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Faculty Development and Interdisciplinary Partnerships: Supporting Change in Instructional Practice of Engineering Faculty Members Through Professional Learning and Pedagogical Expertise

Rebecca D. Levison

Faculty Development and Interdisciplinary Partnerships: Supporting Change in Instructional Practice of Engineering Faculty Members Through Professional Learning and Pedagogical Expertise

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This dissertation is completed as a partial requirement for the Doctor of Education (EdD) degree at the University of Portland in Portland, Oregon.

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Abstract

A shortage of science and engineering professionals has led to an effort to engage and retain higher education students in science, technology, engineering, and mathematics (STEM) majors in the United States. School reformers call on faculty members to shift their teaching practices towards evidence-based instructional strategies that involve students in the learning process. Professional developers provide awareness of innovative strategies, but support during implementation is rare. This case study research examined how one unique professional learning partnership (PLP) between a School of Engineering and School of Education in the Pacific Northwest supported an instructional change.

Faculty members supported by the PLP created, implemented, and assessed curriculum in an undergraduate engineering program through training, ongoing coaching, and local and national engineering education networks. In aggregate, 19 faculty member surveys, six interviews, and 42 artifacts and were collected for this study. Key findings revealed that faculty members desire more pedagogical training with their colleagues and implement evidence-based instructional strategies if they see value in the changes. While the COVID-19 pandemic disrupted instruction, faculty members continued to implement strategies that connected students to the real-world using problem-based learning. Conditions that led to continued implementation included support from colleagues, pedagogical coaching, and ongoing feedback. Data evidenced an educational-related research component for faculty development could improve participation and application of new initiatives.

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A special thank you to the Kern Family Foundation for financial and technical support. Your mission and vision is a catalyst to instructional change.

Finally, to all the lifelong learners I've met along the way. Thank you for trusting me to provide input and support to improve instructional practices together.

Dedication

To my mother and first teacher Dr. Peggy Levison.

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Chapter 1: Introduction

The pursuit of scientific understanding, applying engineering solutions, and technological innovations drove global economies' growth over the past century. Advances in transportation, communication, health, and agriculture are the result of purposeful investments in the education of the next generation of scientists and engineers (National Academy of Sciences and Engineering, 2007; Donovan, Moreno Mateos, Osborne, & Bisaccio, 2014; Hanushek, Ruhouse, & Woessmann, 2016; Langdon, Mckittrick, Beede, Khan, & Doms, 2011; Organization for Economic Cooperation and Development, 2018). The products of innovations in science, engineering, and health are evident in the vast infrastructure of electric power, transportation, sanitation, and an entirely new form of communication through technological advancements such as the internet. New technologies in the health, nuclear, and computer sectors have resulted from an educated workforce in science, technology, engineering, and mathematics, otherwise known as STEM.

The STEM workforce is more educated, highly paid, and is growing faster relative to non-STEM occupations (National Academy of Sciences and Engineering, 2007). The demand generally exceeds the supply of qualified workers. Nine out of ten STEM workers completed high school, and most have an advanced degree. Those with graduate degrees earn $4.50 more per hour than those in non-STEM fields, and STEM jobs are projected to grow 8% faster than non-STEM jobs. Although, as it stood in 2012, the U.S. produced approximately 300,000 STEM graduates per year, far below the expected need of 1,000,000 STEM workers by 2025 (Holdren & Lander, 2012). Compounding the shortage of STEM workers is the state of math and science education in the U.S. compared to other nations. The United States ranks tenth among industrial countries in college completion rates for STEM majors putting a strain on the U.S. economy (Organization for Economic Cooperation and Development, 2018). The disparity in gender, race, and ethnicity in STEM employment extends the shortage of workers, according to the United States Department of Commerce (Langdon et al., 2011). Non-Latino white males hold seven out of 10 STEM positions in the US. Black, Native American, and Latin@ (any race) workers are half as likely to hold STEM positions than the overall predominately white workforce.

Efforts to improve math and science education and increase college-level students' completion rates could benefit the economy (Hanushek, 2019). For example, suppose the achievement gap between the United States and Canada were cut in half. In that case, some estimate the result could be enough economic growth to pay for the looming Medicare and Social Security costs that are predicted to cripple the U.S. economy in the next two decades (Hanushek, 2019).

STEM Students in Higher Education

Students entering higher education institutions are more interested in majoring in science, technology, and engineering than they were in 1980 (Eagan, Lozano, Hurtado, Figueroa & Case, 2013). Of the 1.8 million bachelor's degrees earned in 2016, 18% were in STEM fields (National Center for Education Statistics, 2017). Yet STEM majors remain predominately male. Although women earn a higher percentage of bachelor's degrees than their male counterparts (58% vs. 42%), women receive a significantly lower rate of STEM-related degrees (36% vs. 64%). Latino and Black students are also underrepresented in STEM majors in higher education by three to six percentage points than their white counterparts (NCES, 2017). Currently, more than half of all first-time students intend to major in STEM, yet just over 40% complete a STEM degree within six years. Filling the workforce STEM gap is challenging due to the low international ranking of students in STEM education. It is compounded by the fact that STEM majors change their major at a higher percentage than their undergraduate counterparts, particularly in engineering and mathematics (National Center for Education Statistics, 2017). The National Center for Education Statistics (NCES) conducted a nationwide longitudinal study of 25,000 undergraduates who declared their major in associate's and bachelor's degree programs. Over 35% of students who initially majored in STEM changed their majors, compared to 29% of non-STEM majors. Engineering and engineering technology students left the major slightly above the average at 32%, but over half (52%) of students who majored in mathematics left to study in another field within three years (National Center for Educational Statistics, 2017).

Furthermore, data from a study of 18,000 students in Ohio suggests Black students are more likely to abandon their declared STEM major even though they are entering colleges and universities at higher rates than their white counterparts (Riegle-Crumb & King, 2010). Examining the factors that may contribute to the loss of students in the STEM field, particularly students of color, could increase retention rates. Research-based best practices in education could make STEM courses more accessible to marginalized groups of students and increase the number of graduates overall (Chen, 2014; Olson & Labov, 2012).

Engaging Students in STEM

One way to retain and increase the number of students in STEM majors is to improve teaching practices that engage students effectively (Freeman et al., 2014; Holdren & Lander, 2012; Wieman, 2014). The adoption of evidence-based instructional strategies (EBIS) improves academic achievement and engagement through collaboration, student-centered problem solving, and relevant curriculum (Felder, Felder, & Dietz, 1998; Froyd, Borrego, Cutler, Henderson, & Prince, 2013; Henderson, Beach, & Finkelstein, 2011). EBIS are active learning strategies that demonstrate improved student learning through empirical research and student retention (Borrego, Cutler, Prince, Henderson, & Froyd, 2013; Froyd et al., 2013; Henderson, Dancy, & Niewiadomska-Bugaj, 2012; Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001). EBIS increase student interaction, such as peer instruction, collaborative learning, service-learning and put students in the center of instruction as the main actors in the class. Table 1 presents some of the most common evidence-based instructional strategies.

Table 1

Summary of Evidence-Based Instructional Strategies

EBIS	Description
Active learning	A general term to describe what all students do in class other than watching, listening, and taking notes
Case-based teaching	Students analyze authentic case studies of historical or applicable situations that involve solving problems and making decisions
Collaborative learning	Students work together in small groups toward a common goal
Cooperative learning	A structured form of group work where students work towards a common goal while being assessed individually
Gallery Walk	A flexible discussion technique that allows for formal evaluation of oral presentations, written exercises, and group interaction
Inquiry learning	Students are presented with questions, problems, or a set of observations at the beginning of a lesson to drive the learning
Jigsaw	Students learn a segment of content in groups and teach it to their peers
Peer instruction	Students use a classroom response system such as "clickers" to answer questions posed by the instructor. Students form pairs, discuss their answers, and then vote again
Problem-based learning	Instructor acts primarily as a facilitator and places students in self-directed teams to solve open-ended problems that require significant learning of new course material
Service-learning	Intentional integration of community service experiences into academic courses to enhance the learning of the core content and give students broader learning opportunities about themselves and society at large
Think-pair-share	Instructor poses problems or questions and ask students to work individually for a short time, then ask students to pair up and discuss their responses

Note. Sources: Borrego et al., 2013; Felder, 2009; Froyd et al., 2013; Henderson et al., 2012; Lee, 2004; Lundberg & Yadov, 2006; Mazur, 1997; Owens et al., 2019; Prince et al., 2013; Prince,2004; Woods, 2012

Increasing student interaction to improve cognition is based on sociocultural learning theory, which suggests knowledge is a social construct whereby learning occurs through interactions with other people, objects, and events in a collaborative environment (Vygotsky, 1978). Individual and collective understanding is mediated through dialogue and collaboration and can increase academic achievement in the classroom. However, traditional lecture remains the predominant method of instruction in most STEM courses at the college level (Freeman et al., 2014; Henderson, Beach, & Finkelstein, 2011; Henderson, Dancy & Niewiadomska-Bugaj, 2012;). Traditional lecture involves a one-way mode of communication of information from the instructor to the students. Examining how faculty change their teaching practice and using EBIS could shed light on how and why best practices are not evident. Faculty are often aware of evidence-based instructional strategies, and many receive training, yet few implement them consistently in their classrooms (Henderson et al., 2011). Facilitating improving pedagogical practices could increase implementation of evidence-based instructional strategies.

Change in Faculty Instruction

To understand how and why faculty shift instructional practice and use new evidence-based instructional strategies, it is important to look at how people change. Some change research principles emphasize that change takes time, change is influenced by people’s perceptions, and is a process that people move through in predictable phases (Ellett, Demir, & Monsaas, 2015; Hord, Rutherford, Huling-Austin, & Hall, 1987). Successful efforts to change instructional practice involve concentrated and sustained efforts over at least 12 weeks. These efforts should be focused, coordinated, and facilitated by a change agent who specifically attends to faculty beliefs about the innovations in practice (Henderson et al., 2011). Lastly, change is more effective when the change agent recognizes the stages faculty move through as they begin to understand and implement the innovation or new instructional strategy. The change agent can facilitate formal and informal structures for faculty to exchange ideas and share experiences. These experiences are often referred to as professional learning or professional development whose aim is to improve instruction in higher education.

Although 20 years of research on effective evidence-based instructional strategies pervades the field of higher education, traditional lecture remains the predominant method of instruction in most undergraduate science, technology, engineering, and math courses today (Freeman et al., 2014; Henderson et al., 2011, 2012; Macdonald, Manduca, Mogk, & Tewksbury, 2005). The lecture is the most common content delivery method in STEM undergraduate courses, which relies upon a one-way transmission of knowledge from faculty to student. Yet, some argue that the reliance on lectures, particularly in the sciences, meets students' cognitive needs who may lack foundational knowledge (Burgan, 2006). Faculty can be resistant to changing their instructional practice towards a more learner-centered approach due to their beliefs about teaching and learning, time constraints, research priorities, and content coverage (Fairweather, 2008; Henderson et al., 2011; Sharkey & Weimer, 2003).

Lecture can be viewed as a more efficient method to deliver large amounts of content or complicated material by an expert in the field.

One way to begin to change the culture of lecture-based content delivery as the primary mode of instruction towards more evidence-based instructional strategies that engage students actively is to provide professional learning opportunities, particularly to those who have limited experience. According to the American Association of University Professors (2017), the predominate work requirement is teaching classes amongst 73% of faculty positions; however, most faculty have little to no pedagogical training (Bok, 2014; Holdren & Lander, 2012). Faculty development centers on campus focus on improving instruction across departments. In 2010, faculty development programs shifted to a more constructivist approach that focuses on coaching and mentoring rather than professional development to transmit content (Hutchings et al., 2011; Phuong et al., 2018).

The scholarship of teaching and learning (SOTL) is a research method designed to influence teaching and learning in higher education (Felten, 2013; Hutchings et al., 2011). The scholarship of teaching and learning (SOTL) is based on an inquiry into student learning to advance teaching practice and then make the results public. SOTL has been in place in schools of education in action research and other methodologies and has recently spread to other disciplines.

Interdisciplinary Partnerships

Strengthening interdisciplinary relationships across college and university campuses could be one way to provide professional learning and increase evidence-based instructional strategies. Schools of education presumably have in-depth knowledge about evidence-based instructional strategies and focus research projects that seek to understand the teaching and learning process. Interdisciplinary partnerships between education and science departments at the university level are often limited in scope and center around improving pre-service teachers' practice, not higher education faculty (Carbone, 2000; Cole et al., 2001; Schneider & Pickett, 2006). Frequently, faculty members who work in both departments come together to create new teacher-preparation programs or improve existing ones, often to provide pre-service teachers with in-depth knowledge of scientific principles and practices. Much less common are collaborative efforts using education departments' expertise to improve science faculty's instructional practices, particularly engineering faculty members (Schneider & Pickett, 2006; Sechrist et al., 2002). It is presumed that faculty in schools of education have access to the most current research on teaching and learning and could provide expertise to colleagues in other disciplines. Yet, universities lean towards outside consultants or establish faculty development centers to improve instruction at the university level (Amundsen et al., 2005; Steinert et al., 2016). A few universities developed science education initatives across the United States using the concept of *embedded experts* in various science departments, selecting and hiring recent doctoral graduates who provide both scientific and pedagogical expertise directly to their departments (Bonner et al., 2020; Wieman, Perkins, & Gilbert, 2010). These federally funded programs seek to improve science instructional practice by changing the departments' culture towards a more student-centered approach. Besides embedded experts, few universities work directly with education faculty to improve instruction and there is limited information regarding the use of their instructional knowledge. Therefore, there is a potential gap in the research on the use of education faculty expertise in providing professional learning opportunities to their colleagues. This study could contribute to a better understanding of this area.

Purpose Statement

The purpose of this case study is to understand how faculty members in one School of Engineering change their teaching practice through professional learning in partnership with their university's School of Education.

This professional learning experience was a partnership with the School of Education that sought to support faculty in creating, implementing, and assessing curriculum in an undergraduate engineering program. The partnership provided training and ongoing coaching to faculty members and support through local and national engineering education networks. First, the School of Education provided engineering faculty members professional development on evidence-based instructional strategies. Also, some received ongoing one-on-one support in designing learning activities, curriculum, and assessments. At the end of each implemented course, quantitative and qualitative data analysis provided faculty with information regarding their newly developed curriculum and posted on a national engineering networking site. Some faculty members sought to publish their findings at national engineering education conferences and in journals.

By collecting data from Engineering faculty members who participated in a professional learning program two years from when it commenced, this study will examine the following research questions:

RQ1: Why did faculty members choose to participate in a professional learning partnership?

RQ 2: How, if at all, do faculty members describe changing their teaching due to participating in a partnership?

RQ2a: If changes in teaching practice occurred, were they sustained over time, and if so, how or why?

RQ 3: What conditions of the partnership facilitated change in teaching practice?

Significance

Science, Technology, Engineering, and Mathematics (STEM) substantially impact the United States economy, yet the higher education system produces fewer and fewer graduates in this field. Students leave STEM fields at higher rates than non-STEM majors due to poor performance in the first year of coursework (Chen, 2014). Evidence-based instructional strategies have been linked to increased student achievement and retention amongst undergraduate students (Felder et al., 2013; Haak et al., 2011; Terenzini et al., 2001). This case study seeks to understand the extent to which STEM faculty members who teach undergraduate students change their practice and implement new strategies over time after participating in a unique interdisciplinary partnership.

Understanding to what extent and why faculty members adjust teaching methods could support further improvements in STEM education. This study's findings could help policymakers, university leaders, faculty members, and students in higher education understand how faculty beliefs about teaching and learning impact adopting new instructional practices, particularly in STEM fields. Also, findings could contribute to a new faculty development model using interdisciplinary partnerships with Schools of Education to improve teaching and learning. Faculty development programs could also benefit from understanding barriers to implementing new strategies into their classrooms (Phuong et al., 2018).

Schools of Education exist on many college campuses to train the next generation of K-12 teachers to use the most current evidence-based instructional strategies (Cole, Ryan, Serve, & Tomlin, 2001; Schneider & Pickett, 2006). Schools of Education are untapped resources on college and university campuses. There is currently a gap in the research around interdisciplinary partnerships, which this study is designed to address. Faculty development centers exist on many campuses to improve instruction and provide professional development, yet most are not connected to departments whose primary purpose is to develop highly effective teachers (Amundsen et al., 2005). In addition, university faculty members are highly trained in their disciplines but usually do not receive pedagogical instruction on how to teach those disciplines (Wieman, 2014; Winberg et al., 2019).

Theoretical Framework

Understanding how and why engineering faculty members make changes to their instructional practice is the basis of this study. Implementing new education strategies can be situated in the Concerns-Based Adoption Model (CBAM), a widely used theoretical framework to understand and plan for implementing educational innovations (Hall, Wallace & Dossett, 1974; Hord et al., 1987). The model focuses on the people making the changes, not the change itself, and people often avoid changes because they are risk-averse. Understanding individuals' change processes may help realize new initiatives and innovations (Henderson et al., 2011; Tagg, 2012). The tenets of CBAM include: (a) change is a process, not a product; (b) change takes time; (c) people are an essential part of the change process; (d) the change process is highly personal; (e) individual perceptions of change strongly influence the result; (f) organizations cannot change unless their members change; and (g) individuals advance through predictable stages in their reaction to the innovation (Ellett et al., 2015; Hord et al., 1987). The predictable stages of concern are in Table 2.

Table 2

Stages of Concern and Typical Expressions of Concern About the Innovation

Stage of Concern	Expressions of Concern
Unaware	I don't know anything about it (the innovation).
Awareness	I have heard about the innovation, but I don't know much about it.
Exploration	How much of my time would the use of this innovation take?
Early Trial	I seem to be spending all my time getting material ready for students.
Limited Impact	I can now see how this innovation relates to other things I am doing.
Maximum Benefit	I am concerned about relating the effects of this innovation with what other instructors are doing.
Renewal	I am trying a variation in my use of the innovation to result in even more significant effects.

Note: From "The Concerns-Based Adoption Model: A Developmental Conceptualization of the Adoption Process Within Educational Institutions," by G. Hall, 1974, February. Paper presented at the Annual Meeting of American Educational Research Association, Chicago, IL.

CBAM has evolved, and subsequent STEM scholars created a common five-stage framework to determine how likely higher education faculty use a new instructional strategy or innovation (Froyd et al., 2013; Henderson et al., 2011, 2012).

1. Awareness: the individual learns about the innovation,
2. Information: the individual looks for more information,
3. Reflection: the individual considers the pros and cons,
4. Adoption or Rejection: the individual tries the innovation (or not) and analyzes the results, and

5. Follow-up: the individual decides to continue or discontinue applying the innovation.

This theoretical framework is the basis for this case-study research study to compare and generalize findings are related to the theory (Stake, 1995). This study seeks to understand the change process for participants after the first stage of the CBAM framework. Due to the limited scope of case-study research design, generalization to a large population is inappropriate, yet researchers can often compare particular theories (Stake, 1995). This study seeks to understand how the change process in Engineering faculty members who work within a specific professional learning program's parameters compares to the CBAM theoretical framework.

Summary

A national shortage of science and engineering professionals has led to an effort to engage and retain students in STEM majors at the university levels. School reformers ask faculty members to shift their teaching practices towards evidence-based instructional strategies that involve students in the learning process (Wieman, 2014). Although there are many opportunities to support this shift, this research seeks to understand how and why engineering faculty change their practice. This case study will investigate the following research questions:

1. Why did faculty members choose to participate in a professional learning partnership?
2. How, if at all, do faculty members describe changing their teaching due to participating in a partnership?

3. If changes in teaching practice occurred, were they sustained over time, and if so, how or why?
4. What conditions of the partnership facilitated change teaching practice?

This research study contains a literature review in Chapter 2 that discusses STEM education research and the impact of professional learning in higher education. Examining evidence-based instructional strategies and the pursuit of change in science teaching practices in higher education is also addressed. Chapter 3 describes the qualitative methodology used in a case study design to examine how Engineering faculty members change teaching practices in partnership with the School of Education. Chapter 4 describes the data collected in the case study, and Chapter 5 discusses the results, implications, and suggestions for future research.

Active learning: increase student interaction and collaboration where the students are actively participating in the teaching.

Embedded Experts: Professionals hired to support faculty members to improve teaching and learning.

Evidence-based Instructional Strategies (EBIS): instructional strategies that demonstrate improved student learning through empirical research and student retention.

Instructor-centered practices: Teaching practices in which the instructor is the primary actor, including how the information is presented, summative assessments, and grading policies.

Module: A set of lessons or activities in engineering education.

Passive learning: The learner's learning process is receiving information and not interacting with the content.

Science Technology Engineering and Mathematics (STEM): An educational term used to describe a broad scientific field

Student-centered practices: Teaching practices in which students are the key actor in the class, including interactions among students, engagement with course content, and formative assessment.

Chapter 2: Literature Review

This literature review seeks to understand how and why higher education faculty members change their practice over time by examining teaching and learning in higher education, particularly in the STEM field, best practices for instruction, and professional learning for faculty. The first section discusses how STEM education research is organized and the impact of passive versus active learning on student achievement. The following section reviews Evidence-Based Instructional Strategies (EBIS) currently in use today. The following section reviews professional learning opportunities for faculty, including the use of coaching and networks. The Scholarship of Teaching and Learning (SoTL) is discussed, and finally, the context of change within teaching and learning is reviewed as an overarching concept for this study. Figure 1 represents a change model in teaching practice, such as faculty development and the scholarship of teaching and learning related to evidence-based instructional strategies and change theory.

