beliefs, attitudes, and self-efficacy. In other words, individuals change their environments, and environments change the behaviors of individuals. Thus, as we continue in our efforts to improve undergraduate STEM education, we can be hopeful that these efforts will interact within the complex ecosystem of personal, social, and contextual factors to magnify their impact.

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DISSERTATION CONCLUSION

In this dissertation, I have investigated the factors that influence STEM faculty decision-making about evidence-based instructional practices; proposed a conceptual framework that can be used to conceptualize the complex and varied ways that personal, social, and contextual factors interact to support or hinder the adoption and use of EBIPs; and tested the ability of that framework to predict teaching behaviors of STEM faculty.

Future work in this arena may work toward creating a survey instrument that could assess the personal, social, and contextual influences that individual faculty members experience and gathering additional quantitative data that may demonstrate the generalizability of an ecological model for STEM faculty instructional decision-making. Although this model is relatively simple, containing only three parts, it is general or broad enough to encompass the range of factors that faculty articulate as affecting their instructional decisions. It has been said that all models are wrong, but some are useful (Box & Draper, 1987).

All models have some error (i.e., are wrong), but they can still be useful for understanding and predicting phenomena. Three important criteria for utility are (a) theoretical basis, (b) parsimony, and (c) data-model fit. These criteria interact, so the researcher must make wise choices for each situation.

First, a model should be consistent with the theoretical understanding of a phenomenon and what is known about the data. This is a strength of the ecological model for STEM faculty instructional decision-making. It is consistent with the research literature about STEM faculty change that was reviewed. Additionally, it is grounded in the rich qualitative data that we gathered from interviews with the faculty participants in the studies described in this dissertation.

Second, the model should be parsimonious. Simple models are easier to understand and interpret, which makes them easier to use. Models that can't be easily explained to other researchers or end users will be less useful. Again, this is a strength of the ecological model for STEM faculty instructional decision-making. There are three primary categories of factors that influence instructional choices to consider: personal, social, and contextual. Individual faculty members, with some reflection, can probably identify the major helps and hindrances that they experience in each of these three categories. Providers of professional development can likewise work with faculty to identify the major conflicts that they experience when thinking about using EBIPs. Information from these reflective activities can be used to design targeted interventions that focus on those factors most likely to support evidence-based teaching by the individuals involved.

Third, the model should fit the data. If a model does not fit the data, it cannot be used to explain phenomena or predict behavior accurately. We have explored the possibility that an ecological model for STEM faculty instructional decision-making could be used to predict teaching behaviors, and the preliminary data presented in this dissertation support the assertion that the personal factors we've outlined are correlated with teaching behaviors. However, we have insufficient data to draw any definite conclusions about the other factors in the model. Further research in this area is required to determine whether this model appropriately fits data about STEM faculty members' social and contextual environments and predicts teaching behavior.

Importantly, parsimony, fit, and theory sometimes interact. More complex models will generally result in greater data-model fit. So researchers must decide if an improvement in model fit is meaningful enough that it warrants sacrificing parsimony. Further, as the field progresses, the theoretical basis for the model may warrant additional complexity. A useful model should be as simple as possible, descriptive of reality, and theoretically sound. While an ecological model for STEM faculty instructional decision-making is strongly supported by the literature on STEM faculty change, providing a theoretical rationale, it remains to be seen whether this model finds the right balance between parsimony and data-model fit.

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