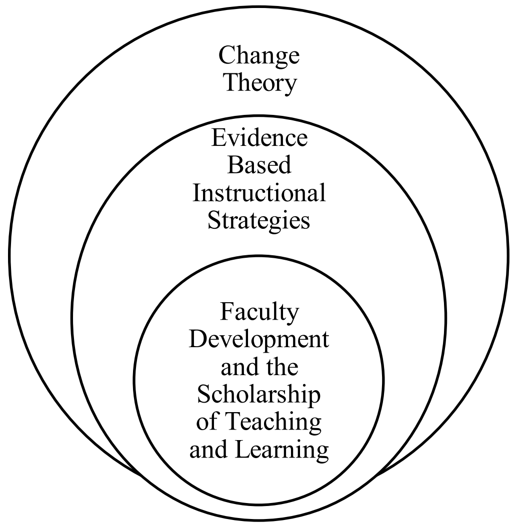

Figure 1. *A Model of Change in Practice*

STEM Education Research on Change in Instructional Practice

Higher education researchers who focus on instructional change in STEM include STEM education researchers, faculty development researchers, and higher education researchers (Henderson et al., 2011). Each group of researchers may overlap in their inquiry, yet they are often isolated from one another. STEM education researchers (SER) are faculty in STEM departments that focus on student learning, developing curriculum, and disseminating it to their colleagues. Larger research focused universities are more likely to have SER. Faculty development researchers (FDR) are usually situated in teaching and learning centers and focus on providing professional development to an interdepartmental staff to facilitate reflective teaching. FDR works to increase motivation and often provides a general skills-based approach to pedagogical practices across university campuses. Higher education researchers (HER) are situated in university leadership departments and focus their research on organizational structures and the impact of policy implementation. All three types of researchers may or may not exist on university campuses but often do not coordinate their efforts to improve teaching and learning (Henderson et al., 2011).

Higher education efforts to improve STEM education involve disseminating information, using an active change agent, and being consistent over time. Henderson et al. (2011) conducted a meta-analysis of how to change instructional practice in STEM education within the higher education system. An analysis of 191 journal articles published between 1995 and 2008 categorized research into four central interventions to facilitate change: disseminating curriculum and pedagogy, developing reflective teachers, enacting policy, and developing a shared vision. Successful interventions that focused on distributing curriculum and pedagogy typically involve a coordinated, focused, and sustained effort lasting at least one semester. A change agent facilitated these efforts and included a deliberate focus on changing faculty conceptions of innovations and provided specific instructional strategies. Another intervention found to be effective was a focus on the development of reflective teachers. Efforts that encourage individuals and communities to use their knowledge and skills to improve instructional strategies were more relevant and applicable to faculty members. The change agent may provide faculty members with resources and facilitate formal and informal structures for opportunities to exchange ideas and share experiences. These structures could be departmental, interdepartmental, or external to the university.

Interventions around policy development and implementation to improve instructional practice focused less on traditional top-down mandates from campus leadership over time. Single policy solutions no longer proved useful for multiple departments or disciplines within an institution or among institutions. Policies that took into account departmental or institutional culture were more likely to be successful because they aligned with cultural and operational norms at lower system levels (Henderson et al., 2011).

Pedagogical Approaches in STEM Higher Education

Traditional lecture. Traditional lecture remains the predominant instruction method in most undergraduate science, technology, engineering, and math courses today (Freeman et al., 2014; Henderson et al., 2011, 2012; Macdonald et al., 2005; Wieman, 2014). Many faculty in higher education continue to rely on the traditional lecture for a variety of reasons that include: the experience of the lecture as a learner, limited use of teaching methods, incentivization of research and publishing over teaching in many institutions, fear of negative evaluations, complaints from students, and resistance to change in practice often due to beliefs about themselves as experts in their field (Henderson et al., 2011; Henderson, Khan, & Dancy, 2018; Holdren & Lander, 2012). STEM faculty were taught via lecture in their undergraduate and graduate courses and not exposed to various teaching methods. Research and publishing within STEM disciplines are rewarded in the tenure system as well as monetarily. Teaching is not weighted as heavily as research and publication in the tenure process. Focusing on new strategies could bring about complaints from students or other faculty members who may perceive lectures as a superior method for discipline-specific expertise.

On the other hand, Reimer et al. (2016) found little evidence to suggest that the use of teaching practices that focus on interactive learning improves student outcomes such as grades and retention, as observed in 40 large introductory STEM courses over the year at a large research university. Additionally, some faculty believe lecturing maximizes student learning and improves course performance, particularly in extensive introductory courses where students have made gains in conceptual understanding and problem-solving (Hake, 1998; Reimer et al., 2016). Burgan (2006) argues a need to resist a “new p.c. or pedagogical correctness” (p. 31), which has infiltrated higher education to focus on group work and problem-solving without regard to student preparation or faculty expertise rather than more traditional methods of instruction, particularly in the sciences. One caveat suggests that group-based instructional strategies benefit first-generation college students and positively impact retention in the STEM series of courses. This impact may be significant since first-generation students disproportionately drop out of STEM (Chen, 2014; Sevo, 2009; Sharkey & Weimer, 2003). However, student achievement can be negatively impacted by relying on the traditional lecture as the primary method to deliver content. There is a concerted effort in the STEM education field to move away from lecture-based instructional delivery towards more active learning for students (Bowen, 2000; Freeman et al., 2014; Haak, HilleRisLambers, Pitre, Freeman, & Shepard, 2011; Henderson et al., 2018; Wieman, 2014).

Active learning and student achievement. Active learning is a general term used to emphasize students' intentional engagement in the learning process through discussion and class activities (Freeman et al., 2014). Active learning describes what all students do in a class beyond watching, listening, and taking notes (Borrego et al., 2013; Felder, 2009; Prince et al., 2013). The opposite of active learning is passive learning, such as traditional lecture, whereby students receive information and are expected to digest, synthesize, and retain that knowledge.

Faculty members can employ active learning strategies in introductory STEM courses to increase student achievement. Haak et al. (2011) studied the impact on student performance when pedagogical approaches in large- enrollment introductory biology courses shifted from traditional lecture to active learning and included more discussions and group activities. The data suggests increased student performance in courses designed with highly structured active learning strategies compared to students in the same courses, which were lecture intensive. Students performed higher on exams that engaged higher-order cognitive skills such as problem-solving rather than simple content-related questions in the more traditional course design. These changes were particularly beneficial for females and students of color.

Several undergraduate STEM education studies found that students perform better in classrooms and courses that employ more active learning strategies than passive learning (Freeman et al., 2014; Haak et al., 2011; Hake, 1998; Rutz, Condon, Iverson, Manduca, & Willett, 2012). In a meta-analysis of 225 studies, Freeman et al. (2014) found that undergraduate students in traditional, passive listening STEM lecture courses were 1.5 times more likely to fail the course than students in similar classes taught through active learning strategies included group work and class discussions. The most significant impact on student performance occurred in studies where a more considerable portion of class time was devoted to active learning strategies, suggesting that a "more is better" approach could increase student achievement.

Hake (1998) used pre/posttest survey data across 62 introductory physics courses of undergraduate students (*N* = 6542) that measured conceptual understanding and problem-solving skills in active learning and more traditional lecture courses. The data suggests that students enrolled in courses that made substantial use of "interactive engagement" (p. 65) methods such as student discussion and hands-on activities had gains twice as large as those in traditional courses and a strong positive correlation (r = 0.91) between problem-solving and conceptual understanding data results.

Positive student attitudes towards STEM courses increase with active learning strategies. Bowen (2000) conducted a meta-analysis of active learning strategies in introductory college chemistry courses that utilized cooperative learning strategies where students work in small groups to access content and solve problems. The data suggest that collaborative learning had a significant and positive effect on student achievement and positively impacted students' attitudes towards STEM courses.

Seminal STEM education researcher Wieman (2014) suggests that due to overwhelming evidence that lecture is considerably less effective, future research should compare active learning strategies to each other. Lecture teaching as the comparison standard to active learning is irrelevant, and continual reform efforts should focus on active learning, mainly to retain students.

Evidence-based instructional strategies in STEM. Higher education disciplines, particularly in engineering and physics, use the term *Evidence-Based Instructional Strategies* (EBIS) to describe active learning strategies that have been proven effective at improving student learning through empirical research (Borrego et al., 2013; Froyd et al., 2013; Henderson et al., 2012). The use of EBIS in undergraduate STEM courses also contributes positively to effective student engagement and the retention of STEM students in the field. Table 3 illustrates common evidence-based instructional strategies.

Table 3

Summary of Evidence-Based Instructional Strategies

EBIS	Description
Active learning	A general term to describe what all students do in class other than watching, listening, and taking notes
Case-based teaching	Students analyze authentic case studies of historical or applicable situations that involve solving problems and making decisions
Collaborative learning	Students work together in small groups toward a common goal
Cooperative learning	A structured form of group work where students work towards a common goal while being assessed individually
Gallery Walk	A flexible discussion technique that allows for formal evaluation of oral presentations, written exercises, and group interaction
Inquiry learning	Students are presented with questions, problems, or a set of observations at the beginning of a lesson to drive the learning
Jigsaw	Students learn a segment of content in groups and teach it to their peers
Peer instruction	Students use a classroom response system such as “clickers” to answer questions posed by the instructor. Students form pairs, discuss their answers, and then vote again
Problem-based learning	Instructor acts primarily as a facilitator and places students in self-directed teams to solve open-ended problems that require significant learning of new course material
Service-learning	Intentional integration of community service experiences into academic courses to enhance the learning of the core content and give students broader learning opportunities about themselves and society at large
Think-pair-share	Instructor poses problems or questions and ask students to work individually for a short time, then ask students to pair up and discuss their responses

Note. Sources: Borrego et al., 2013; Felder, 2009; Froyd et al., 2013; Henderson et al., 2012; Lee, 2004; Lundberg & Yadov, 2006; Mazur, 1997; Owens et al., 2019; Prince et al., 2013; Prince,2004; Woods, 2012

Although STEM faculty are often aware of the existence and effectiveness of evidence-based instructional strategies, they are not always prone to implementing new strategies or innovations into their practice (Froyd et al., 2013; Henderson et al., 2012; Prince, Borrego, Henderson, Cutler, & Froyd, 2013). In a study of 99 chemical Engineering faculty, 80% were aware of all but two EBIS, yet gaps between awareness and adoption of the strategies ranged between 35-75% (Froyd et al., 2013). Paradoxically, the strategies that took the least amount of faculty preparation time outside of class were less likely to be implemented.

Considerable effort is needed to assist faculty members in implementing EBIS, and they may need support to tailor strategies for their unique situation (Prince et al., 2013). Understanding the barriers to adoption and implementation could expedite broader usage and improve STEM undergraduate education. Barriers most commonly cited by faculty members include lack of class time to cover content, inadequate preparation time, and departmental support (Henderson et al., 2011).

A national quantitative study surveyed 722 faculty with a 50.3% response rate who taught introductory physics courses to examine their decisions using evidence-based instructional strategies (Henderson et al., 2012). The study identified predictor variables to implement EBIS, including rank, class size, and whether it was a research or teaching institution. Results suggest that professional development has been effectively created by disseminating information about EBIS since over 80% of faculty knew about the strategies. Despite the awareness, one-third of faculty who used at least one EBIS discontinued its use after the first attempt, suggesting a need for more support for faculty who attempt innovations in instructional practice.

Support and feedback during the implementation of new strategies are vital, yet the data suggests it is often lacking (Henderson et al., 2011, 2012). Support from professional developers and peers is more effective when they can consistently provide feedback, engage in ongoing conversations with faculty about class assignments, content coverage, and discuss core issues related to teaching methods such as EBIS and traditional lecturing.

Professional Learning

Professional learning is a process in which adults participate in experiences that deepen knowledge, is ongoing through active engagement in practice, and mediated by the context within the professional's field of work (Fullan, 2001; Rhodes, 2000; Webster-Wright, 2009). Webster-Wright (2009) conducted a meta-analysis of 203 empirical research articles across five professions to understand if professional development literature reflects what is known about effective professional learning. The data suggest professional development connotes a deficit, passive education model where the participant is considered lacking skills or knowledge. Professional learning is considered an active approach by taking into account the learner's background and field of expertise.

Professional learning is knowledge that is mediated by context and includes more than physical locations and social interactions with peers. Each profession has its discourse, practices, and behavior that identify what is important and what counts as knowledge (Rhodes, 2000; Webster-Wright, 2009). There is increased complexity of practice and demand for proficiency in complex inter-disciplinary Engineering education situations, particularly in the social sciences (Reich et al., 2015). Professional learning and development in higher education for engineers shift from focusing on the deficit of engineers' knowledge, attitudes, and skills towards the practice's characteristics such as interactions, opportunities, and challenges.

Professional development. Professional growth is a continual and inevitable learning process that needs to be sustained over time, relevant to the participants, and provide opportunities for collective participation (Clarke & Hollingsworth, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001; Smith, Hofer, Gillespie, Solomon, & Rowe, 2003). The term *professional development* refers to activities and programs designed to improve instruction through professional growth. This general term refers to training, formal education, or advanced professional learning intended to improve instruction (Amundsen et al., 2005; Showers & Joyce, 1996). In higher education, the term *faculty development* is used interchangeably with 'professional development' and is regularly used to describe activities and programs that improve instructional practice across disciplines. Faculty development centers have been created on many campuses to house instructional resources for all faculty and staff to improve student outcomes. Not all university campuses have the resources to maintain faculty development centers and often hire professional development specialists.

Professional development specialists provide quality training and programs to improve instructional practice, yet the transfer of new knowledge and skills is low, even with participants who volunteer for the training (Showers & Joyce, 1996). Professional development is a complex process but is often approached based on a deficit-training-mastery model that views teachers as passive participants who need changing (Clarke & Hollingsworth, 2002). Most professional development experiences involve a “one-shot” approach that includes training on specific skills, new curriculum, or programs that view change as something applied to teachers who need new knowledge. The deficit-training-mastery belief has shifted programs from ones that focus on changing teachers to viewing professional development as opportunities for teachers as complete participants in shaping their professional growth (Fullan, 2001). This shift towards a professional growth approach for teachers focuses on the professional agency as lifelong learners who seek greater fulfillment in the art of teaching rather than fix a defect.

Clarke and Hollingsworth (2002) expounded education focused professional development models based on four studies. Their data suggests four change domains: external sources of information; teacher knowledge, beliefs, and attitudes; application of practice; and outcomes resulting from the change. They created a model to demonstrate that change resulting from professional development occurs non-linearly through constant reflection and action (see Figure 2).

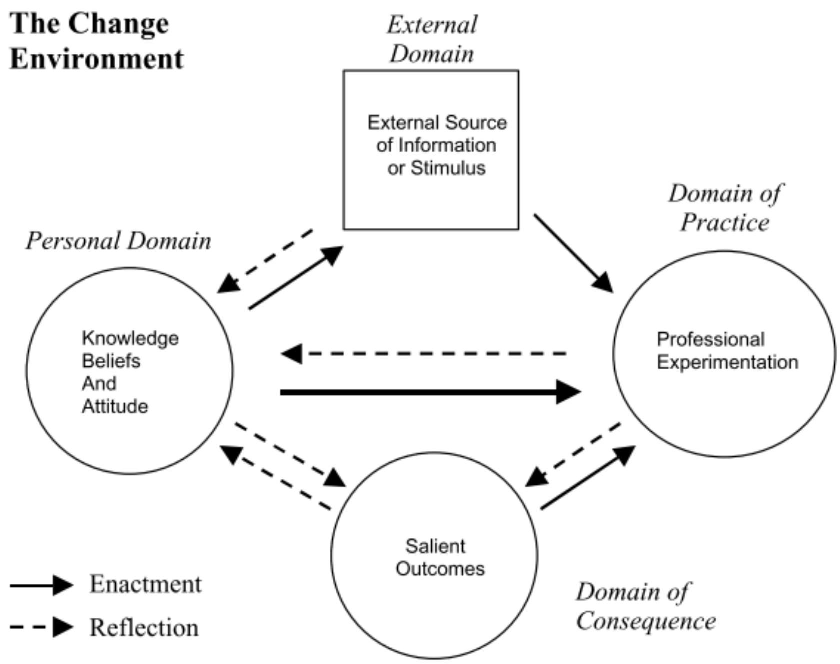

Figure 2. The interconnected model of professional growth demonstrates that changes in one domain can impact other fields. From " Elaborating a Model of Teacher Professional Growth" by D. Clarke & H. Hollingsworth, 2002, *Teaching and Teacher Education, 18, p.* 947-967.

Each domain can influence the other in either a *change sequence* or a more lasting change known as a *growth network*. If a change in one domain caused a shift in another field, however short-lived, that would be considered a *change sequence*. For example, if a teacher attended a workshop (external domain) and then implemented a strategy the next day (the domain of practice), that would be considered a *change sequence*. More lasting change occurs when two or more domains are impacted through reflection and what Clark and Hollingsworth (2002) refer to as *enactment*. *Enactment* is the action of applying a strategy and reflects its novelty to the teacher. When both enactment and reflection impact practice and beliefs, it is considered *growth networks* and is more persistent. Future research and programs can be evaluated with these two lenses (Clarke & Hollingsworth, 2002).

Effective professional development. For professional development to be effective in improving teaching practice and student learning, at least five components need to be in place: a focus on content and how students learn; active learning opportunities for teachers to engage in the content, observe and receive feedback; coherence of goals, beliefs, and needs of students and the policies of the institution; sustained duration of professional development; and collective participation amongst groups of teachers to build a learning community (Desimone & Pak, 2017; Garet et al., 2001). Professional development that provides teachers opportunities for active engagement, such as collaboration with peers and relevant to their daily life at school, is likely to improve participants' knowledge and skills (Garet et al., 2001). Clarke and Hollingsworth (2002) stated, "We must accord the same dignity and status to teachers' developing practices that we exhort them to accord to developing student practices" (p. 965), and one approach is support from peers to provide and receive feedback.

Coaching. Coaching is a learning relationship between two people, usually a teacher and a professional developer, who share the goal of learning about instruction to improve student achievement in a non-evaluative manner (Knight, 2006). Much of the research on coaching stems from the K-12 system, where coaches are an integral part of professional development to improve student outcomes (Fullan & Knight, 2011). The effectiveness of coaching as a method to enhance teacher learning reflects the five features of effective professional development: content, active learning, duration, and collectivism (Desimone & Pak, 2017; Garet et al., 2001). The content or subject matter must be relevant to the participants in effective coaching relationships to improve student outcomes and deepen their knowledge. The content may also include evidence-based instructional strategies and assessments to deliver the content effectively. Active learning increases the effectiveness of professional development. It may consist of observing a debrief session with feedback, video coaching with self-reflection, and face-to-face interactions. Opportunities to immediately apply new information with feedback are practical, active learning components (Knight, 2006). On-going and consistent coaching interactions improve the impact of the results of this form of professional development. Evidence suggests that 20 hours or more of coaching improves student outcomes (Garet et al., 2001).

Collective participation, often through teams at grade levels or in the subject matter, can positively impact coaching relationships' success. Coaches can facilitate social learning processes and shared experiences and provide feedback as needed. Finally, effective coaching can provide coherence within a department or institution when aligned to critical elements such as standards, curriculum, and policies (Aguilar, 2013; Fullan & Knight, 2011; Knight, 2011). Table 4 describes variations in types of coaching.

Table 4

Types of Coaching in Educational Settings

Type of Coaching	Author and Year	Description
Peer Coaching	Showers & Joyce, 1996	Support from teachers who share teaching aspects and planning to practice new skills, strategies and provide feedback.
Facilitative Coaching	Hargrove, 2003; Heron, 2001	Supports teachers to learn ways of thinking through reflection, analysis, observation, and experimentation by building new skills, knowledge, and beliefs.
Directive Coaching	Hargrove, 2003; Heron, 2001	Combines confrontational, informative, and prescriptive approaches when the teacher has a fixed mindset to see a new perspective.
Instructional Coaching	Knight, 2006	Differentiated support that includes research-based instructional practices and modeling and observations.
Transformational Coaching	Aguilar, 2013; Hargrove, 2003; Senge, 1994	Combines strategies from the directive and facilitative coaching and expands to include impacts on the institutions and the broader social system.

The most crucial aspect of coaching relationships is learning in a supportive environment (Aguilar, 2013; Fullan & Knight, 2011; Knight, 2006; Showers & Joyce, 1996). A partnership framework helps support the coach and the teacher (Knight, 2011). The partnership framework is based on trust, choice, dialogue, and reflection. Coaches must believe that the teacher's thoughts and beliefs are valuable, and they must seek to understand and learn rather than intend to persuade. Teachers choose what they learn to be empowered to express their perspectives and opinion about what they are learning. Effective coaching includes authentic dialogue through detailed questions and answers to understand the teacher's needs and the students in partnership rather than one person dominating the conversation. Reflection is a critical part of coaching, particularly self-reflection in a supportive environment. Reflective thinkers are free to choose or reject ideas to implement. Finally, praxis is integral in the coaching relationship to apply their learning to their daily work as soon as possible.

Networks. The majority of faculty members first learn about evidence-based instructional strategies from their colleagues, indicating the importance of conversations and networks to support instructional practice (Borrego et al., 2013; Froyd et al., 2013). Formal and informal networks facilitate change that improves instruction by building peer relationships on and off campus that make it safe to try new strategies, provide fresh ideas and a safe space to learn and brainstorm (Hutchings, Huber, & Ciccone, 2011; Kezar, 2014; Kezar, Miller, Bernstein-Serra, & Holcombe, 2019). A study in 2017 examined the American Association of Universities (AAU) undergraduate STEM education initiative. This five-year project included eight institutions to improve teaching and learning through the support and study of networks. Researchers interviewed 100 faculty and administrative staff, critically reviewed documents, and observed meetings. Data suggest internal and external connections known as intra-organizational and inter-organizational networks, each provided support to implement best teaching practices in different ways. External or inter-organizational networks provide social capital and funding to influence and motivate campus leaders and administrators to support innovations. Internal or intra-organizational networks include colleagues, often from the same institution or field that may have opportunities to take risks, prioritize teaching, and brainstorm with colleagues to overcome challenges to applying new strategies. Overall, the study suggested a positive impact on the participating institutions' culture and offered a model for "scaling up" change in STEM education through active participation and intentional development of inter-and intra- organizational networks.

Communities of practice, a type of network, can also facilitate change depending on strong or weak social network ties and bridging ties (Mestre, Herman, Tomkin, & West, 2019). Strong ties in a network occur when two or more faculty meet frequently and consistently over time. Weak links are infrequent or indirect interactions but are influential in sparking creativity due to their less formal nature. Bridging ties promote change across departments yet are weak.

Frequent conversations with local colleagues about implementing instructional strategies are critical to adopting and implementing EBIS (Mestre et al., 2019; Prince et al., 2013; Wright, 2002). Change agents proved effective in catalyzing change in the large undergraduate STEM department at one large university (Mestre et al., 2019). The University of Illinois catalyzed change in their comprehensive undergraduate introductory STEM courses and across departments because of a network of embedded change agents who focused on evidence-based instructional strategies. This change began to spread from STEM departments to other departments when change agents across departments started to meet and share information about their communities of practice. After funding ceased for entire communities of practice, 80% remained functioning.

Scholarship of teaching and learning. The scholarship of teaching and learning (SoTL) is the study of teaching and learning in higher education. Hutchings, Huber, and Ciccone (2011) stated that the goal of SoTL is to "focus on inquiry, innovation, collaboration, and knowledge-building that raise student's levels of learning and build on the instructor's pedagogical networks and expertise" (p 5). Studies contend there should be a research component to effective professional development initiatives in higher education (Hutchings et al., 2011; Rutz et al., 2012). Benefits accrue when faculty utilize research methodology in their teaching.

Hutchings et al. (2011) set out to understand how integrated the scholarship of teaching and learning was across departments in higher education institutions that participated in a national initiative sponsored by the Carnegie Foundation. Data were collected from 103 participating institutions. The data suggest four significant impacts of SoTL across the institutions: how faculty teach, how professional development is organized, the assessment of teaching and learning, and how institutions value and evaluate faculty. Regarding the first impact, faculty reported when they focus on the scholarship of teaching and learning, they are more inclined to use new engagement activities, incorporate new technologies, and focus on the learning environment.

SoTL also impacted professional development because there was a new sense of permission for faculty to share ideas and create interest within departments and across institutions. This public dimension of sharing has led to faculty's informal and formal networks across departments who share a common interest in teaching and learning and seek to share best practices. Assessment in teaching and learning was the third impact of SoTL in participating institutions. The focus is on systematic, evidence-based approaches to teaching and learning with a public sharing component. Lastly, the effect on the value and evaluation of teaching was mixed across institutions. On the one hand, the focus on SoTL elevated the stature of teaching and sparked conversations on campus, yet the retention system, tenure, and promotion were not influenced. However, data suggests that faculty involved in SoTL are more likely to participate in other institutional initiatives that may accelerate institutional change.

Faculty Development in Science, Technology, Engineering, and Math (STEM)

Pedagogy, the study of teaching and learning, is not universal and may depend upon the discipline, also known as signature pedagogies (Shulman, 2005; Winberg et al., 2019). Signature pedagogies define what counts as knowledge in a field, such as engineering, and how information is transmitted, criticized, analyzed, or discarded. For example, engineering is complex and specialized, and undergraduates bring their understanding of the scientific discipline to the university. Lecture-demonstration is a signature pedagogy in engineering and used to provide new information in a context-specific to a specialized field. Signature pedagogies "define the functions of expertise in a field, the locus of authority, and the privileges of rank and standing" (p. 54).

In a critical review of the literature across eight academic databases and 17 individual journals in 77 total studies, Winberg et al. (2019) found a need to research content knowledge pedagogy in STEM. Most faculty are either not trained or provided some generic pedagogical training. Research on STEM education revolves around generic pedagogy techniques to improve learning, rather than content-specific and the organization of knowledge.

Science education initiatives. National and international science education initiatives (SEI), funded by the National Science Foundation, seek to improve undergraduate science education and contribute to the scholarship of teaching and learning in STEM (AAU, 2017; McVey, Bennett, & Greenhoot, 2019; Wieman, Perkins, & Gilbert, 2010). These initiatives focus on changing departmental culture and influencing STEM departments to support and encourage faculty to use evidence-based teaching practices. The American Association of Universities (AAU) initiated the largest SEI with 55 member universities and 450 unique faculty members known as Transforming Education, Supporting Teaching and Learning Excellence, or *TRESTLE* (AAU, 2017). Through this initiative, an analytic framework included efforts to improve pedagogy, scaffolding, and STEM departments' culture. Data collected over four years at eight sites suggests essential components to enhance teaching and learning quality and effectiveness. Three essential components include a need for departmental collective responsibility for introductory course curriculum, creating collaborative student learning environments, and hiring educational experts within departments to reinforce and support reforms.

Embedded expert is the term used in science education initiatives to employ people who have pedagogical and discipline expertise to support faculty in changing teaching practices (AAU, 2017; McVey et al., 2019; Wieman et al., 2010). The use of 22 embedded experts facilitated 65% of faculty members to change their teaching practices and transform 82% of the introductory courses to include evidence-based instructional strategies (Wieman et al., 2010). The data suggest several factors that contribute to the success of using embedded experts. The unit of change must be departmental. Rather than focusing on individual or isolated faculty, data are necessary to convince science faculty members to adopt new practices since scientists view their work in data terms. Reward structures should align to change initiatives such as monetary, time, or staffing.

The University of Kansas implemented an embedded expert model in its School of Engineering with the assistance of partnerships across disciplines (McVey et al., 2019). Postdoctoral teaching fellows with expertise in engineering but not in pedagogical practices were trained by the university's Center for Teaching and Learning in evidence-based instructional strategies. The Postdoctoral teaching fellows were hired as change agents to work with 130 tenure-track faculty members and 2500 students on course transformation, reducing lecture minutes in favor of collaborative student problem solving, publishing, and funding support. Faculty members reported that the most valuable aspect of working with the postdoctoral fellows emphasized the collaboration of engineering education strategies and course transformation.

Interdisciplinary Partnerships

Interdisciplinary partnerships between education and science departments at the university level are often limited in scope and center around improving pre-service teachers' practice, not higher education faculty (Carbone, 2000; Cole et al., 2001; Schneider & Pickett, 2006). Frequently, faculty members who work in both departments come together to create new teacher-preparation programs or improve existing ones, often to provide pre-service teachers with knowledge of scientific content. This collaboration may be in response to the national call for improved science instruction in K-12 education (Holdren & Lander, 2012).

However, collaborative efforts using education departments' expertise to improve science faculty's instructional practices are much less common (Schneider & Pickett, 2006; Sechrist et al., 2002). Several studies focus on improving the instruction of STEM faculty in collaboration with faculty in education. The data suggest that collaboration takes time, there is a need for clear communication between respective experts, and a focus on how students learn (Carbone, 2000; Dierking, 2010; Schneider & Pickett, 2006). One case study of Engineering faculty who worked with education faculty in Ohio (Schneider & Pickett, 2006) found that each field has specialized language and professional culture that created obstacles in developing a new curriculum to improve instruction. The findings suggest that assessment is vital to surface underlying assumptions regarding students' knowledge, directly impacting instructional planning. In the end, however, the new curriculum created in collaboration was considered more teacher-centered rather than student-centered, as defined by the authors and more time was necessary to continue and deepen the partnership.

Another study focused on the partnership between the education department and the science department to create a program that addresses lifelong learning in science in an online format (Dierking, 2010). New graduate-level courses focused on learning theory and active learning to improve science instruction at the K-12 and collegiate levels. The collaboration process to design new online courses geared towards active learning found students became interested in scientific research as a career path. The STEM department revamped its mission and vision towards lifelong learning and changed its syllabi and readings in most core classes.

While more research may be necessary, it is presumed that faculty in Schools of Education have access to the most current research on teaching and learning and could provide expertise to their colleagues in other disciplines. Yet universities are leaning towards outside consultants or establishing faculty development centers to improve instruction at the university level (Amundsen et al., 2005; Steinert et al., 2016). With a shortage in the literature on School of Education partnerships, this facet of research could understand the relationship or lack thereof.

Conclusion

The review of the literature points to a few key findings and areas of exploration. First, awareness of evidence-based instructional strategies is high amongst higher education STEM faculty members, yet implementation is low. Understanding this discrepancy could be helpful to improve instruction and student outcomes.

Professional developers succeed in providing awareness of innovative strategies, but support during the implementation phase is rare. Networks can be effective at supporting innovations due to the collaboration that faculty seek in taking risks to improve their practice. Schools of Education on college campuses have access to the most current research on teaching and learning, yet little is known how much this wealth of knowledge is utilized. And finally, a research component for faculty development improves participation and application of new initiatives. This study seeks to contribute an understanding of faculty change to the body of literature that presently exists.

Chapter 3: Methodology

This study used a case study methodology to examine how Engineering faculty members change teaching practice over time through a unique professional learning experience in one small liberal arts college in the Pacific Northwest. This chapter presents a rationale for selecting the research methodology, information about participants, setting, sampling, and instrumentation. Included are methods used to describe data analysis procedures.

Research Questions

The purpose of this case study is to understand how faculty members in one School of Engineering change their teaching practice through professional learning in partnership with their University's School of Education.

By collecting data from Engineering faculty members who participated in a professional learning experience two years from when it commenced, this study examined the following research questions:

RQ1: Why did faculty members choose to participate in a professional learning partnership?

RQ 2: How, if at all, do faculty members describe changing their teaching due to participating in a partnership?

RQ2a: If changes in teaching practice occurred, were they sustained over time, and if so, how or why?

RQ 3: What conditions of the partnership facilitated changes in teaching practice?

Rationale for Methodology

Qualitative research is a way for researchers to immerse themselves in participants' everyday lives and the setting being studied (Creswell, 2013; Stake, 1995; Yin, 2018). Qualitative research methodology seeks to understand experiences from various perspectives, emphasizing the viewpoints of the people being studied, not the researcher (Creswell, 2013; Erickson, 1986; Mills & Gay, 2016; Stake, 1995; Thomas, 2006; Yin, 2018). Qualitative research's strength is in the descriptions and themes identified in a specific context and location, which lends itself to a case-study research design.

Case study research is an empirical examination of a contemporary phenomenon that allows for concrete study in a real-world context within a bounded case or issue (Creswell, 2013; Mills & Gay, 2016; Stake, 1995; Yin, 2018). Case study methodology requires the pursuit of an in-depth understanding of a specific case or cases and the development of a thorough description of themes and issues. Depending upon the study's aim, three main variations of case-studies exist: intrinsic, instrumental, and multiple or collective cases (Creswell, 2013; Stake, 1995; Yin, 2018). Intrinsic cases are highly unique or of unusual interest, whereas instrumental cases focus on a single issue or problem in one bounded case. Multiple or collective case studies examine and analyze a topic across more than one case. The most appropriate approach for this study is an instrumental case study because it is bound to unique professional learning partnerships and the singular experience of a group of Engineering faculty members. The study focuses on a unique interdisciplinary partnership between two separate departments at one University to examine changes to Engineering faculty members' teaching practices. Therefore, multiple case studies or intrinsic case study approaches are not suitable. This instrumental case study research sought to identify central issues, discern problems and complex circumstances of the humans involved in the case and the environment they were operating (Stake, 1995).

The case study methodology is most appropriate when the purpose of a study is to investigate questions of *how* and *why* (Creswell, 2013; Yin, 2018). This case study sought to understand why Engineering faculty chose to participate in a professional learning partnership with the School of Education, *how* they were impacted, and *why* their teaching practices may or may not change as a result. Lastly, Mills and Gay (2016) offer case study research as an "appropriate choice if the researcher is interested in studying process and describing the context of the study and the extent to which a particular program or innovation has been implemented" (p. 419). The partnership between the School of Engineering and a School of Education is distinctive because it utilizes faculty experts steeped in the latest evidence-based instructional strategies and offers collegial support to improve teaching practices. Few examples of such an interdisciplinary partnership in higher education are found in the literature. This recent case involved participants who are still working in the setting and, to some extent applying the curricula developed from participation in the program. The case is unique. It examined an unusual interdisciplinary partnership between one School of Education and School of Engineering over a specific period, also known as temporally bound.

Bounding the case. Case study research is unique because researchers study a phenomenon within a clearly defined bounded system (Creswell, 2013; Yin, 2018). The bounds of a case may be determined by time and place and are used to frame the case being studied. This study used a holistic, single-case design that is appropriate when studying a program's global nature with an underlying relevant theory, in this case, the theory of change (Yin, 2018). This study was a single bounded case in one University that examined a professional learning program to understand how and why faculty members change their practice. The case was also temporally bound by and lasted two years.

The study bounded the professional learning program to include faculty members who participated in the professional learning program at a private university on the United States' West Coast. Data were gathered from this group of participants through a survey, structured interviews, documents such as meeting notes, and artifacts developed by the participants. All faculty members in the department received the survey, and the selection of interview participants occurred through purposive sampling. Purposive sampling was used to understand different variations of the phenomenon (Mills & Gay, 2016). There is variation in participation among faculty experience of the professional learning program and criterion sampling, a type of purposive sampling that considers the extent to which faculty members were involved in the partnership and maximized the differences. Faculty members have a wide variety of perspectives on the impact of the professional learning experience;

therefore, the researcher sought to identify key informants who contributed to the researcher's understanding.

Context

This case study research study examined a novel professional learning program (PLP) centered on an interdisciplinary partnership between a School of Engineering and a School of Education at a private liberal arts university in the Pacific Northwest. Grant funding sparked the partnership to focus on fostering change in the teaching practices of Engineering faculty members. Components of the PLP included developing modules similar to a curriculum; training from a national organization and education faculty; and an ongoing coaching protocol that helped facilitate evidence-based instructional strategies and assessments. An interdisciplinary research team composed of faculty members and doctoral fellows from the School of Education and faculty members from the School of Engineering facilitated these efforts.

Kern Entrepreneurial Engineering Network (KEEN). In 2018, the University received a grant from the Kern Family Foundation to participate in a professional learning program to improve teaching and learn in undergraduate Engineering education. The Kern Family Foundation's (2020) mission is to "empower the rising generation of Americans to build flourishing lives anchored in strong character, inspired by quality education, driven by an entrepreneurial mindset, and guided by the desire to create value for others" (KFFDN, 2020, para.1). The Kern Family Foundation supports a national network of engineering educators, the Kern Entrepreneurial Engineering Network (KEEN), to share best practices and address the

Foundation's mission. Engineering educators develop curricula, attend professional development, including conferences, and sharing curricula and resources on a national digital platform. The national digital platform, known as Engineering Unleashed, is a network of over 2,500 Engineering faculty and staff whose mission is to "graduate engineers with an entrepreneurial mindset so they can create personal, economic, and societal value through a lifetime of meaningful work" (Engineering Unleashed, 2020, para. 1). An entrepreneurial mindset is at the core of KEEN. It is defined as "a collection of mental habits that include an attentiveness toward opportunities and a focus on their impact to create value" (Engineering Unleashed, 2020, para. 1). The Engineering Unleashed website is a repository of instructional supports. One of Engineering Unleashed's main supports is the curricula created and shared by engineering instructors from participating colleges and universities. There are nearly 1,400 "Cards," or curricula that provide activities, lesson plans, and course design for virtually all undergraduate levels of instruction in discipline-specific engineering courses.

Also, KEEN has a framework to improve engineering students' outcomes, including a set of learning objectives to increase their *entrepreneurial mindset.* Three critical elements of the entrepreneurial mindset referred to as the "3Cs" include "curiosity about our changing world, connecting information from many sources to gain insight, and create value for others and learn from failure" (Engineering Unleashed, 2020, para. 12). These KEEN objectives focus on ethics and character development in engineering rather than solely content-specific objectives. These learning objectives proved to be an essential component in the professional learning program partnership.

Teaching practices and assessment form a partnership. The grant authors decided to use financial and technical support from the Foundation to improve student outcomes by supporting changes to teaching practices and curriculum development. These changes centered around the KEEN entrepreneurial mindset learning objectives and a university set of learning objectives. At first, the School of Engineering pursued hiring a postdoctoral student in Engineering to fill the faculty support role similar to the embedded expert model found in some science education initiatives (Bonner et al., 2020; Wieman et al., 2010). When those plans fell through, a unique interdisciplinary partnership formed between the School of Education and the School of Engineering. The partnership provided Engineering faculty members with a series of professional development workshops led by faculty from the School of Engineering and the School of Education, opportunities to attend national training that introduced evidence-based teaching strategies and learning objectives to provide technical support in the field of teaching and learning.

The assessment of learning objectives was a vital component of the professional learning program design. Engineering faculty members chose an area of their curriculum to change and incorporated the KEEN objectives and evidence-based instructional strategies to help meet those objectives. A team of doctoral fellows and faculty members from the School of Education and the School of Engineering developed a protocol to support the Engineering faculty in this work. Doctoral fellows from the School of Education met with each faculty member to discuss the curriculum, content delivery, and assessment opportunities. The doctoral fellows provided technical support in instructional strategies and some coaching to support the faculty with the changes. Coaching included brainstorming new teaching strategies, assessment opportunities, and general feedback on the curriculum design. Doctoral fellows and faculty members scheduled classroom observations and created, disseminated and collected the assessments. The team used qualitative and quantitative analysis of assessment data to augment the curriculum or *modules* faculty members were required to post on the national digital platform.

As part of a program requirement, each faculty member developed at least one *module* based upon a set of learning objectives and presented the findings with the interdisciplinary team's support. In most cases, the doctoral fellows observed the module at least once during the semester. At the end of the semester, the Engineering students evaluated the learning objectives through an assessment, and the interdisciplinary research team analyzed the results. The modules were then reformatted to be posted on the Engineering Unleashed website and renamed *Cards* (Engineering Unleashed, 2020). The Cards included step-by-step instructions for instructors, important teaching tips, examples of student work, student handouts, and links to the essential engineering concepts. Also, Cards included data analysis of the faculty member's objectives; these data were sometimes developed into published papers and conference presentations. Once faculty members posted their Card on the national network website, a stipend was provided to compensate participation in the program. Appendix D provides an example of a published Card.

During the second year of the program, I was a doctoral fellow in the program. I worked with faculty members to develop, implement, and assess various curricula focused on the above-stated mission. Parameters to limit bias in this study are described in more detail in a later section. In sum, 19 School of Engineering faculty members participated in the program by developing and publishing 32 modules on the national digital platform.

Participants

Engineering faculty members at a small liberal arts college in the Pacific Northwest participated in this case study research study. The Engineering Department consisted of 36 faculty members, including instructors, assistant professors, professors, and professor emeritus. The survey was distributed via email to all faculty members and completed by 24 (67%) in the department across six various departments: Civil Engineering, Computer Science, Electrical Engineering, General Engineering, Mechanical Engineering, and Physics. The survey included the Postsecondary Instructional Practices Survey, or PIPS (Walter, Henderson, Beach & Williams, 2016), and seven open-ended questions designed by the researcher. The PIPS measured the instructional practices of postsecondary instructors and validated the participants' self-reported strategies. Seven open-ended questions were added to the survey to collect data on Engineering faculty members' experience on the impact of the partnership with the School of Education. Out of 24 survey respondents, 53%, or 19 of the 36 Engineering faculty, participated in the grant-funded professional learning program to some extent. The PIPS results helped validate their responses to the research questions. The final question in the open-ended portion of the survey invited respondents to voluntarily offer their name and participate in an interview as part of this study, of which six volunteered.

Qualitative research samples are not as large nor representative compared to quantitative research because the purposes are different (Creswell, 2013; Mills & Gay, 2016). Qualitative sampling seeks to select a small number of participants that a researcher can access, can use discretionary judgment to select those who can contribute to an understanding of the problem, and participants who can communicate effectively with the researcher (Creswell, 2013; Mills & Gay, 2016; Yin, 2018). As a doctoral fellow and member of the interdisciplinary research team, I was in a unique position to access participants because of my presence in the program. For example, it was essential to collect data from participants who championed the program and those who participated on the periphery to understand various experiences.

Purposive criterion-based sampling was used to determine who would be interviewed for this study (Mills & Gay, 2016; Patton, 2001). The advantage of using purposive sampling is to access the participants' rich experience in the program to understand the complexity of the case. Criterion sampling, a type of purposive sampling (Patton, 2001), was used to identify interview participants. Criterion sampling allowed the researcher to pre-determine the criteria for participation in the interview to ensure the sample is "information-rich" (p. 238). The participants volunteered to be interviewed. Other data was easily accessible due to my prior experience with the site, program, and pre-established relationships with the faculty and their gatekeepers. Six participants were selected for structured interviews. Overall, the set of criteria for participant selection include faculty who have: (1) completed the survey, (2) participated in at least one KEEN training or event, either on or off the university campus, (3) written at least one module, and (4) posted it on the KEEN website. In addition to structured interviews, data gathered from the survey's open-ended questions captured the experience of those not interviewed about professional learning programs.

Participants were not identified by name, course number, or discipline-specific to ensure anonymity. Survey respondents were randomly assigned a number, and all identifying information from structured interviews was deleted. The only demographic information collected was the number of years teaching Engineering, which was not included in the data analysis.

Instrumentation

Case-study research investigates a contemporary phenomenon and relies on multiple sources of evidence to support validity (Yin, 2018). Various methods of data collection were used to understand the experience of the participants (Patton 2001). The Postsecondary Instructional Practices Survey with seven additional open-ended questions and structured interviews were the primary data collection instruments.

Surveys. The Postsecondary Instructional Practices Survey or PIPS (Walter, Henderson, Beach & Williams, 2016) is designed to measure postsecondary instructors' instructional practices from any discipline. However, it was primarily tested in the STEM field. The PIPS was developed as a psychometrically sound instrument to address the inaccuracy of self-report surveys of teaching practices. While several tools attempt to measure instructional practice, most are discipline-specific, and none are designed to measure teaching practices across all disciplines.

Validity is the extent to which an instrument measures what it intends to measure consistently (Muijs, 2016). Content validity supports whether or not the survey questions' content accurately represents the concepts or aspects that are being measured. An instrument has face validity if it measures what it is supposed to measure from the participants' perspective, often a panel of users. The PIPS was derived from extensive research on instructional practices, teaching observation protocols, and current self-report teaching practice surveys to collect validity evidence. Initially, PIPS combined 153 items from four interdisciplinary surveys and two observational protocols and triangulated them with four literature reviews. Items were reduced through an iterative process using outside researchers to revise questions and field-testing of five non-participating instructors and a panel of four education researchers to achieve content and face validity. A convenience sample surveyed 891 postsecondary faculty from four institutions and 72 departments with a response rate of 36%. The research team used factor analysis to determine good model fit statistics and overall reliability of 0.80.

The survey consists of 24 instructional practice items on a 5-point Likert scale from *not descriptive of my teaching* (0) to *very descriptive of my teaching* (5). Two models are used to score factors that describe a respondent's instructional practice: a two-factor model that divides the survey questions into practices that are student-centered and instructor-centered or a 5-factor model that provides more detail on instructional practice. Table 5 provides sample items in the PIPS for the two-factor model. Appendix A includes the survey in its entirety.

Table 5

Sample Items from the PIPS Instrument

Teaching Practice Factors	Total number of items in PIPS	Sample Item 1	Sample Item 2
Instructor-centered	9	I guide students through major topics as they listen and take notes	My test questions focus on important fact and definitions from the course
Student-centered	13	I design activities that connect course content to my students' lives and future work	I use student questions and comments to determine the focus and direction of classroom discussion

Each survey took the participants approximately 15 minutes to complete, including the additional seven open-ended questions. The open-ended questions were designed to answer each research question and capture data from participants who did not participate in the structured interviews. Questions included the extent to which the faculty member participated in the professional learning program and the interdisciplinary collaboration impact. Seven questions were included to attempt to mitigate researcher bias by collecting data about the partnership in written form and triangulating the interview responses. The open-ended questions can be found at the end of the PIPS survey in Appendix A.

The stimulated recall method facilitated realistic recollections of participation in the program and was used to promote and activate memories concurrent with the naturalistic context (Lyle, 2003; Meade & McMeniman, 1992). The method is most effective when used with artifacts such as videos or documents that evoke memories of the decision-making process. In this study, participants created, implemented, assessed, and posted modules with various interdisciplinary research teams' assistance. Each participant received a link with the survey to his/her published module, or Card, from the Engineering Unleashed website to stimulate the memory and recall the context to which it was created.

Interviews. Qualitative researchers focus on multiple perspectives to describe and interpret a phenomenon, and interviews are one source of data that encompasses various viewpoints (Creswell, 2013; Stake, 1995). Interviews help the researcher propose explanations of important events and perceptions of participants, often answering the *how* and *why* of specific experiences (Yin, 2018). Interviews can provide researchers with evidence to examine the participants' attitudes, feelings, concerns, and values and are often used in case-study research (Mills & Gay, 2016).

Structured interviews are a form of questioning that provides a strict guide for the researcher to follow a coherent inquiry line (Creswell, 2013; Yin, 2018). The structured interview questions sought to collect data on why faculty members chose to participate in the professional learning program (PLP), how they perceived making changes to instructional practice, and whether those changes sustained over time. Also, structured interviews were used to collect data to understand which conditions of the unique partnership facilitated instructional practice change. An outside trained researcher conducted one of the structured interviews and followed an exact protocol to limit bias due to the involvement of the author of the study. The interview questions and protocol can be found in Appendix C.

Interview questions were designed to collect qualitative data from the participant's perspective in the program, specifically on the School of Education and Engineering department partnership. Eight questions were designed and refined based on the research questions delineated in the study. The interviewer built a rapport with the participant to make them comfortable in the interview process. Each interview started with the interviewers' background and interest in the study's topic and explained why they were asked to participate (Creswell, 2013; Patton, 2001). Participants were sent a written confidentiality statement before the interview and asked if they would like to continue or not in the interview process.

Immediately following each interview, data was transcribed by Rev.com, a transcription service approved by the IRB. The transcriptions were sent to the interview participants for review.

Artifacts and documents. In qualitative research, artifacts and documents are written or visual evidence that adds to a complete understanding of the studied case (Mills & Gay, 2016; Yin, 2018). In case study research, artifacts are primarily used to validate and enhance data from other sources (Yin, 2018). This case-study collected and analyzed various electronic documents from the professional learning program and artifacts from the KEEN grant-funded program. Documents used to validate the data included notes from pre-observation and post-observation meetings between Engineering faculty members and School of Education doctoral fellows. These meeting notes confirmed, in some cases, the use of evidence-based instructional strategies and coaching between the Engineering faculty members and the doctoral fellows. Artifacts used to validate data primarily consisted of the posted modules on the national network website. These artifacts confirmed in most cases the use of specific learning objectives and evidence-based instructional strategies.

Data Collection Procedures

Collecting, organizing, and analyzing data is specific to case study research (Patton, 2001). Data collection for this study was established by the qualitative research design and the literature (Creswell, 2008; Patton, 2001). Surveys, interviews, artifacts, and document collection were performed between September and November 2020. Data analysis did not begin until all the data were gathered, although preliminary coding and analytic memo writing occurred as the data were collected (Saldaña, 2016).

Contact with participants was primarily conducted via video conferencing on Zoom due to the COVID-19 pandemic (Park et al., 2020). Interviewing is optimal in person but was not possible at this time for health and safety reasons. The video interview was recorded and transcribed by Rev.com for further analysis. This case-study collected data from interviews, surveys, documents, and artifacts over 12 weeks.

First, approval was acquired from the Institutional Review Board (IRB), permission from the Department Chair, and Dean of the School of Engineering to conduct the case-study research study during weeks one through four. A list of faculty members in the Engineering departments and those involved in the professional learning program was obtained. All Engineering faculty members received a letter by email explaining the study's purpose, procedures for maintaining confidentiality, and an informed written consent form (Appendix B). Also, faculty members received a link to the survey via Qualtrics and a link to both their published Card, if available. The survey included the 24 items from the *Postsecondary Instructional Practices Survey* (PIPS) and seven open-ended questions asking faculty members to describe their experience in the PLP. The survey took approximately 15 minutes to complete.

Also, artifacts and documents from the partnership were collected. Artifacts included 32 posted Cards obtained from the Engineering Unleashed website, modules the faculty created in partnership with the School of Education. The posted Cards were used to stimulate recall and included as individual links in the electronic survey and analyzed as products from the professional learning program. Documents included pre-meeting and post-meeting notes between faculty members and doctoral fellows and observation notes from classroom visits.

Next, structured interviews were scheduled and completed by a trained volunteer who is not involved in the professional learning program and me. Participants were identified and selected based on participation in the program and the survey results using the following criteria for sampling (1) completed the survey, (2) participated in at least one KEEN training, either on or off the university campus, (3) written at least one module, and (4) posted it on the KEEN website. All faculty members who completed the survey were invited to participate in an interview to understand their partnership perception. Those who indicated they were interested were chosen to participate as long as they met the above-stated criteria. Interviews lasted approximately 30 minutes over video conferencing during mutually agreed upon times. Interviews were audio and video recorded, with permission from the participant. The interviews were transcribed for further analysis.

Data Analysis

Data analysis occurred after data collection, including structured interviews, concluded. In this case-study research study, data sources analyzed consisted of a survey with additional open-ended questions, structured interviews, artifacts, and documents. In qualitative data analysis, a code is created construct that represents data (Saldaña, 2016). Coding the data is the process or method of describing, categorizing, and interpreting data collected in this case-study research study (Creswell, 2013; Saldaña, 2016). Codes are applied and reapplied to the qualitative data, divided, then grouped, and reorganized to begin to develop an explanation (Saldaña, 2016). Five phases of data analysis occurred with multiple coding methods to provide accountability and validity to the research. These five include the organization of the data, preliminary coding, first and second cycle coding, and inductive analysis.

Organization of data. Raw data from the survey, interviews, artifacts, and documents were organized by type in password-protected folders in Excel. Data from interviews were organized by research question in order to analyze the data set in its entirety. Artifacts and documents were labeled and organized by the research question.

Preliminary coding. Pre-coding is a method used as data are collected and formatted to capture initial and often fruitful vital pieces of information (Creswell, 2013; Saldaña, 2016). Pre-coding included circling and underlining key phrases and words, along with "preliminary jottings" alongside the raw data (Saldaña, 2016, p. 21). I read through the transcripts in their entirety and then wrote margin notes for initial thoughts and ideas and wrote reflective passages after each cycle. Analytic memoing was another method used as data were collected to capture initial thoughts, exemplar quotes, and preliminary codes for future reference. After each interview, analytic memos encapsulated the feelings, notions, and spirit of the participant. During the pre-coding process, meaningful quotations were identified by the researcher for later use.

Coding cycles of interviews and open-ended survey questions. Cycles of coding is an analytic method used to reveal themes and categories in transcribed data (Creswell, 2013; Saldaña, 2016). Data were read numerous times to extract meaning in an iterative process. First cycle coding consisted of in vivo coding, which isolates data verbatim to provide authenticity to the data and focus on the participants' voices (Creswell, 2013; Saldaña, 2016). Participant perspectives of a professional learning experience were essential to describe using verbatim data to develop codes. The codes derived from in vivo codes were put into quotations to distinguish between the inferred codes I generated.

The second cycle of data analysis applied pattern coding, which looks at the frequency or pattern of the codes or categories that emerged in the first cycle (Creswell, 2013; Saldaña, 2016). Pattern coding grouped and merged similarly coded data into inductively identified categories. Cycles pattern coding of identified categories revealed significant themes, which allowed me to search for explanations. Codes and categories can be found in Appendix E.

Creswell (2013) describes the final stages of data analysis as an inductive-deductive logic process, where the researcher works back and forth between the data and themes to “establish a comprehensive set of themes” (p. 45) that are continually checked against the data. In this case study, inductively identified categories led to deductive themes. For example, the inductively identified categories of lack of training, feelings of isolation, and a desire for collegial support led to the deductive theme: a sense of belonging, also supported in the literature (Owens et al., 2018). Themes and categories that emerged from in vivo and pattern coding are presented in Chapter 4 using narrative, tables, and figures (Creswell, 2013; Yin, 2018).

Postsecondary Instructional Practice Survey. The PIPS was used to corroborate data that emerged from the interviews and open-ended survey questions (Yin, 2018). Scoring the PIPS was calculated based on the proportion of possible points for each factor which created a weighted sum scaled to 100. Scores were calculated by adding each item in the factor, dividing by the maximum possible sum, and then multiplying by 100. Each item was scored between 0 (not at all descriptive of my teaching) to 4 (very descriptive of my teaching). The PIPS was administered and scored by the researcher online using Qualtrics. Also, seven open-ended short answer questions were included in the survey to collect data on faculty members' perception of the partnership with the School of Education.

Artifacts and documents. Data from the artifacts were used to corroborate the findings from data analyzed in the interviews and surveys (Yin, 2018). Artifacts were analyzed using descriptive coding (Saldaña, 2016) in the first cycle. Descriptive coding is a simple method of summarizing data with a word or short phrase, most commonly a noun. Descriptive coding was appropriate in this case study to examine 32 modules created due to the PLP to identify commonalities. The use of pattern coding in the second cycle allowed me to group the data and compare the categories and themes to those which emerged from the interviews and survey data. First and second cycle coding methods were applied to documents such as classroom observations and meeting notes between the doctoral fellows and the Engineering faculty members.

In order to assess and analyze the data as a whole, triangulation was used to substantiate the body of evidence (Creswell, 2013; Merriam, 2009; Mills & Gay, 2016). A comparison of codes and subsequent categories from each data set informed the themes. For example, evidence-based strategies such as case-based teaching were described by survey respondents, interview participants, and found in the anlaysis of the modules, or artifacts as a result of the professional learning partnership.

Issues of Trustworthiness

Qualitative research can be subjective due to the participants' proximity, researcher bias, and methods used to collect and analyze data (Creswell, 2013; Lincoln & Guba, 1985). As a result, validation strategies strive to ensure the accuracy of the findings. Throughout the design, data collection, and analysis of this case study, validation strategies were employed to ensure this qualitative research study's quality.

This case study research study's limitations were subject to scrutinization mitigated through a rigorous research design process. Yin (2018) provides research design tests to establish the quality of case study research. To increase construct validity multiple sources of evidence should be provided. In this study, multiple sources evidence were used and included data derived from structured interviews, open-ended survey questions, a survey, and artifacts and documents resulting from the PLP. In addition, there was a clear chain of evidence as each data set was designed to support the findings of the other. To increase internal validity pattern matching of codes derived from in vivo first cycle coding were used (Saldaña, 2016). Qualitative studies are not designed to be generalizable to larger populations, although to increase external validity, single case studies should use a theory to compare findings (Yin, 2018). This case study used change theory as its framework. And finally, reliability can be increased using a protocol, developing a database, and maintaining a chain of evidence. This case study was designed with these four design tests in mind as well as other methods to validate the findings.

Triangulation. Case-study research collects data sources to seek an understanding of the phenomena and triangulate their findings (Creswell, 2013; Merriam, 2009; Mills & Gay, 2016). A key validation strategy in qualitative research is triangulation, in which the researcher uses multiple sources of data to substantiate the evidence (Creswell, 2013). This case-study research included various evidence to corroborate the findings, such as survey and interview responses and artifacts and documents such as modules the participants created and observation and meeting notes from the professional learning program. For example, faculty were asked in the survey and the structured interviews to reflect on the professional learning program's impact on their teaching practice. The reflection included a description of changes, if any, made to instructional practice including the addition of a variety of evidence-based instructional strategies. Descriptions of instructional changes were compared to data found in 32 modules produced during the PLP. Additionally, the categories derived from interview and survey data on the use of evidence-based instructional strategies were corroborated using the results of the PIPS and evidenced in the modules and documents. They were analyzed to validate support from the School of Education.

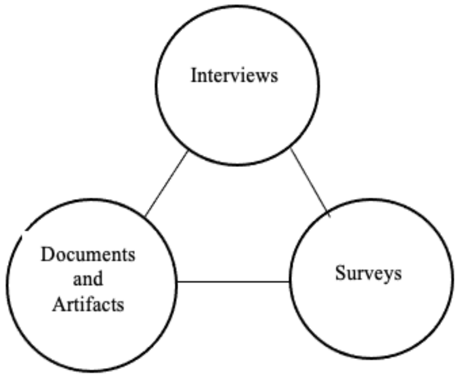

Figure 3: Triangulation by data type

Data analysis in qualitative research comprises planning and organizing the data for analysis and then condensing it into themes through coding techniques and finally presenting visual representation and discussion of the findings (Creswell, 2013). Analytic strategies included identifying codes and reducing them to themes, writing margin notes, and writing reflective passages (Creswell, 2013; Huberman & Miles, 1994). Data were triangulated in order to validate the findings.

Member checks. Member checking is another validation strategy used to involve the participants in the study's legitimacy (Creswell, 2013; Lincoln & Guba, 1985; Stake, 1995). Transcripts from all structured interview transcripts were sent back to the participants to check for the accuracy of concepts and ideas conveyed during the interview. Two interviewees sent back minor clarifications from their interviews, which were noted in the transcripts. This contributed to the confirmation of the credibility of the data collected.

Bracketing. In qualitative research, when the researcher is the instrument, it is essential to discuss researcher bias, past experiences, assumptions, and potential impact on the investigation as a validation strategy to ensure the study's accuracy (Creswell, 2013; Mills & Gay, 2016). Bracketing involves bias awareness and an intentional suspension of assumptions and experiences to take a “fresh perspective” (Creswell, 2013, p. 80) towards the case study. In this case study, I was directly involved in the second year of the professional learning program as a doctoral fellow. I worked with several Engineering faculty members, who were participants in this study, to design, implement, and assess their modules. The first part of bracketing was to participate in dialogue with fellow researchers to discuss biases, past experiences, and assumptions with the research topic. The cohort of researchers in my doctoral program and my dissertation committee served as the primary source of dialogue. Next, I used a bracketing journal to write memos and capture ideas when I sensed a preconceived notion as the study progressed. Finally, I am addressing the bracketing findings in the limitations section of Chapter 5 to make the audience aware of the researcher’s bias (Creswell, 2013; Mills & Gay, 2016).

Role of the Researcher

As noted earlier, it was a priority to limit researcher bias in this case study by utilizing an interviewer not associated with the professional learning program, bracketing, member checks, and keeping an audit journal. These steps were used to mitigate researcher bias as much as possible. As a long-time educator, I have extensive experience working with science teachers to improve instructional practice. Professional development around evidence-based instructional practices is something I design and implement as a K-12 educator in a large urban school district. As a doctoral fellow, I participated in the university program to assist faculty members in creating and assessing their curricula and coached several faculty members on instructional practices. Also, I am listed as a co-author on some conference publications. I took every measure to mitigate researcher bias and not influence the findings. It is important to note that some bias is unavoidable as “any research report is a representation by the author” (Creswell, 2013, p. 250). Lastly, my experience as an adult educator with an informed perspective on education in the United States was considered a constructive part of the research process.

Philosophical assumptions. Qualitative research’s philosophical assumptions are varied and connected to an interpretive framework that guides the research approach (Creswell, 2013; Guba & Lincoln, 1994). Guba and Lincoln (1994) developed an approach to uncovering assumptions for the social sciences based on ontology, epistemology, axiological, and methodology beliefs. They argued that research should begin with a set of beliefs about reality, which frame the questions asked, and the methods used to collect the data. Many social scientists use this understanding of the interpretive frameworks and their association with philosophical beliefs to conduct research (Creswell, 2013). This study is positioned in a practical teaching approach focused on the conditions that fostered change in an Engineering program. This positionality framed the research questions and case study method design.

Pragmatism. This study was situated in pragmatism, an interpretive framework that focuses on the circumstances, actions, and consequences- the research outcomes (Creswell, 2013). Pragmatism was not included in most social science research paradigm discussions until recently, although pragmatism in education originated with John Dewey's work. Dewey (1910) theorized that education needed to apply a scientific approach to the work of teaching. Teachers experience the consequences of their actions and develop beliefs about what will work in their classrooms. Teachers can change their actions based on the outcomes of their students and their practices. In this study, faculty members experienced a unique program seeking to change their actions as they taught with ongoing support and provided constructive feedback.

The ontological beliefs were underlying pragmatism centered around practical and applicable research (Creswell, 2013). This study seeks to understand how and why Engineering faculty members change their practice, including using evidence-based instructional practices, in other words, the study of how and why faculty are utilizing or not utilizing substantiated results.

Ethical Procedures

Ethical procedures in research are paramount to protect the participants, data, and the integrity of the study. The research proposal was scrutinized and approved by an Institutional Review Board (IRB) before any data collection. Participants read and signed a consent form and were numerically assigned codes. All data were kept in a password-protected computer without any link to faculty member names. Participation was voluntary, and whether or not to participate did not affect any relationships with the University or the Foundation that initially funded the program. Participants were free to withdraw consent and discontinue participation at any time without penalty.

Summary

This case study research study sought to understand how Engineering faculty change their teaching practice over time through professional learning in partnership with the School of Education at a small liberal arts university in the Pacific Northwest. A survey of instructional practices helped determine participants in the study and collect data on participants' experiences. Structured interviews followed the survey along with a collection of artifacts and documents. Artifacts were analyzed along with the data from the interviews. Cyclical coding rooted out codes, categories, and themes, and findings presented in multiple formats. Triangulation is vital to increase trustworthiness in a qualitative study; therefore, this study used various tools to answer the research questions using deductive and inductive logic through a case-study design (Creswell, 2013; Lincoln et al., 2011). Interviews, surveys, and artifacts were collected and analyzed to understand the multiple perspectives of Engineering faculty members and their instructional change experience.

Chapter 4: Findings

The purpose of this case study was to understand how faculty members in one School of Engineering changed their teaching practice through professional learning in partnership with their university's School of Education. The findings of this qualitative case-study were based on data analyzed from 19 survey responses of faculty members in the Engineering department, six remote interview responses from program participants, 32 modules developed by program participants, and 10 sets of meeting notes between faculty members at the School of Engineering and doctoral students from the School of Education.

This case study addressed the following research questions:

RQ1. Why did faculty members choose to participate in a professional learning partnership?

RQ2: How, if at all, do faculty members describe changing their teaching due to participating in a partnership?

RQ2a: If changes in teaching practice occurred, were they sustained over time, and if so, how or why?

RQ3. What conditions of the partnership facilitated change in teaching practice?

The first part of this chapter presents data gathered from survey responses to understand the extent to which faculty members participated in the interdisciplinary partnership. The research question's findings are organized by the major themes identified for each research question and the categories linked to each theme. Findings from research questions include data from interviews and survey responses along with analyzed data from artifacts and documents. Finally, tables are presented for each research question to summarize thematic findings.

Faculty members from one School of Engineering participated at various levels in the professional learning partnership (PLP) with the School of Education described in Chapter 3. Nearly 80% (*n* = 15) of the survey respondents participated to some extent, including attending local and national training, developing curriculum with the School of Education's support, and receiving coaching by the School of Education doctoral students in content delivery. Table 6 demonstrates the extent to which respondents participated in the professional learning partnership.

Table 6

The Extent to which Engineering Faculty Members Participated in the PLP

Program component	Percent Responding (N = 24)
I participated in at least one local KEEN training on the University campus.	46
I attended at least one national KEEN training or conference.	58
I developed at least one KEEN module and published it on the KEEN Engineering Unleashed website.	67
I met with an education doctoral student from the School of Education to plan and discuss ideas to develop my module.	54
An education doctoral student observed my class at least once while I was teaching from my module.	46
I met at least once with an education doctoral student after I completed my module to obtain feedback.	38
None of the above (did not participate).	21

Note. Total participants in the partnership program equal 19.

The majority of respondents created a curriculum with doctoral students' assistance from the School of Education, a significant component of the PLP.

This case study collected limited demographic information for confidentiality purposes due to the Engineering department's small size. However, the average number of years teaching engineering to college students was 16.21 (SD = 11.33) and suggests an experienced group of teachers.

Research Question 1: Why did faculty members choose to participate in a professional learning partnership?

Structured interviews formed the basis of the data that describe reasons faculty members chose to participate in the professional learning partnership (PLP). Inductive analysis is an appropriate qualitative research approach that links research objectives with the raw data, such as in vivo codes, in this case, to determine overarching themes (Saldaña, 2016; Thomas, 2006). One central theme emerged from inductive analysis of the data to understand why faculty members participated in a PLP: to foster a sense of belonging.

Faculty members choose to participate in a partnership to foster a sense of belonging. A sense of belonging is a foundational human need that emerged from the field of psychology and is defined as the feeling of being valued by individuals or organizations while experiencing a fit between one's self and others (Baumeister and Leary, 1995; Owens et al., 2018). Identity, inclusion, and acceptance for members of a group are fundamental to fostering a sense of belonging. Members of a group identify with others to feel as if they belong and often pertains to demographics such as race and ethnicity but also may include skill and expertise. The inclusion or exclusion of members of a group also contributes to the cultivation of a sense of belonging and acceptance within the group. Interviewee 6 explained, “You’re surrounded by people who are teaching. None of them have had any formal education on how to teach.”

Faculty members described three reasons for participating in the partnership that contributed to a sense of belonging: Identity as a teacher due to lack of pedagogical training, feelings of isolation from colleagues, and feelings of inclusion and acceptance in a community of learners. These three categories emerged in the development of the theme and will be discussed individually.

Lack of pedagogical training. Experiencing a fit between oneself and others is fundamental to a sense of belonging, yet faculty members described themselves as untrained in instructional strategies. The university in this study is a teaching university, denoting instruction as the priority for faculty members. However, 100% of the interviewees described the absence of formal teacher training in responding to the second interview question, “Why did you choose to participate in the program?”

Some interviewees described how the lack of pedagogical training impacted their identity as a teacher and the decision to participate or not, as Interviewee 3 stated, “I am very cognizant that my doctoral training did not make me a good educator.” Others described a sense of belonging in terms of being in a group of professors who were not trained in pedagogy, as Interviewee 6 said, “None of us have studied how to teach.” Table 7 presents interviewees’ descriptions of their lack of pedagogical training that contributed to a sense of belonging.

Table 7

Interview Responses Regarding Sense of Belonging and a Lack of Pedagogical Training

Interview	Sense of Belonging	Responses
1	Inclusion Identity	In engineering, not very many of us have ever had any formal training on how to teach or teaching theory. I took a couple of classes. I took a class in grad school, and I took a workshop, then I was a teaching assistant to try to learn something about teaching, but I think a lot of people show up to do teaching, and they've never been trained in it.
2	Identity Inclusion	I really should not do what was done to me. I really should come up with a better way to do this and to spend time thinking through this thoroughly, and then actually doing it and implementing it.
3	Identity Inclusion	There was only one professor that I had that did anything that even remotely similar to active learning.
4	Identity Inclusion	We're engineers, so we're not trained in education. Some of us have done a lot of thinking about it and learning about it, and some haven't.
5	Identity	I'm a computer scientist by training, never really received any formal training on how to do education.
6	Identity Inclusion	You're surrounded by people who are teaching. None of them have had any formal education on how to teach.

Faculty members described choosing to participate in a partnership because of their lack of pedagogical training within a profession that requires them to teach as their primary responsibility. They identified as engineers and scientists who had limited opportunities to learn about instructional strategies and voluntarily participated in a professional learning opportunity.

Feelings of isolation as a teacher. Coupled with a lack of pedagogical training, interviewees also described feelings of isolation as a professor and therefore, decided to join in the PLP. Participating in the partnership was a catalyst for some faculty members to foster a sense of belonging, inclusivity and diminish feelings of loneliness. Interviewee 2 described why they chose to participate by stating, “I wanted to improve my teaching because being a professor is kind of lonely sometimes. All your colleagues are just so busy.”

The small size of the university and School of Engineering may have created a situation where faculty members are the only teacher in their field or the sole teacher for a specific course, and therefore expressed a reason to participate due to isolation. Interviewee 4 elaborated on this issue:

> I’m the only one that teaches [course], and the only other faculty that I could talk about this with is not interested in innovative teaching. [They’re] a standard lecturer and at the end of their career, and I don’t feel like [they] would support this sort of change either.

Interviewee 5 also described a similar situation, stating, “I don’t have another professor that I even co-teach with. We’re all working towards the same goal but individually in our own lanes sort of, so having [Program] was really valuable to me.”

Faculty members described feelings of isolation and loneliness as a teacher that contributed to their sense of belonging and provided a reason to participate in the partnership. Some faculty members saw the collaboration as an opportunity to increase their connection to others who are working towards a common goal.

Collegial support and encouragement. A sense of belonging also stems from the acceptance and inclusion of members in a group. Participants in the partnership noted that their colleagues’ support and encouragement were factors in deciding to take part in the PLP. Some participants wanted to be a part of a community of learners, such as Interviewee 4, who answered why they wanted to participate by stating, “Because it provided a community around teaching engineering.” Interviewee 2 expressed being a part of a larger group, saying, “[University] values teaching, and I wanted to be a part of it to do something with my colleagues.”

One component of the PLP involved support from a national network of Engineering faculty members that formed a larger community of learners. When asked Interviewee 6 why they decided to participate, they answered, “To meet with people in the network, like-minded faculty.”

Inclusion and acceptance in the form of collegial encouragement to initiate involvement in the PLP was a factor that emerged from the interviews. Interviewee 3 explained, “There were some senior faculty that I knew that I respected, and they said that they went through it and that it was helpful for them. So, I expressed interest to participate." And Interviewee 5 expressed, "It was somebody from the college, the School of Engineering who told me, 'You have to [participate in the partnership].' And I'm like, 'All right, that sounds like a good idea,' so I did and yeah, it was really good."

Support from colleagues at the university, faculty in a national network, and a community of engineers contributed to a sense of belonging for some faculty members. Inclusion and acceptance from peers, senior faculty, and a more extensive network of engineers provided the impetus for faculty members to begin their journey to change teaching practices with the School of Education and School of Engineering support. After faculty members in the PLP decide to participate, the next section illustrates how faculty members described any instructional changes they made as a result.

Research Question 2: How, if at all, do faculty members describe changing their teaching due to participating in a partnership?

Data were collected and analyzed from surveys and structured interviews to understand how faculty members describe changes they made to instruction, if any, as a result of the professional learning partnership to answer the second research question. All of the interviewees (n = 6) and the majority of survey respondents (n = 14) who participated in the PLP with the School of Education reported implementing some changes to their instruction as a result (N =19).

Artifacts and documents helped validate participant responses to changes described in the PLP. An integral part of the collaboration was developing a curriculum known as modules and included assessments of the learning objectives. The School of Education supported faculty members to transform their modules into web pages called ‘Cards,’ which included lesson plans, student materials, assessments, and the findings from the qualitative and quantitative data analysis. These Cards were posted on the national network website for use by over 2,500 engineering educators and staff. As part of this case study, an analysis of 32 Cards and 10 sets of documents helped validate survey and interview responses about changes made to teaching practices reported by the respondents. Meetings were documented before, during, and after module implementation, assessments, and developing the Cards. These notes served as a method of validating changes made pursuant to the PLP.

One central theme emerged from the inductive analysis of the data to understand how faculty members describe changing their teaching due to participating in a professional learning partnership. The central theme was that faculty members used evidence-based instructional strategies, sometimes referred to as active learning, connecting students to real-world experiences, providing project-based learning, and collaborative learning opportunities as a result of participating in the PLP.

Faculty members describe using evidence-based instructional strategies as a result of participating in the partnership. One main purpose of the PLP was to improve teaching practices using expertise from the School of Education. Part of that expertise provided support for faculty members to cultivate and use a student-centered approach to teaching and learning. Student-centered approaches involve students as the primary actors in the class (Walter et al., 2016). Sometimes the term active learning and student-centered are synonymous. Active learning is a general term used to describe evidence-based instructional strategies (EBIS) that include student activities beyond solely listening, watching, or taking notes. Higher education disciplines, particularly in engineering and physics, use the term Evidence-Based Instructional Strategies (EBIS) to describe active learning strategies that have been proven effective at improving student outcomes through empirical research (Borrego et al., 2013; Froyd et al., 2013; Henderson et al., 2012).

Interviews and survey results provided information on changes made due to participating in the PLP, including implementing specific evidence-based instructional strategies. Among survey respondents, 84% (n = 16) described using EBIS as a result of participating in the program, with the majority implementing active learning, case-based teaching, problem-based learning, and collaborative learning strategies into their instructional practice. Artifacts such as Cards posted by faculty members who participated in the program appear to corroborate the use of evidence-based instructional strategies. Table 8 summarizes the use of these strategies described by respondents as a change of teaching practice due to participating in the PLP.

Table 8

Partcipants Report Use of EBIS Strategies Due to Participating

n (%)	Strategy	Description
16 (84)	Active learning	A general term describing what all students do in class other than watching, listening, and taking notes (Borrego et al., 2013; Felder, 2009; Prince et al., 2013)
12 (63)	Case-based teaching	Students analyze authentic case studies of applicable situations that involve solving problems and making decisions using real-life scenarios (Borrego et al., 2013; Lundberg & Yadov, 2006; Prince et al., 2013)
12 (63)	Problem-based learning	Instructor acts primarily as a facilitator and places students in self-directed teams to solve open-ended problems that require significant learning of new course material (Froyd et al., 2013; Prince, 2004; Woods, 2012)
10 (53)	Collaborative learning	Structured group work where students work towards a common goal (Borrego et al., 2013; Johnson et al., 2006)
4 (21)	Think-pair-share	The instructor asks students to work individually for a short time, then ask students to pair up and discuss their responses to questions or problems (Felder, 2009; Henderson et al., 2012)
3 (16)	Jigsaw	Students learn a segment of content in groups and teach it to their peers (Owens et al., 2019)
2 (11)	Peer instruction	Students use classroom response systems such as “clickers” to answer questions. Students form pairs, discuss their answers, and then vote again (Mazur, 1997; Prince, 2004)
1 (1)	Inquiry learning	Students are presented with questions, problems, or a set of observation at the beginning of a lesson to drive the desired learning (Borrego et al., 2013)

Note. The total number of survey respondents determine the percentage ($N = 19$).

The most common approach described in interviews and surveys was active learning strategies in general, case-based teaching that focused on real-world issues, the use of open-ended problem solving, and the implementation of collaborative learning strategies with students. Faculty descriptions of these strategies often overlapped. For example, a module might provide real-world exemplars (case-based teaching) with open-ended problem solving (problem-based learning) and require students to work in groups (collaborative learning).

Presented below are the top four strategies describe the use of EBIS by faculty members due to the PLP. Some faculty members did not attribute changes made in instructional practices due to the collaboration but described benefits to their instruction as a result by including active learning strategies in their teaching.

Active learning strategies describe a variety of evidence-based instructional strategies. Faculty members described changes they made due to the PLP predominately in the use of active learning strategies. The term active learning strategies encompasses a wide range of evidence-based instructional strategies yet is also considered an EBIS on its own (Borrego et al., 2013; Felder, 2009; Prince et al., 2013). As noted above, 84% of participants stated in surveys and interviews that they used active learning strategies due to participation in the PLP. In describing changes made to their teaching practice, Survey Respondent 10 noted, “I've increased the amount of active learning in my classes even more. Traditional lectures are becoming increasingly rare in my courses. I also am requiring more group work both in and out of the classroom." Interviewee 2 stated when asked to describe changes made due to the partnership, "I'm trying to incorporate more active learning."

Survey Respondent 18 reported instructional changes that include active learning strategies without using the terminology but have implemented them as a result of the partnership by stating, "In addition to changing how the material is presented, I have, in multiple places, changed the emphasis. Students, for example, now work in teams to build devices to build/demonstrate understanding through discussion and testing."

Faculty members reported using a variety of active learning strategies as a result of participating in the PLP. They described using more interactive activities, open-ended problems, and real-world connections. There is evidence of the use of active learning strategies in an analysis of artifacts created due to the partnership.

Artifacts support active learning strategies. Cards were created and posted on a national network website and demonstrate the partnership's results in one concise location. Thirty-two Cards were analyzed for evidence-based instructional strategies to help validate the survey and interview responses. All 32 Cards implemented by the participants (100%) contained some reference to at least one active learning strategy as an integral component of teaching the module. Some of the most common techniques include requiring students to work in teams and problem-solving mainly in a real-world context.

Case-based teaching strategies connect teaching and learning to the real world. Faculty members described using case-based teaching strategies that connect learning to the real-world as a predominant outcome from the PLP. Case-based teaching strategies are evidence-based and include complex real-life scenarios used to engage students to make authentic and real-world connections. Twelve respondents (63%) and all six interviewees (100%) described the use of real-world connections and applications in changes made to instructional practice. Survey Respondent 17 commented, "I felt good about assigning a real-world oriented [Program] project about a topic related to my course that I don't usually teach in my course, and I would like to do this more in the future."

The case-based approach and its relevant application as an EBIS reported to resonate with student learning. Interviewee 3 described, "I think students really like the idea of the things that they're learning being applied to the things that are in the real world, and particularly things that they care about." In addition, Interviewee 1 explained:

> I've always thought that students learn better if they can see how the material is connected to the real world and that this is not just theoretical things that we're studying, but this actually can be very useful and impactful.

Case-based strategies use real-world connections with authentic examples to engage students in the learning process actively. Faculty members produced artifacts demonstrating this evidence-based instructional strategy as a result of the PLP.

Artifacts support the use of case-based strategies. Cards produced by the partnership participants were analyzed for evidence-based instructional strategies to help validate the survey and interview responses. All 32 Cards written and taught by the participants (100%) supported using case-based instructional strategies with real-world connections in their learning objective or referred to real-world applications in student examples or student outcomes. Table 9 below presents the number of Cards that contain case-based learning objectives, which include real-world connections.

Table 9

Case-based Learning Objectives Used in Cards Developed as a Result of the Partnership

Learning Objective	*n* (%)
Students will identify links between course knowledge and real-world systems to create value	16 (50)
Students will connect life experience with course content	10 (31)
Students will identify real-world engineering opportunities and constraints based on the exploration of the field	6 (19)

Note. The total number of Cards determine the percentage ($N = 32$).

Examples of case-based strategies that used real-world scenarios include ethical dilemmas around vaccine distribution, accessing clean drinking water, and preventing catastrophic events such as dam breaches during hurricanes and tornados. Students applied course content such as engineering formulas, computer programming, and surveying instruments to help solve problems in a real-world context.

Increase use of problem-based learning strategies. Problem-based learning strategies are evidence-based instructional strategies that use open-ended questions to derive more than one solution. Survey respondents and interviewees reported an increase in the use of problem-based learning strategies resulting from participating in the PLP. The survey included a question about new teaching strategies or changes made due to the participation in the partnership. Survey Respondent 15 reported, “I have used more problem-based learning strategies” and Survey Respondent 18 wrote, “I am much more likely to ask students open-ended questions and to ask for reflection on applications and implications.” Also, Survey Respondent 4 stated, “I try to use more open-ended problems in courses where they are applicable.”

Interviewee 3 discussed using problem-based learning as a means to tackle bias in the curriculum during the interview:

> Historically, engineering textbooks have screened for a subset of the population. When you look at a physics textbook, and every problem is a rocket or a rifle, you choose a certain subset of the population to be engaged by those examples. So, I feel pretty strongly about saying I’m going to make a conscious decision to choose examples that try to connect with a really broad subset of my students and making sure that I'm not preferentially engaging some homogeneous part of the population. Engineering is just a good problem solving here a lot of different problems to be solved in this world besides making planes, trains, and automobiles.

As noted previously, there was an overlap of case-based strategies and problem-based learning strategies. Survey Respondent 12 reported a change in their teaching practice utilizing both approaches as a result of the partnership, “[Program] had encouraged me to broaden the focus of my problems from real-world to more open-ended and relatable real-world problems."

Problem-based learning was a strategy described by most participants in the partnership between the School of Engineering and the School of Education. Artifacts confirmed this report.

Artifacts support problem-based learning strategies. Cards created from the implemented modules were analyzed for evidence-based instructional strategies to validate the survey and interview responses. All 32 posted Cards on the national website from program participants (100%) referred to problem-based learning or contained a problem-based learning component in the student handouts or other materials. Problem-based learning objectives found on the Cards reflect the use of multiple solutions inherent in this evidence-based instructional strategy. Table 10 below presents the number of Cards that contain case-based learning objectives, which include problem-based learning.

Table 10

Problem-based Learning Objectives Used in Cards Developed as a Result of the Partnership

Learning Objective	*n* (%)
Students will expand their ability to explore multiple solution paths	11 (34)
Students will connect content from multiple sources to solve a problem	8 (25)
Students will consider a problem from multiple viewpoints	6 (19)

Note. The total number of Cards determine the percentage (*N* = 32).

Examples of problem-based learning strategies with multiple solutions include designing energy-saving electrical devices in homes or analyzing solutions to prevent low oxygen levels for fish in local rivers. Students often work in groups and present their findings to learn from each other.

Collaborative learning increased student engagement. Participants in the partnership reported using collaborative learning, an evidence-based instructional strategy due to the PLP to increase student engagement. Collaborative learning is a strategy that increases student interactions, such as working in pairs, small groups, or teams. The strategy involved discussions and teamwork in learning course content and engaging all students in the learning process. Interviewee 2 described using collaborative strategies to engage all students:

> I tried to incorporate more active learning, so instead of having students just answer questions, have them talk about it first to bring out some of the students that wouldn't normally be engaged in that way or would be too afraid to share their opinions.

Interviewee 6 spoke about how open-ended discussions regarding a module created on ethics led to new types of collaborative learning for engineering students:

> It also opens up the classroom to discussions. There's not a lot of discussion about Newton's Laws. It's kind of a one-way street. I get up and say them, and nobody debates them. But now we can talk about, 'Well, what is the right thing to do? Who gets to decide whether cost or environmental impact is more important?' Just having those types of open-ended discussions in a classroom setting, in an engineering classroom setting is novel. I mean, that has not been the norm. Those are really valuable experiences for them.

Artifacts and documents support collaborative learning. Artifacts, such as Cards posted on the national network and sets of meeting notes between doctoral students and faculty members as they planned and implemented their modules, evidenced the use of collaborative learning strategies. Collaborative learning was cited in 97% of the Cards ($N = 32$). Often found in the teaching tips and student handouts, participants referred to collaborative learning as an evidence-based instructional strategy either through partner work, small groups, or teams. Most collaborative learning opportunities were paired with problem-based learning. Small groups of students worked together to solve open-ended problems, present their findings, and critique other groups. These problem-based, open-ended problems all contained a real-world context or connection in every Card examined.

Ten sets of meeting notes and classroom observation documents between School of Engineering faculty members and School of Education doctoral students revealed student collaboration activities such as group work, out of class collaborations, and partner work in class. Cooperative learning strategies were present in 90%, or 9 out of 10 documents.

Participants in the PLP reported using more collaborative learning strategies as a result of the professional learning experience. They put students in small teams and required them to work together on projects both in and out of class.

Faculty members did not change their teaching practice but found some benefit. While many did, some faculty members reported that their teaching practice did not change. Three faculty members (16%) responded on the survey that they did not attribute changes to their teaching practice due to the partnership. Still, they found some benefits to increase student participation in their classroom. For example, Survey Respondent 9 noted when asked if they adopted new strategies as part of the partnership, "No, I was already using these teaching strategies; however, it has provided me with an opportunity to add more interactive content to my classes." Survey Respondent 6 responded, "I don't think I've adopted any new strategies yet. I have used some tools to facilitate participation, like the concept map activity for feedback." Survey Respondent 7 noted:

> Not too much change has resulted from the [Program] experience. However, I have utilized a project I found on the network for a class I taught, and I use active learning a bit more, but this originally started with another conference I went to.

Survey Respondent 10 reprted conflicting descriptions regarding the benefit of the PLP and it's impact on instruction. While this responsent described a decrease of lecture and an increase of active learning strategies in their class as a result of the PLP, the final question of the survey asked "Is there anything else we need to know about the [Program]?" Survey Respondent 10 wrote, "I think entrepreneurial learning is, ironically, too restrictive. I've migrated away from doing things exactly as [Program] would like me to." Not all faculty members attributed changes to their teaching practices as a result of the PLP but most decribed changes in their practice. These descriptions were supported with data from the survey.

Postsecondary instructional practices survey (PIPS) supports participant responses. Due to the inaccuracies of self-reporting in instructional practices, an effort to corroborate these findings was built into this case study design, as described in Chapter 3. The Postsecondary Instructional Practices Survey (PIPS) is a valid self-reporting tool to confirm related instructional practice changes attributed to participation in the professional learning partnership. PIPS measures postsecondary instructional practices based on 24 survey items on a Likert scale from 0 (not at all descriptive of my teaching) to 5 (very descriptive of my teaching). Table 11 provides definitions for PIPS factors.

Table 11

Definitions for Each PIPS Factor

Factor	Definition
Instructor-centered practices	Practices in which the instructor is the sole or primary actor, including how the instructor presents information, design of summative assessments, and grading policies
Student-centered practices	Practices in which the students are the key actor(s), including interactions among students in a class, students' active and constructive engagement with course content, and formative assessment
Student-student interactions	Practices that describe interactions among students in a class
Content delivery	Practices that describe or influence how the instructor transmits information to the students
Student-content engagement	Actions in which students manipulate or generate learning materials or products beyond what was provided by the instructor attributed to active learning
Formative assessment	Actions to monitor student learning that provide feedback to the instructor to inform teaching and/or to students to inform their learning
Summative assessment	Actions for formal evaluation of student learning, including grading policies

Note. Source from Walter et al., (2016) PIPS: A New Survey of Teaching Practices

All participants in the study completed the PIPS, and scores were calculated by determining the proportion of possible points for each factor, creating a weighted sum of the scaled factors to 100. For instance, participants' survey's highest-rated factor was student-content engagement, which consisted of 5 items that speak to student's creation of learning materials or products attributed to active learning. The maximum possible sum for student content engagement is 20 because each item can be rated as high as four (very descriptive of my teaching). Weighted sums can be easily compared when the actual factor score is divided by the possible sum and multiplied by 100.

Student-content engagement was the highest-rated factor from the PIPS' dissemination, which suggests that faculty members participating in the PLP are using evidence-based instructional practices as they reported. In particular, two items appear to corroborate the findings and are similar to the learning objectives found in the modules: I design activities that connect course content to my students' lives and future work, and I structure problems so that students consider multiple approaches to finding a solution. Figure 1 presents the average scores for each of the PIPS factors.

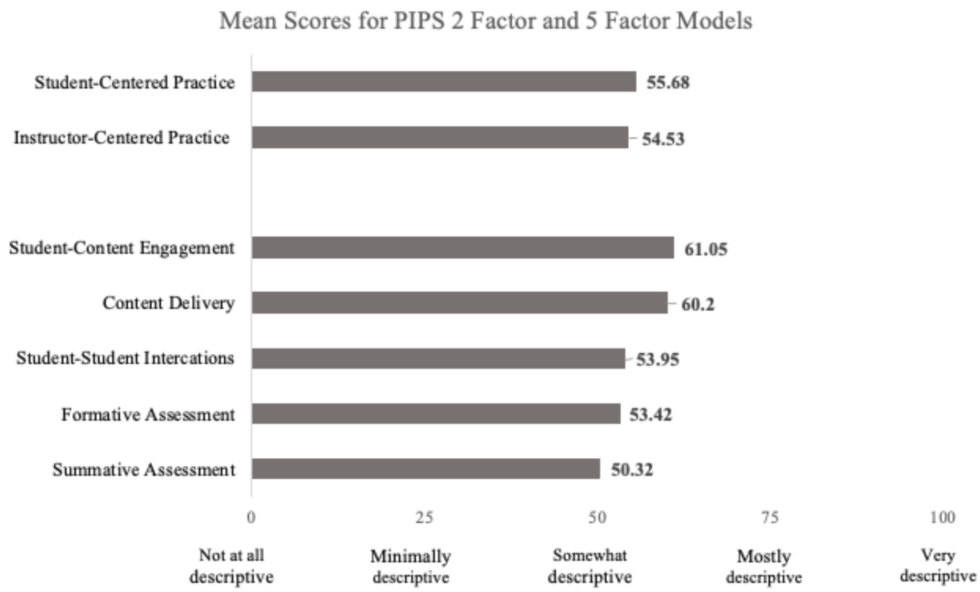

Figure 4. PIPS 2F and 5F scores for respondents ($N = 19$) from the School of Engineering

The postsecondary instructional practices survey findings suggest that the use of some evidence-based practices was reported accurately by the survey participants and responses in the structured interviews. Problem-based learning and active learning strategies were the highest rated as an overall group. Overall, the group is slightly more student-centered than instructor-centered in their practices. While it is difficult to attribute these findings to the PLP due to small sample size, if changes reportedly occurred, the next research question considers if these changes were sustained over time.

Research Question 2a: If changes in teaching practice occurred, were they sustained over time, and if so, how or why?

Two themes emerged from the data collected and analyzed from surveys and structured interviews to understand if changes in teaching practices were sustained over time and, if so, how or why. The first theme suggests that faculty members continue using the practices and products resulting from the partnership, although the recent COVID-19 pandemic described below impacted their efforts. The second theme indicates faculty members continue to implement changes made due to the partnership because they want to contribute to something greater than themselves. Faculty members described using new instructional strategies due to the beneficial impact on student learning and the positive effect to society.

Faculty continued using the practices and products resulting from the partnership, although the COVID-19 pandemic has a negative impact. Efforts to change instructional practice need to be concentrated and sustained over time, eight weeks at a minimum, to be successfully implemented (Desimore & Pak, 2017; Ellet et al., 2015; Garret et al., 2001; Henderson et al., 2011; Hord et al., 1987). The partnership between the School of Engineering and the School of Education was implemented and sustained for two academic years (2018-2020) and faculty members report they continue to implement instructional changes they made.

Continuation of implementing changes. The majority of faculty members who attributed changes in their instructional practice due to participating in the partnership are continuing to apply those changes. Faculty members who were unsure if they would continue to implement new strategies cited the shift to distance learning as the reason for their uncertainty. Table 12 represents survey responses to the question that addresses sustainability over time.

Table 12

Survey Question 4. If you did adopt a new strategy or change your teaching practice due to your participation, are you still using it or plan to use it this year?

Responses	*n* (%)
Yes, I am still using it or plan to use it.	10 (71)
No, I am not using it or planning on it.	1 (7)
Maybe in the future.	3 (21)

Note. (*N* = 14) Not every survey respondent answered this question.

Survey and interview respondents stated that they still plan to use many of the new teaching strategies and the modules they created in the PLP. Interviewee 3 stated, “I would say the modules that I created were well received, and I continue to do those in my classes every year.” Survey Respondent 12 wrote in answering if they were planning on using the modules again, “Yes, I find this approach much more effective.”

As stated previously, the School of Engineering is small, and in most cases, professors created their modules for use in their specific courses. However, faculty members developed modules for multiple course sections and continue to be implemented. As Interviewee 1 explained,

> These modules got implemented and were used by lots of students. The module I did was used in all five sections of the class last year, and the other module I did was used both fall and spring, and then in the summer as well. I think we’ve used those modules for two years now, actually. Yeah, they are being used not just in my class but in other sections that other instructors teach.

Some faculty members responded that they would partially implement new strategies and modules due to the unforeseen global pandemic that catapulted all faculty members to teach online in early 2020. When asked if they would be implementing new strategies, they learned due to the PLP or teaching their modules again, Survey Respondent 12 stated, “In some cases, yes. Particularly those that translate easily to distance learning.”

Overall, faculty members stated they are continuing to use new instructional strategies and implement modules they created due to the School of Education and the School of Engineering partnership. Faculty members who stated they were not continuing or were unsure attributed this decision to the unprecedented global pandemic that disrupted in-person instruction.

COVID-19 pandemic. In March of 2020, a global pandemic shut down the education system in the United States. Teaching and learning moved online, also known as distance learning (Park et al., 2020). Faculty members transformed their curriculum from in-person instruction to remote teaching in a matter of a few weeks. The impact of this dramatic change is still being researched and was evidenced in this case study.

When asked participants in the program if they continue to use new instructional strategies or plan to teach the modules developed during the partnership, the impact of the COVID-19 pandemic and distance learning was a factor. The COVID-19 pandemic negatively impacted changes they made to their teaching practice, as reported by 68% of the respondents ($N = 19$). Survey Respondent 17 wrote, "Not this year but maybe next year, due to COVID-19." Interviewee 4 described the impact on the course they teach when they stated, "This is the hardest year that I've ever had as an educator. A lot of the content I cannot translate online, and I actually argued to have the course postponed."

Although the move to distant learning has impacted the continuation and sustainability of instructional changes, several respondents said they are still planning on using the strategies and modules after the pandemic is over. Survey Respondent 15 stated, "This year has been tricky due to the move to online. I plan to use it more in the future." Survey Respondent 14 also plans to use the module created when they stated, "The second module will not be used this year due to COVID-19, but when we are back in person, it will be used."

Overall, participants in the PLP between the School of Education and the School of Engineering continue to use the practices they developed and products they created. Although the COVID-19 and the move to distance learning have dramatically impacted instruction delivery, most faculty members describe the continuation of instructional changes they implemented. One of the reasons they continue to carry out changes in instructional practice in the face of a global pandemic could be the result of the data that emerged in the second theme suggesting the desire to make a more considerable impact beyond themselves.

Faculty members continue to implement instructional practice changes because they want to contribute to something greater than themselves. All of the faculty members interviewed ($n = 6$) and 79% of survey respondents ($n = 14$)

described continued use of new strategies and participation in the PLP because it created a more significant impact on the students they teach and a greater impact on society at large. Survey Respondent 19 concisely stated,

> If your goal is impact, [Program] helps you reach more students. If your goal is inspiration, [Program] helps you give students voices. I became a teacher to make better engineers in service to humanity, and [Program] has given me community.

The overarching theme to impact something greater than themselves was further broken down into the impact on students, and the impact on society as a whole and discussed individually.

Impact student learning. Faculty members described a desire to contribute to something greater than themselves when they discussed the impact on student learning as a reason to continue to implement changes in instructional practice. Interviewee 5 explained, "Students face very manicured problems; everything is cleaned up and prepped for them to illustrate a method. I want to change it up." And Interviewee 4 stated, "Talking at students for an hour at a time is not an effective way to teach, but this [module] is engaging for students." When asked why they continue to use the newly adopted strategies, Interviewee 1 stated,

> I've always thought that students learn better if they can see how the material is connected to the real world and that this is not just theoretical things that we're studying, but this actually can be very useful and impactful. That appeals to me.

Faculty members described a desire to impact student learning beyond the classroom. Survey Respondent 17 stated, “Now I assign more real-world oriented projects to provide the students a bigger picture understanding of what they are learning.”

Faculty members described continuing to implement the changes to impact student attitudes about engineering significantly. Interviewee 2 described connecting content to the student lives by stating,

> I try to incorporate some of the things that we learned, incorporate more real-life examples, or just stopping the class and asking, ‘How would you use this in real life?’ And doing a think, pair, share just till they start thinking more entrepreneurially like ‘Well, what added value does this have?’ as opposed to just like ‘Oh, this is something I need to learn to get an A.’

Survey Respondent 5 noted a concern for student learning by continuing to implement changes in teaching practice, “Changes need to make sense for our students and be something that brings added value to our students.” Finally, impacting student learning motivated some faculty members to sustain changes to their teaching practice. Interviewee 6 explained, “When you see value, you are motivated to change, or when you see students succeed, it makes you want to succeed.”

When asked why faculty members continue to implement new teaching strategies, they described contributing to something greater than themselves by impacting student learning. The new strategy needs to add value to students and provide students with a greater understanding of real-world implications. Faculty members portray assisting students in understanding their impact on society, which leads to the second theme that emerged from the data.

Impact on society. Faculty members describe the impact teaching engineering has on society as a reason they continue to implement changes to teaching practices. When asked why they continue to make the changes Interviewee 1 stated that “Engineering impacts humanity, the environment, and safety.”

Interviewee 3 described teaching Engineering as a means to have a more significant impact by saying,

> Engineering is really tough, and a lot of people drop out, go into other programs, and I think when you understand that what you’re doing is really important and has the ability to affect positive change on things around you, I think it helps to try a little bit harder.

Interview 4 depicted how the impact on society emerged as a reason to continue the effort. Interview 4 stated,

> I’m asking students to do something very different. I ask my students to think more broadly about technical skills that we're working on and connect them out to society. It’s worth thinking about how this data impact engineering projects, how the data changes as the world, the actual physical world, and the globe changes.

Contributing to something greater than themselves by impacting student learning and society as a whole were the themes that emerged as faculty members explained why they continue to implement instructional changes. Faculty members described efforts to teach their students to think more globally and conveyed the importance the field of engineering has to impact society for the greater good.

Research Question 3: What conditions of the partnership facilitated change in teaching practice?

Two major themes emerged from the inductive analysis of data gathered through surveys and interviews when faculty members described conditions of the partnership that facilitated changes in their teaching practice. The first theme that addresses partnership conditions includes the need of faculty members to have a sense of value to make a change. A second theme arose that facilitated change which included reflectiveness in teaching and learning, collegial support the program provided, and pedagogical support which reportedly facilitated instructional changes.

The need for value to make a change. Faculty members described several conditions within the PLP that facilitated change in their instructional practice if there was a clear sense of value in making the change. Overall, 74% of the participants were willing to change their instruction if there was value in modifying their curriculum, particularly if it took a significant amount of time. Second cycle coding suggested the concept of "time" was an essential value for faculty members, such as instructional time, planning time, and time to conduct research. Faculty members were willing to negotiate valuable time as they made changes to their practice, which led to the first two conditions: the effectiveness of the change and trade-offs in curricular decisions. Faculty members described two additional conditions present in the partnership that facilitated change: accountability to others when making a change and feedback on their instructional practice.

Effectiveness of the change is a valuable condition. Faculty members described valuing the change's effectiveness as a condition that informed their decision on whether or not to adopt that change. Effectiveness included the validity of the new practice and evidence that it worked.

When asked on the survey what conditions were necessary in the PLP to change teaching practices, Survey Respondent 14 wrote, "Effectiveness is the main condition." Survey Respondent 9 linked effectiveness to his/her own experience as a condition needed to change teaching practice. "I need to see formal evidence that it works, and it also needs to resonate with my own experiences." Survey Respondent 18 explained that the program was not practical for the subject matter taught,

> I needed to see a clear path to apply it in a [Department] classroom. A lot of 'how to use this strategy' examples seem to focus on discussion-based liberal arts courses rather than the technical skills taught in [Department].

Faculty members reported that it takes time to use new strategies to demonstrate effectiveness, but that assessment could be a method to validate the effort. One emphasis of the partnership was assessing the modules created by the faculty members as a demonstration of their effectiveness and likelihood for replication.

Assessment as a measure of effectiveness. Assessments helped inform the effectiveness of the instructional changes and were a considerable component of the

PLP. The School of Education doctoral students met with the faculty members to discuss learning objectives to facilitate the creation of the assessments prior to the development of the modules. The research team was responsible for monitoring the implementation of assessments from creation to dissemination and collection when completed. Interviewee 1 stated, “Being able to connect with someone at the School of Education, to talk about, especially the assessment piece, I think was really, helped me have more confidence in the validity of what I was doing in the end.”

When asked to provide an example of supports that are necessary to make changes to instructional practices, Interviewee 4 responded,

> The school of ed people helped develop the assessment tools we used to evaluate the modules. When we were making up questions, we shared those with people from the school of ed and got feedback on them, so we can learn a lot about assessing teaching methods and learning.

All 32 Cards posted on the national network included quantitative and qualitative assessment results for each module. This data led to five published papers at the American Association of Engineering Education conference in 2020.

Trade-offs in curricular decision making. Faculty members reported time was a valuable consideration when making curricular decisions, and each decision required inevitable trade-offs. Trade-offs include time for planning and personal time, active learning strategies versus the ability to cover content, and the impact on other courses. Interviewee 4 described the trade-off between planning and personal time when they stated, “If I’m going to spend a couple of hours reworking how I present a topic, or how students access that topic, that's a couple of hours that I'm not doing something else. I need to recharge."

Faculty members may perceive the use of active learning strategies as time consuming. Several faculty members described the trade-off between the time it takes to use an active learning strategy and completing course content. Interviewee 2 shared,

> You can either teach a lot of stuff or cover less topics in more depth. Adding active learning modules, I think, gives much more depth, but it just will take a lot more time than just lecturing at a student.

Interviewee 1 explained, "To incorporate the big picture things sometimes feels like you're going to have to take away some of the technical content, and it's hard to make those trade-offs sometimes."

Some faculty members expressed the trade-off was too great to change their instructional practice. Survey Respondent 18 contemplated the use of a new strategy when they asked, "Will the strategy slow down amount of course material that I will be able to cover?"

And Survey Respondent 16 stated,

> The buy-in to the new idea can't be too high of cost (time and energy). Also, I am not one to make drastic changes to my teaching methods, as I believe they work for me at this instant in time.

Trade-offs in course content can also impact other courses. Interviewee 1 expressed a concern,

> What if what you're doing affects other people's classes? Sometimes there's pressure just to keep doing it the way you're doing it, right? If your class is a prerequisite for other classes, it may be difficult to make changes that affect other people's classes. Some of the faculty don't want to make too many changes because it just takes a lot of time.

Faculty members described trade-offs in curriculum decision making as a valuable condition when considering implementing a change in instructional practice. The exchange needed to be of value predominately when it comes to planning time and executing a modification to instruction within a class.

Accountability to others is a valuable condition. Faculty members described accountability within the partnership as a condition that facilitated the implementation of instructional changes. Accountability measures such as transparent systems and oversight and financial rewards were in place as part of the program's design. Accountability to colleagues was also expressed by faculty members as a condition when considering changing instructional practices.

Accountability was built into the design of the PLP. Each doctoral student was assigned a set of faculty members to work with directly by scheduling meetings to support curriculum development, set up observations and provide assessment assistance. The research team met regularly to discuss the progress of each faculty and devise needed supports as necessary. Also, faculty were paid a small stipend only after their module was assessed and posted to the network site, most often with the assistance of someone from the research team.

Interviewee 1 described how the condition of accountability facilitated the implementation of the module by stating, “The fact that they (PLP) held you accountable for actually implementing the module, I think that made it much more likely that I would actually do it because I knew I was going to be held accountable.” Interviewee 5 described how the partnership overall kept them accountable by sharing,

> [Doctoral student] did the assessment, helped me review the modules, and gave me feedback. If nothing else, they kept me on track because I knew that he would be coming Monday, X, Y, Z, so I couldn’t just be running the labs on the printer 10 minutes before class.

Faculty members also described being held accountable to their colleagues as a condition when deciding to make changes to instructional practices. Interviewee 1 stated, “So certainly, if you’re trying to change what you teach in your class, that can affect follow-up classes, but even if you’re just trying to change how you teach it, it seems like often it’s going to take more time.” And Interviewee 3 explained, “If your class is a prerequisite for other classes, it may be difficult to make changes that affect other people’s classes.”

Overall, faculty members described accountability as a valuable condition within the partnership to change instructional practice. Accountability was described as a motivator to stay focused on implementing changes within the partnership and being aware of changes that colleagues who teach other courses.

Feedback is a valuable condition. Providing feedback to faculty members from the School of Education as they created and implemented their modules was a

PLP design element. A pre-meeting and post-meeting were scheduled with the doctoral students to discuss the module and provide feedback before and after instruction. Faculty members described value in the feedback they received from the School of Education as a condition to make changes to instructional practices.

When asked what supports are necessary to change instructional practice, faculty members cited feedback as an essential element. Interviewee 2 said, “Just being able to bounce ideas off the school of education, to have somebody there observing, to observe my class and be able to talk immediately after class about how it went, that was helpful.”

Interviewee 4 also discussed feedback as helpful when making curricular decisions.

> Being able to bounce some ideas off school of ed folks was helpful when I'm thinking about a teaching change that doesn’t traditionally fit a specific course. So, having someone to run some parts of this by it was really helpful because one of the things that I personally find as an impediment when I think this would be a good thing to do and I’d like to bring it in is I’m really busy and what’s if it’s too much and we don’t have time for it.

Faculty members described feedback from their colleagues that added value to their participation in the program. Survey Respondent 13 stated, “It was a good way to get feedback from other colleagues and have time to spend on thinking about new activities to complete in class and learn what other colleagues were doing.”

Feedback was cited as a condition of the partnership that facilitated a change to instruction. Faculty members described feedback as useful and helpful, particularly in an informal and collegial manner. Feedback was also evidenced in artifacts and documents found in the products created from the partnership.

Artifacts and documents support feedback. The participants described feedback as a condition that facilitated a change to instructional practice within the PLP. Posted Cards ($N = 32$) and observation notes ($N = 10$) were examined to verify the interviews and surveys' data. Faculty members received feedback on their modules or cards posted on a national website supported by a grant that funded the program. In an analysis of the 32 Cards published by the participants, 23 unique comments provided feedback on eight Cards with questions, accolades, and encouragement. Examples include, "Thanks so much for sharing the course assignment, handout, and an example of student work! I think we often struggle to find meaningful, hands-on examples for a mathematically intensive course, but this is a great example of how to do so!" Another comment expressed, "As a former instructional designer, I love the fact that your instructions are clear and that you provide relevant examples to your students. Well-designed activity!"

Six out ten observation notes included references to feedback ascertained by the doctoral students from Engineering faculty members. One set of pre-observation notes stated, "Met to discuss a rethink of the module. We discussed options and decided it would be more worthwhile to share several alternative options of code with students." In another document, a doctoral student made a note, "[Faculty member] would like to have one of us go through the lab with [him/her] once it is done and get some feedback."

Artifacts from the national network and documentation in meeting notes supported the use of feedback within the PLP described by participants while making instructional changes.

Reflectiveness and support from others facilitate change. The second theme that emerged from the data in research question three described conditions of the PLP that facilitated change include reflectiveness as a teacher and the need for support. When asked about which conditions facilitated change in instructional practice, faculty members began to reflect on personal experiences as a teacher and learner. They also discussed support from others, including departmental approval for taking risks and interdisciplinary support from the School of Education.

Self-reflection as a teacher and learner. Faculty members described self-reflection in their teaching practices as one of the conditions in the PLP that facilitated change. Participants described their own experiences as a learner and how that impacted them as a teacher.

Interviewee 6 stated,

> I need time to be reflective in how I teach (before adopting a new strategy). As somebody who came through the traditional engineering education background, ethics has always just been one sterile case study after another, where you learn about that space shuttle Challenger. It's really hard to engage,

> but when we're sitting in the classroom looking at something that they (students) made it's pretty interesting.

Interviewee 5 also reflected on their undergraduate experience when asked about conditions needed to make a change. "I didn't feel engaged in my own undergraduate Engineering education. It's a miracle I've ended up in this place (teaching undergraduate Engineering courses)."

Faculty members reflected on decisions they made as a professional as Interviewee 3 described,

> There's always this assumption that it's like 'Oh well, I'm the professor and I just make these decisions because I have a Ph.D.' But the idea that you can still maintain some academic rigor by also allowing students to participate in the formation of the class that they're in and giving them the autonomy to have control that is hugely motivating. That has permeated my classes and more facets than I ever thought it would.

One faculty member reflected on their decision making as a teacher and flexibility when asked about conditions of the PLP that facilitated change.

Interview 4 stated,

> You've got to be okay with failure, right? You can't have an attitude that my job is to be the expert and never have a chink shown in my armor. I've got to recognize that something I think is going to take 5 minutes or 10 minutes might end up taking 30 in the classroom, and then I have to adjust. I think you have to be able to roll with things; if you're not willing to accept that the day

> might not go the way, exactly the way that you planned, then you're never going to able to try this, something new.

Self-reflection as a teacher and learner was reported as a condition of the PLP that facilitated change to instructional practice by participants.

Collegial support for changing practice. Faculty members described collegial support as one of the conditions within the PLP that helped to change teaching practice. Participants reported this condition, particularly in the context of taking risks when making an instructional shift. Survey Respondent 14 reported, “It was a good way to get feedback from other colleagues and have time to spend on thinking about new activities to complete in class and learn what other colleagues were doing.”

Interviewee 4 discussed the importance of their colleagues in a community by stating,

> I think community is the most important piece of it for me. I think early on in my career, and it was when I was looking at changing from how I was taught, which is the first thing you do at least in Higher Ed, that’s the first place you look to be a teacher what you’ve seen. To be able to see how other faculty these things in their classroom do was critical for me to be able to it because you can read an article about this is what you can do. You can hear from someone else that they can recommend you try it but to see what it actually looks like was critical. How are you as a teacher in the room while you’re trying to change over the educational process to the students? I think it was really helpful.

The national network also provided collegial support as a condition of the PLP that facilitated change in teaching practice. Faculty members can attend national conferences and use the national network website to share information with other engineering educators across the country. Interviewee 6 described the support by explaining,

> They (community) can help get you out of the trap of still using the same lecture notes you had six years ago. It's also nice to know there is a group of people, not just at my institution but nationally that are looking for ways to make the experience better. I'm excited about how that leads towards modifying how we teach.

Collegial support also contributed to facilitating change within the partnership to try new strategies and take risks otherwise not attempted.

Taking risks to change practice. Participants expressed changes to instructional practice can involve taking risks and making mistakes. The need for support from colleagues and departmental leadership, in particular, was a condition of the PLP that faculty members described to feel safe and take risks. The following excerpts are from interviews where two faculty members answer the question about the support necessary to change instructional practice within the PLP and describe the need for leadership support. Interviewee 4 explained:

> Having other faculty and especially administrators who are supportive of innovative teaching is needed because if they're not and things go a little bit sideways, or students don't like working in groups, they complain. You need

> faculty and administrators who understand that talking to students for an hour at a time is not an effective way to teach.

Interviewee 3 shared,

> It's always nice to have support from your colleagues or support from leadership. Sometimes when you make a change, it doesn't go well, so making sure that 'Hey, I'm going to make these changes. I might screw up on some of things, but ultimately, I'm going to figure this out.' In that muddy process, I need somebody to be like, 'Keep doing that. Don't stop and revert to the safe thing.'

Faculty members reported support from colleagues as a condition of the PLP that facilitated making a change in instructional practice. Faculty members went further to describe the need for support from departmental leadership when trying something new.

Pedagogical support as a condition. Researchers in the School of Education and School of Engineering partnership supported implementing evidence-based instructional strategies to faculty members participating in the partnership. Support provided included training, one on one coaching, classroom observations, feedback, and assessment. Researchers analyzed data derived from the assessments and facilitated the Cards' development and posting on the national network website.

Pedagogical support emerged as a condition of the PLP that facilitated changes in instructional practices. Faculty members referred to pedagogical support in five out of the six interviews when asked about supports and barriers to instructional practice within the PLP.

Interviewee 6 explained,

> I think that the piece that was maybe the most impactful was the contributions of the School of Ed. That is something I hadn't had before. It's one of the things where we all teach, but none of us have studied how to teach. It was really great to have people in the class, in the workshop, helping us develop methods for implementation and also to come to classes and listen to us and give us feedback on that. I think those pieces tend to be overlooked.

Another pedagogical support faculty members described as a condition that facilitated change was direct classroom support. Interviewee 5 stated, "I love their presence (School of Education) in the School of Engineering. They were the ones who gave me three, five, different ideas of how to actually remap my ideas into kind of deliverables." And Interviewee 2 stated, "The [PLP] helped me put together the material, which was really helpful and really helped with the that sort of time barrier."

Working directly with the doctoral students to provide feedback and discuss curricular ideas was described as beneficial. Interviewee 4 explained, "I'm the only one that teaches it, so someone to run some parts of this by with was really helpful."

Survey respondents described the partnership's training as a condition that facilitated changes and had a positive impact. Survey respondent 12 wrote, "It's been great professional development. Far exceeding any other trainings or education-focused conferences." And Survey Respondent 6 stated, "It's great training and a very supportive community!"

Pedagogical support facilitated instructional change as reported by faculty members participating in the partnership. Training, coaching, and feedback provided some of the necessary conditions to try new strategies and minimize time barriers during implementation.

Summary

This chapter discussed findings developed through data analysis of 19 surveys, six interviews, and 42 artifacts and documents in higher education faculty members' professional learning experience. Deductive themes and inductive categories emerged from the data and related research questions to the findings. Explanations of how faculty members describe changing their teaching practices due to participating in a unique partnership are also presented. Faculty members expressed a sense of belonging aiding the potential change, a sense of value when making a change, and the need for support in the process.

Summary of Research Question 1. Each research question is summarized through inductive analysis, a qualitative research approach that links research objectives with the raw data to ascertain overarching themes. Table 13 summarizes the deductive themes and inductively identified categories of research question one.

Table 13

Deductive Theme and Inductively Identified Categories for Research Question 1: Why did faculty members choose to participate in a professional learning partnership?

Deductive theme	Inductively identified category	Exemplar quotes
Sense of Belonging	Lack of pedagogical training	"We're engineers, so we're not trained in education."
	Feelings of isolation	"Being a professor is kind of lonely sometimes because all your colleagues are just so busy."
	Collegial support and encouragement	"I wanted to do something with my colleagues."

Faculty members reported the feeling of belonging in choosing to participate in a PLP. Faculty members expressed a desire for formal pedagogical training and a sense of connectedness with their colleagues.

Summary of Research Question 2. Research Question 2 made an effort to understand how faculty members described any changes made due to the PLP. Table 14 represents a summary of the findings for research question 2.

Table 14

Deductive Themes and Inductively Identified Categories for Research Question Two: How, if at all, do faculty members describe changing their teaching due to participating in a partnership?

Deductive theme	Inductively identified category	Exemplar quotes
Use of EBIS in STEM	Active learning	"I've increased the amount of active learning in my classes even more."
	Case-based real-world connections	"I felt good about assigning a real-world oriented project about a topic related to my course that I don't usually teach in my course, and I would like to do this more in the future."
	Problem-based learning	"I have used more problem-based learning strategies."
	Collaborative learning	"More student group work."
	Benefits but no change	"I was already using these teaching strategies; however, it has provided me with an opportunity to add more interactive content to my classes."

Faculty members described using evidence-based instructional strategies in changes made to their teaching practices due to participating in the professional learning program. Strategies that put groups of students at the center of authentic learning experiences were most common. While not all faculty changed due to the partnership program, they reported applying some active learning into their instructional practice.

Summary of Research Question 2 A. Research Question 2 A examined if changes to teaching practices were sustained over time, if so how and why. Table 15 presents an overview of the findings.

Table 15

Deductive Themes and Inductively Identified Categories for Research Question Two A: If changes in teaching practice occurred, were they sustained over time, and if so, how or why?

Deductive theme	Inductively identified category	Exemplar quotes
Faculty continue the use of new practices	Continuation of implementing changes	"I would say the modules that I created were really well received, and I continue to do those in my classes every year."
	COVID-19	"Not this year, but maybe next year, due to COVID-19."
Contribute to something greater than themselves	Impact student learning	"If your goal is impact, (Program) helps you reach more students."
	Impact society	"I became a teacher to make better engineers in service to humanity."

Faculty members continue to implement changes made due to the partnership, even though a global pandemic disrupted their teaching practice. While the pandemic impacted content delivery, faculty members reported feeling a desire to make a more considerable contribution to society beyond themselves.

Summary of Research Question 3. Research Question 3 begins to address the conditions that facilitated instructional practice change within the partnership program itself. Table 16 presents an overview of the findings.

Table 16

Deductive Themes and Inductively Identified Categories for Research Question Three: What conditions of the partnership facilitated change in teaching practice?

Deductive theme	Inductively identified category	Exemplar quotes
Sense of Value	Effectiveness of the change	“I need to see formal evidence that it works.”
	Trade-offs in curricular decision making	“Will the strategy slow down amount of course material that I will be able to cover?”
	Accountability to others	“I would actually do it because I knew I was going to be held accountable.”
	Feedback is a valuable condition.	“To observe my class and be able to talk immediately after class about how it went, that was helpful.”
Reflectiveness and Support	Self-reflection as a teacher and learner	“I need time to be reflective in how I teach.”
		“I didn’t feel engaged in my own undergraduate engineering education.”
	Collegial support for taking risks	“Having other faculty and especially administrators who are supportive of innovative teaching because if they’re not and things go a little bit sideways, or students don’t like working in groups, they complain.”
	Pedagogical support	“It was really great to have people in the class, in the workshop, helping us develop methods for implementation and also to come to classes and listen to us and give us feedback on that.”

Faculty members described valuable conditions facilitated by the PLP to change instruction, such as understanding the effectiveness of a new strategy, deriving feedback about it, and feeling accountable to their peers when expending time to implement something new. Other conditions that facilitated a change to instructional practices included support from colleagues on teaching and learning and being a reflective educator.

This case study's findings are organized by themes and categories and exemplified with direct quotes from participants. Chapter 5 provides a discussion and implications of these findings.

Chapter 5: Discussion

The Science Technology Engineering and Mathematics (STEM) workforce is in high demand in the United States, yet the higher education system is not graduating enough students to fill the expected need (Committee on Prospering in the Global Economy of the 21st Century, 2007; Holdren & Lander, 2012). Significant reform efforts to increase college-level completion rates have flourished since the Obama administration's call to action that included funding and incentives to improve teaching and learning within the STEM field. University faculty members are highly trained in their disciplines but most often do not receive pedagogical instruction on how to teach those disciplines (Wieman, 2014; Winberg et al., 2019). Faculty use of evidence-based instructional strategies is linked to increased student achievement and retention in undergraduate students (Felder et al., 2013; Haak et al., 2011; Terenzini et al., 2001). This case study seeks to understand the extent to which STEM faculty members who teaches undergraduate students change their practice over time after participating in a unique interdisciplinary partnership.

This chapter includes a discussion of the overarching problem and noteworthy findings from each research question and how these findings relate to current research. Implications for professional practice, limitations of the study, and suggestions for future research are also presented.

The purpose of this qualitative case study research was to understand how faculty members in one School of Engineering change their teaching practice through professional learning in partnership with their university's School of Education. This instrumental case study focused on a single case, bounded by one unusual professional learning partnership (PLP) in a real-world context (Creswell, 2013; Mills & Gay, 2016; Stake, 1995; Yin, 2018). The PLP sought to improve teaching and learning by providing faculty members with training and ongoing support from an interdisciplinary team with pedagogical expertise.

The professional learning partnership (PLP) was a joint effort between the Schools of Engineering and Education to support and coach Engineering faculty members in designing, implementing, and assessing curriculum over two years. Data were collected and analyzed from 6 interviews, 19 surveys, and 32 modules created by the professional learning program participants (PLP) at one small university in the Pacific Northwest. Participants in the study were selected based on purposive-criterion sampling, which was used to access participants' rich experiences in the professional learning program (Mills & Gay, 2016; Patton, 2001). All faculty in the Engineering department received a survey that included seven open-ended questions to gather data about instructional strategies, perceptions of participation in the PLP, and conditions needed to change teaching practice. A decision was made to analyze data from faculty members involved in the program to some extent. Criteria included faculty members who attended at least one local or national training related to the PLP, developed at least one module, and posted it on a national network website. Engineering faculty members selected for in-depth structured interviews also had to complete the survey. To understand how faculty members changed their teaching practices, if at all, as a result of the PLP, it was essential to capture various experiences from faculty members from those who heavily participated to those who were only slightly involved in the PLP. Structured interviews were used to gather data on why faculty members chose to participate, how they described any changes they may have made due to their participation, and conditions they need as teachers to change their instructional practice. Patterns and themes surfaced from transcripts of structured interviews, survey results, and modules corresponding to each research question.

Findings suggested faculty members chose to participate in a professional learning opportunity because it provided a sense of belonging they may not receive otherwise in their profession. Faculty members described feelings of isolation as the lone professor in a specialized field coupled with a lack of pedagogical training and a desire to improve in the craft of teaching. Encouragement from colleagues and subsequent support also likely contributed to a greater sense of belonging and incentive to participate in the PLP.

Participants reported an increase in implementing evidence-based instructional strategies (EBIS) due to the PLP that engaged students with relevant and applicable curricula. Strategies that put students at the center of instruction and increased engagement in the curriculum were implemented most often. Faculty members used collaborative learning strategies to encourage students to solve problems in a real-world context. While not all faculty members described changes to their practice due to the PLP, they still described active learning strategies in their instructional practice.

The use of EBIS by participants of the PLP persisted over time, despite a global pandemic, partially due to faculty members' desire to contribute to something greater than themselves. The COVID-19 pandemic shuttered the doors of the education system in early 2020. However, the Engineering faculty members continued to implement changes they made to their curriculum due to the partnership. Participants created 32 modules in the span of the PLP, and most are still using them or plan to use them once in-person learning resumes. One of the reasons faculty members continued to utilize the modules might be to contribute to something greater than themselves that impacted their students and society. Teaching students to solve problems that impact society's health and welfare may have motivated faculty members to continue changing their practices and improving student learning.

Lastly, findings suggest that certain conditions were in place that facilitated faculty members to make changes in their teaching practice. Although time appeared to be the most significant barrier in making a change, faculty members were more willing to transform their practice if they saw the value in the change itself. When faculty members saw the change's effectiveness and could weigh the trade-offs in curricular decisions, they would be more likely to continue with the effort. Accountability systems and opportunities for feedback embedded in the PLP likely facilitated faculty members' instructional practice changes. Other conditions of the partnership that facilitated change included time for reflection, support from colleagues, senior leadership to take risks, and the school of education's solid pedagogical support.

The study filled a gap in the research on using embedded experts, specifically those with pedagogical expertise, to pursue professional learning in higher education.

While a limited number of universities utilize embedded experts to provide scientific and pedagogical support, few, if any, work directly with Schools of Education that presumably possess cutting-edge research on instructional practices (Bonner et al., 2020; Wieman, Perkins, & Gilbert, 2010). This case study revealed insights into a professional learning program that used a partnership between two schools on a university campus to provide ongoing pedagogical supports to Engineering faculty members. This final chapter discusses this case study's findings, connections to the literature, implications of the findings, and future research ideas. Significant findings for each research question are discussed individually.

Research Question 1: Choosing to Participate

Research findings from this case study suggested faculty members chose to participate in a professional learning partnership because of a basic need for a sense of belonging within their professional practice. Fundamental to fostering a sense of belonging is identifying with an individual or group, feelings of inclusion, and acceptance (Baumeister & Leary, 1995; Owens et al., 2018). Participants seemed to elect to participate in the PLP because they lacked the necessary training in pedagogy, felt isolated from their peers at a small university, and wanted to be a part of a group of learners that included their colleagues.

Most faculty members in higher education, particularly in STEM, have little to no pedagogical training (Bok, 2014; Henderson et al., 2011; Holdren & Lander, 2012; Wieman, 2014; Winberg et al., 2019). STEM graduate education programs primarily focus on discipline-specific rather than pedagogical content knowledge (Shulman, 2005). In this case study, all participants interviewed discussed a lack of instructional knowledge and a desire to improve teaching practice as primary reasons for participating. Although faculty members identify as teachers, they may not believe they have the skills and expertise to provide instruction to their students. Interviewee 4 candidly stated, "We are engineers, so we're not trained in education." Much of a professor's daily work revolves around instruction, particularly at a small university that prioritizes teaching. Hence, a professional learning program that offered support from pedagogical experts was likely appealing. Interviewee 6 also explained, "You're surrounded by people who are teaching. None of them have had any formal education on how to teach." Participants in this study seemed to describe feelings of a disconnect between highly educated and trained faculty members in the Engineering field and their skills and knowledge of instructional strategies that comprise much of the demands of day-to-day work. Therefore, this may have led 53% of faculty members in this particular Engineering school to participate in professional learning focusing on instructional strategies, curriculum design, and assessment.

Feelings of isolation in a small University likely contributed to faculty member motivation to participate in a program that potentially increased feelings of inclusion and led to a greater sense of belonging (Baumeister & Leary, 1995; Owens et al., 2018). Inclusion in a group takes into account a fit between oneself and others. Some faculty members described wanting to participate because they could find others interested in changing their practice. As Interviewee 4 explained, "I'm the only one that teaches this course, and the only other faculty that I could talk about this with is not interested in innovative teaching." Isolation can lead to loneliness, and faculty members likely chose to participate in order to find community. Interviewee 2 also spoke of feelings of loneliness as a professor, "I wanted to improve my teaching because being a professor is kind of lonely sometimes. All your colleagues are just so busy."

Collegial support and encouragement from departmental leaders motivated faculty members to participate in the PLP. When innovations take into account and develop departmental culture and focus on collegiality, they are more likely to succeed (Froyd et al., 2013; Henderson et al., 2011). Faculty members wanted to connect with their colleagues around teaching and learning and likely felt safe taking risks to change their practice. Interviewee 4 stated, "[University] values teaching, and I wanted to be a part of it to do something with my colleagues."

Successful interventions often involve a *change agent*, a person responsible for facilitating efforts, and deliberately focusses on beliefs about the latest strategies (Gelles (2020); Henderson et al., 2011). The design of the PLP included a focal person, or change agent, in the Engineering department that had trusted relationships with colleagues and was instrumental in establishing the program from design to implementation. This change agent encouraged participation, provided support where needed, and held faculty members accountable in creating the modules and their presentation to a more extensive network of the Engineering education community. Interviewee 6 reflected, "[Change agent] certainly was foundational in the forming of this effort." Informal networks of faculty members worked together to create modules and to support the national network of Engineers. Formal and informal networks, often facilitated by a change agent, provide a safe and supportive environment to try new strategies, motivating faculty to participate in the PLP (Hutchings, Huber, & Ciccone, 2011; Kezar, 2014; Kezar et al., 2019). Interviewee 3 explained, “There were some senior faculty I knew and respected, and they said they went through it and that it was helpful for them.” In this case, the change agent acted as an embedded expert that bridged the partnership between the School of Engineering and the School of Education. Also, the change agent seemed to earn colleagues’ trust and respect.

Faculty members described a lack of instructional knowledge, a central component of their jobs, and feelings of isolation from their colleagues. Seeking a sense of belonging could explain why they gravitated toward a professional learning opportunity that provided expertise in instructional strategies, support in curriculum design, and fostered a community of learners. Faculty members probably thought that they lacked some of the necessary skills to do their job, felt isolated, and may have found solace in a community of learners that offered them collegial support and encouragement.

Research Question 2: Faculty Members Describe Instructional Change

Research Question 2 sought to answer how faculty members described changes to their teaching due to participating in the professional learning partnership. While not all participants described changes to their practice, 84% reported using evidence-based instructional strategies (EBIS) as a result. EBIS is also referred to as active learning strategies and involves student-centered instructional methods that place students as the main actors engaging with relevant content often in collaborative groupings (Borrego et al., 2013; Felder, 2009; Prince et al., 2013). Interviewee 2 stated, “I’ve increased the amount of active learning in my classes even more.” Faculty members used the term *active learning* to describe various strategies, although it is a general term to describe what all students do in the class other than watch, listen, and take notes. Faculty members likely used EBIS due to the training, one-on-one coaching with doctoral students, and the emphasis on the assessments used to evaluate each module. A careful examination of the 32 modules created and posted on a national network website corroborated these findings, of which 100% included some form of active learning.

Three forms of active learning include case-based teaching, problem-based learning, and collaborative learning, three EBIS that overlapped and found in most modules. In case-based teaching, students analyze authentic case studies of practical situations that involve solving problems and making decisions using real-life scenarios (Borrego et al., 2013; Lundberg & Yadov, 2006; Prince & Felder, 2004). Case-based teaching often encompasses problem based-learning, in which the instructor places students in collaborative, self-directed teams to solve open-ended problems (Froyd et al., 2013; Prince, 2004; Woods, 2012). Self-directed groupings are also considered a collaborative learning strategy (Borrego et al., 2013; Johnson et al., 2006). While these three strategies often intersected, 100% of the learning modules were grounded in a real-world context. Faculty members included real-world scenarios such as ethical dilemmas around vaccine distribution and preventing catastrophic events such as dam breaches resulting from natural disasters. Survey Respondent 17 wrote, "I felt good about assigning a real-world project about a topic related to my course that I don't usually teach in my course."

In a national survey, Lundberg and Yadov (2006) found that when faculty members use case-based teaching, students are more engaged and able to view the problem from multiple perspectives. This study supported their findings. All six interviewees described incorporating real-world connections, problem-based learning, and collaborative learning as the main strategies to engage students in the learning process. Interviewee 3 explained, "I think students really like the idea of the things that they're learning being applied to the real world, and particularly things they care about."

Learning objectives appeared to reflect the use of case-based and problem-based learning. All 32 modules contained learning objectives connecting the content to real-world scenarios and reflected problem-based learning as one of the strategies. Learning objectives such as "Students will consider a problem from multiple viewpoints" and "Students will identify links between course knowledge and real-world systems" exemplifies their connection to the research on increased engagement in students (Lundberg & Yadov, 2006). Modules developed due to the PLP were designed to increase student engagement because they are grounded in a real-world context and problem-based learning.

Faculty members used various strategies to increase student interactions as part of their participation in the PLP. Collaborative learning used in 97% of the modules suggested faculty members applied new strategies and sought to engage students with each other to learn content actively. In sociocultural learning, individual and collective understanding is mediated through collaboration and dialogue in the learning process(Vygotsky, 1978). The use of collaborative learning such as partner work, group work, and class discussions using real-world examples and open-ended problems seems to demonstrate the use of EBIS within the professional learning program.

A few faculty members reported on the survey that they did not experience any changes to their instruction due to the PLP. However, they seemed to find some benefit in increasing student participation in their classrooms. Survey Respondent 9 stated, "I was already using these strategies; however, it has provided me with an opportunity to add more interactive content to my classes."

To further corroborate the findings, faculty members completed the Postsecondary Instructional Practice Survey (PIPS), a valid self-reporting tool (Walter et al., 2016) used to confirm related instructional practice changes attributed to participation in the PLP. The highest-rated factor amongst faculty members was student-content engagement, which appears to corroborate the reports from faculty members that they used strategies that engaged students with content through problem-based learning, case-based teaching, and other active learning strategies.

Coaching from the research team possibly contributed to faculty members' seemingly abundant use of EBIS. Instructional coaching includes a research-based approach to strategies and provides differentiated supports, depending on the person coached (Knight, 2006). Within the PLP, no two participants received the same level of coaching. Some met with doctoral students consistently before and after each created module, some developed more than one module, and others met only once. In many cases, doctoral students were viewed as experts in instructional strategies and offered support when requested. Ongoing and consistent coaching interactions improve this type of professional development, but this detail level was not a part of the study (Garet et al., 2001).

Research Question 2a: Changes Sustained Over Time

Research Question 2a sought to answer whether changes to teaching practice due to the PLP persisted over time and, if so, why. In order for professional development to be effective, the intervention must be sustained over time for at least one semester, coordinated and focused (Desimone & Pak, 2017; Ellet et al., 2015; Garet et al., 2001; Henderson et al., 2011; Hord et al., 1987). According to survey data and interviews, 71% of faculty members who participated in the program are either continuing or plan to use the changes they made to their practice. Another 21% reported uncertainty in future use, and 7% said they would not continue the changes. Several reasons may contribute to these findings' results, including a change agent's efforts, a focus on student learning, a desire to contribute to something greater than themselves, and the impact of the COVID-19 global pandemic.

The PLP lasted over two years and seemed to be sustained partially due to the change agent's efforts within the Engineering department. Henderson et al. (2011) conducted a meta-analysis of 191 journal articles about change in STEM education and found that change agents were vital to facilitating professional development efforts. The change agent in this case study coordinated faculty member participation in the program and focused the PLP team's effort in coaching and assessment. The change agent's role was likely central to the program's success due to student assessment and providing fast results to faculty members. STEM faculty are more likely to adopt a new strategy if data suggest it is effective (Wieman, Perkins, & Gilbert, 2010). The PLP supported faculty members in assessment design, implementation, and analysis. Students completed the assessment, and the PLP research team provided qualitative and quantitative results directly back to the faculty member. Further, the PLP research team worked with faculty members to disseminate their findings by creating a Card, a one-page snapshot of the quantitative and qualitative results that included a description of the module, links to student materials, and examples of teaching tips for replication. A sample Card is included in Appendix D.

Faculty members were also encouraged to publish results in a national engineering conference and journals. Five faculty members published results in 2020 based on their participation in the PLP and the modules they developed. When faculty members focus on the scholarship of teaching and learning, they are more inclined to use new engagement strategies (Hutchings et al., 2011). Several faculty members spoke of the tension between the recognition and rewards for publishing in discipline-based journals instead of education-related journals. Interviewee 6 contemplated, "The School of Engineering values pedagogical research; whether or not that should be counted towards a promotion or not is up for debate. If I do a paper for ASEE [American Society for Engineering Education], is that seen as service or is that seen as actual research?" Therefore, further understanding in this area may be warranted.

Faculty members' beliefs about instructional practice changes are vital for continual implementation over time (Henderson, Khan, & Dancy, 2018; Hord et al., 1987; Reinholz & Apkarian, 2018). Understanding what faculty members believe about the change, their agency over the shift, and intrinsic motivation may sustain it over time (Stupinksy et al., 2018). Participants in the case study likely continued to use new instructional practices and implement new modules because they felt a need to contribute to something greater than themselves. Impacting students and society seemed to be a motivator to continue using new strategies and modules that resulted from the PLP. Survey Respondent 17 noted, "Now I assign more real-world oriented projects to provide the students a bigger picture understanding of what they are learning." Faculty members described teaching in what appeared as an altruistic calling to help solve problems facing society. Interviewee 1 explained, "Engineering impacts humanity, the environment, and safety." Furthermore, Interviewee 3 expressed, "I became a teacher to make better engineers in service to humanity." Likely, the beliefs about the impact of modules that asked students to think about real-world implications and solving problems together may have contributed to their continued use.

The COVID-19 global pandemic was probably a significant factor in implementing innovations that resulted from the professional learning partnership.

Participants reported that they would continue to use the latest strategies and innovations. However, the sudden switch to online learning, remote teaching, and the new working conditions' stress prevented implementation in some circumstances. Survey Respondent 3 stated, "I am teaching virtually for the first time in my life, I am having to incorporate many changes." The effect of the shift to distance learning on teaching practice and the higher education system, in general, is still unknown at the time of this study but likely to have significant implications.

Research Question 3: Conditions Facilitate Change

The final research question sought to understand the professional learning partnership conditions that facilitated change in faculty members' instructional practice. Time is the main barrier to change in instructional practice for higher education faculty (Froyd et al., 2013; Prince et al., 2013). It takes time to design curriculum, plan lessons, and implement active learning strategies such as group discussions or case-based projects. Hence, the predominant content delivery method is the traditional lecture, which may be perceived as a time-efficient method (Freeman et al., 2014; Henderson et al., 2011, 2012; Macdonald et al., 2005; Wieman, 2014). Participants described the conditions that the PLP provided that seemed to inspire them to change their instructional practice from traditional lecture to EBIS. Survey Respondent 10 wrote, "I've increased the amount of active learning in my classes even more. Traditional lectures are becoming increasingly rare in my courses. I also am requiring more group work both in and out of the classroom."

Faculty members appeared to be willing to redesign the curriculum and implement new teaching strategies if they could find value in the process. They wanted to know how effective the instructional strategy was for students, and prompt assessment data possibly motivated faculty members to evaluate the program and publish their findings. Data are necessary to persuade science faculty to teach differently, and the PLP was designed to provide faculty members with support in the analysis (Wieman, Perkins, & Gilbert, 2010). When asked what conditions were needed to make a change, Survey Respondent 14 wrote, “Effectiveness is the main condition.” Assessments were an essential component in the PLP. They provided student learning information, direct feedback to the faculty members, and material and insights to publish results. Interviewee 1 explained, “Being able to connect with someone at the School of Education, to talk about the assessment piece helped me have more confidence in the validity of what I was doing in the end.”

When faculty members saw the change’s effectiveness, they likely weighed trade-offs in curricular decisions, such as the amount of course content to provide and how to deliver it to students. Time becomes an essential consideration in decision-making when adopting new strategies (Wieman et al., 2010). Interviewee 2 discussed, “You can either teach a lot of stuff or cover fewer topics in more depth. Adding active learning modules gives much depth, but it will just take a lot more time than just lecturing at a student.”

Accountability systems and feedback opportunities facilitate instructional practice changes (Desimone & Pak, 2017; Garet et al., 2001). Accountability systems and feedback mechanisms were in place. They likely contributed to faculty members' feelings of responsibility to the PLP research team and their colleagues as a condition to make changes. For example, faculty members were expected to meet regularly with doctoral students to discuss course design and implementation. An observation during implementation was also another expected component of the program. Also, faculty members were paid a small stipend for each module they created but were paid only after posting it with assessment data on the network site.

In most cases, the research team assisted in the creation of the posted module or Card. Interviewee 1 explained, "The fact that they [PLP] held you accountable for actually implementing the module, I think that made it much more likely that I would actually do it." The system to provide feedback appeared to be another valued condition of the participants of the PLP. Doctoral students met individually with faculty members and provided input on course design and teaching strategies. They scheduled observations during instruction and provided feedback when mutually agreed upon. Interviewee 5 explained,

> [Doctoral student] did the assessment, helped me review my modules, and gave me feedback. If nothing else, [doctoral student] kept me on track because I knew that [doctoral student] would be coming Monday, so I couldn't just be running the labs on the printer 10 minutes before class.

Additional conditions of the partnership that likely enabled change included time for reflection, support from colleagues to take risks, and direct pedagogical support from the School of Education. Henderson et al. (2012) noticed that when

STEM instructors were encouraged to be reflective and use their knowledge and skills to improve and make a change, they were more likely to do so.

The PLP provided faculty members with time to reflect on their practice, and faculty members described needing time to be reflective while contemplating their own experience as a learner. Trying a new teaching strategy can be a risky endeavor, particularly for faculty members who reported that they lack pedagogical training. However, formal and informal networks can facilitate change that improves instruction by building peer relationships and providing a safe space to try new strategies and brainstorm new ideas (Hutchings, Huber, Ciccone, 2011; Kezar, 2014; Kezar et al., 2019). The PLP appeared to provide an informal network of colleagues within the department and a national network to gather new ideas, share knowledge, and ask questions. Often faculty members who taught sections of the same course worked together to create modules. The change agent provided many opportunities for informal conversations about teaching practices and the program. Frequent conversations with local colleagues about implementing instructional strategies are critical to the adoption and implementation of EBIS (Mestre et al., 2019). Survey Respondent 14 stated, “It was a good way to get feedback from other colleagues and have time to spend on thinking about new activities and learn what other colleagues were doing.” Interviewee 4 shared, “Having other faculty and especially administrators who are supportive of innovative teaching is needed because if things go a little bit sideways, or students don’t like working in groups, they complain.”

Lastly, a condition faculty members stated likely facilitated change in practice was the direct pedagogical supports from the School of Education, a unique partnership model. More common change models in national science education initiatives, predominately at large research universities, use embedded experts or Science Education Specialists with expertise in pedagogy and discipline-specific knowledge (AAU, 2017; McVey et al., 2019; Wieman et al., 2010). In those models, Science Education Specialists (SES) collect, distill, and communicate data and develop curricular materials and teaching approaches in collaboration with faculty. SES serves as a local resource and facilitates sustainability by archiving and disseminating materials. The PLP was similar in its approach but served a smaller-sized institution and did not necessarily have the discipline-specific knowledge in Engineering. First, the PLP research team collected and distilled data and then communicated the findings as soon as they were available. Doctoral fellows assisted in the development of curricular materials and provided support for new teaching strategies. Sustainability was facilitated by posting 32 modules developed by the faculty onto a national engineering education website. Over 1,000 engineering educators access this website for innovative curricular ideas and educational information. Interviewee 6 reflected on the model by stating,

> I think that piece that may be the most impactful was the contributions of the School of Ed. That is something I hadn’t had before. It was really great to have people in the class, in the workshop, helping develop methods for implementation, and come to classes and listen to us and give us feedback.

Interdisciplinary partnerships between STEM and education faculty often focus on improving pre-service teachers in K-12 science education, not higher education instructional practices, but a few provide some insights (Carbone, 2000; McVey et al., 2019; Schneider & Pickett, 2006; Sechrist et al., 2002). McVey et al. (2019) found that faculty members reported the most valuable aspect of working with postdoctoral fellows with pedagogical expertise was a collaboration of engineering education strategies and course transformation. Similarly, the PLP focused on using EBIS and course design which faculty members appeared to have appreciated as a professional learning experience. Interviewee 5 explained, "I love their presence [School of Education] in the School of Engineering. They were the ones who gave me different ideas of how to remap my ideas into deliverables." Survey Respondent 12 wrote, "It's been great professional development. Far exceeding any other trainings or education-focused conferences." Conditions of the PLP that likely facilitated change in instructional practice included knowing the value of the change and its effectiveness, accountability and feedback, time for self-refection, and collegial and pedagogical support.

Connections of Findings to Theoretical Framework

This case study research is grounded in a theoretical framework of change in instructional practice based on the seminal work of Hall et al. (1974) Concerns Based Adoption Model (CBAM). The tenets of CBAM view change as a process, not a highly personal product, of which individual perceptions of change strongly influence the results. A five-stage framework was adapted from this original model to determine how likely higher education faculty are to use a new instructional strategy or innovation (Froyd et al., 2013; Henderson et al., 2011, 2012). STEM scholars created a five-stage theoretical framework that determines how likely higher education faculty use a new instructional strategy or innovation (Froyd et al., 2013; Henderson et al., 2011, 2012; Hord & Hall, 1997). Awareness, search for information, reflect, adopt or reject, and follow up make up the five-stage framework. Participants described all of the stages of the theoretical framework within the findings throughout the research questions. Each stage is described individually.

Awareness: Learning about the innovation. Change theory suggests that awareness of teaching innovation is the first step in how likely faculty members choose to participate, and collegial support can be a motivator to try an innovation (Froyd et al., 2013; Henderson et al., 2011, 2012; Hord & Hall, 1997). All interviewees attributed becoming aware of the professional learning partnership through leadership within the department. Some faculty learned about it through the Dean, others through senior leaders in the School of Engineering. Faculty members described being encouraged to participate knowing that the majority of Engineering faculty would be involved. The School of Engineering culture appeared to be embracing this new partnership, and the literature suggests that faculty members are more likely to adopt an innovation when departmental culture is taken into account (Henderson et al., 2011).

Information: Looks for more information. After awareness, it appeared as though faculty members wanted to learn more about the program, expectations, and effectiveness. Survey Respondent 1 explained, “I need time to research the strategy and implement it in a course,” when asked about conditions needed in adopting new strategies. Departmental colleagues, the PLP, and the national network likely provided information about the strategies, program, and expectations for participation.

Reflection: Considers pros and cons. Changes to teaching practices are highly personal, and individual perceptions of the change strongly influence the results (Ellett et al., 2015; Hord et al., 1987). Consideration of the pros and cons of adopting a new strategy seemed prominent in research question three that discussed the conditions needed to adopt a new strategy. Faculty members likely reflected on the benefits and drawbacks of making changes to instruction. Time constraints appeared as a predominant factor in weighing whether or not faculty members try a new instructional strategy. When asked about barriers and supports in adopting a new strategy, Survey Respondent 7 wrote, “Time to actually plan for the implementation. As an instructor, I don’t have a lot of extra time to try new things.”

Moreover, Survey Respondent 6 noted, “It has to be relatively easy to implement.” The STEM field relies heavily on lecture-based instruction, which could be more challenging to change due to beliefs about themselves as experts in their field (Henderson et al., 2011; Henderson, Khan & Dancy, 2018; Holdren and Lander, 2012). Most faculty teach how they were taught, and faculty may be resistant due to their own identity as experts in engineering.

Adoption or rejection: Tries the innovation (or not) and analyzes the results. Scientists are more likely to adopt a new strategy if they have access to data

(Wieman, 2010). Assessment data provided to the faculty members for each module they created appeared helpful in determining to adopt or reject a strategy.

Follow-up: Decides to continue or discontinue to apply the innovation. The participants in the PLP reported continuing the use of the modules they created, possibly as a result of the assessment data provided. For some, the assessment data likely helped determine the effectiveness of the change.

This case study was grounded in the theoretical framework of the Concerns Based Adoption Model (Hall et al., 1974). This model theorizes that change is a process, not a product, and individual perceptions of change strongly influence the results. Engineering faculty members described why they participated, instructional changes they made, if any, and the circumstances that facilitated any shifts in instructional practice. Descriptions of changes were highly personal as faculty members discussed feelings of isolation and a desire for community, a lack of training, and a strong commitment to a positive impact on students and society.

Implications for Professional Practice

This case study research resulted in several implications for professional practice. First, higher education institutions should incentivize educational-related research in order to improve teaching and learning. The scholarship of teaching and learning (SoTL) is the study of teaching and learning in higher education and is systematic, evidence-based, and public about the results of student outcomes. Educational-related research is often not included in tenure portfolios in the sciences. Two participants in this case study discussed the stigma of educational research in the field, particularly as it pertains to junior faculty seeking tenure. Higher education institutions should include published research efforts as part of the tenure process. However, there is a challenge with the public airing of results of teaching and learning research. An authentic assessment arises from looking at classroom practice, activities, and learning, yet assessing and looking at institutional effectiveness and public accountability, which may cause fear or deter innovation (Henderson et al., 2018; Hutchings et al., 2011).

A second implication for professional practice is the use of change agents to improve instruction in higher education. Change agents, also referred to as knowledge brokers, effectively catalyze change in undergraduate STEM departments (Gelles, 2020; Mestre et al., 2019; Shulman, 2005). Universities should identify trusted and respected faculty members in their respective departments to lead and galvanize change. These change agents could be incentivized with time, money, or flexible workload in order to provide the capacity to facilitate change efforts.

Faculty members are more prone to try new instructional innovations if they have frequent conversations with their colleagues about the implementation (Prince et al., 2013; Wright, 2002). The creation of communities of practice should result from these efforts. Discussions in real-time about implementing and assessing new strategies could increase the likelihood of sustained practice and reduce isolation amongst faculty members.

The third implication for professional practice is a need for more ongoing support of faculty members implementing evidence-based instructional practices. One-third of faculty who us at least one EBIS discontinued its use after the first attempt (Henderson et al., 2011, 2012). The K-12 public school system has embraced the use of instructional coaches and a partnership framework which would be ideal in a higher education setting (Knight, 2011). The partnership framework is based on trust, choice, dialogue, and reflection. Coaches value the faculty members' thoughts, beliefs, and expertise and seek to understand and learn rather than intend to persuade. Also, having another person accountable could prove to be the nudge faculty members need to sustain changes. Universities do not seem to utilize this model, which could prove beneficial as a supplement to faculty development endeavors.

Finally, Schools of Education and faculty development centers have much in common relating to knowledge and dissemination of best practices in teaching and learning. Together these experts could transform instruction on university and college campuses across the United States. However, asking faculty members in the School of Education to provide time and expertise could prove to be a barrier due to their departments' responsibilities, but incentivizing with resources could prove beneficial. Doctoral students in education may be underutilized and could contribute to professional learning on campuses.

Implications for professional practice include incentivizing educational-related research by including it in the tenure process and investing in change agents in higher education institutions. Supporting coaching models often successfully used in the K-12 system may also impact positive changes. Lastly, universities could find ways to partner with Schools of Education, including their graduate programs, to tap into the knowledge and skills they exhibit as part of the daily practice.

Limitations of the Study

This study, like all research, has its limitations. While efforts were made to mitigate researcher bias and establish validity, this case study's small sample size and narrow scope had limitations that inform future research. Data gathered through interviews and open-ended survey questions were inherently subjective as they reflect participant experience and interpretations. Secondly, the sample size of the study of six interviews and 19 survey respondents is small due to the size of the university, departments, and participation in the professional learning program. Although the response rate of 53% seemed robust, the number of actual respondents limited the results. Future research could include quantitative research methodology with larger sample sizes.

Another limitation of this case study is the narrowness of the scope of the study. This single case study focused on one professional learning program at one university. There were no other comparative settings, which made it unique, attempted to fill a gap in the research, but may have limited findings. The scope was limited to only one side or perspective of the School Education and Engineering department's partnership. The point of view from those providing the support to Engineering faculty members was not taken into account. It could be an essential finding related to implementing evidence-based instructional strategies or changes to instruction in general.

Although interview participants were chosen based on pre-established criteria such as participation in the PLP, they self-selected for the interviews. This form of convenience sampling can limit the credibility of the study (Creswell, 2013). The use of an outside interviewer also warranted a structured interview protocol that did not allow for follow-up questions to capture nuanced answers or the ability to ask for clarification. This may have limited the data set overall.

The use of a self-report instrument was an additional limitation of the study. The Postsecondary Instructional Practices Survey (PIPS) instrument was designed to measure faculty members' instructional practices. Each respondent self-assessed their teaching strategies and approach to instruction. Walters et al. (2016) developed the instrument and tested it for validity and reliability. Self-reporting is not entirely reliable due to response bias. Also, the PIPS was not designed to measure specific evidence-based instructional strategies; therefore, the findings resulting in their use were limited.

Lastly, and most important limitation of this study was the impact of researcher bias. While steps were taken to mitigate this bias, in qualitative studies, the researcher acts as the data collection instrument and brings subjective experiences and perspectives to the study (Creswell, 2013). This inherent threat to validity may bias the results. First, as a doctoral fellow, I was closely involved in implementing the professional learning program. I participated in course design, implementation of the modules, and analysis of the assessment data. Also, I am a co-author of several conference papers and received a small financial benefit for my role during the PLP, although I did not receive any financial assistance once data collection commenced.

As a teacher in the K-12 public school system, my expertise is in pedagogical content, not Engineering. Engineering has its signature pedagogy (Shulman, 2005) which is unique to that discipline. This lack of discipline content knowledge may have limited the findings and the participants' involvement in the PLP in general. Participants also received a stipend for their participation. This was not a prominent finding but maybe a reason they chose to participate and reluctant to divulge. Furthermore, due to my proximity with the participants as a doctoral fellow, some participants may have been less than honest about the impact of the PLP, which could put into question the study's trustworthiness. For these reasons, member checking, triangulation, analytic memo writing, and bracketing were employed in this research process to note the potential bias and minimize its impact (Creswell, 2013; Saldana, 2016).

Future Research

Further research is recommended to build upon the findings, discussion, and implications of this case study research study. The first recommendation for future research is to broaden this study's size and scope using quantitative methodology. Participants in this single case study reside in one small university Engineering department. While their perspectives and experiences are valid and essential, a broader array of viewpoints could prove worthwhile. Student perspectives of the use of evidence-based instructional strategies as well as accounting for the faculty members' experiences and participants of the School of Education could offer a unique understanding of the program model, particularly as it pertains to replication on other campuses. The capacity of faculty members in the School of Education to provide support to other departments and manage a team of doctoral fellows in addition to their teaching and research responsibilities may prove exhaustive.

Another possible future research study could include more quantitative research. The postsecondary instructional practices survey (PIPS) provides information on evidence-based instructional strategies and could be given to faculty members as before and after they participate in a professional learning partnership. This may provide more data on the effectiveness of such a program.

Another recommendation for professional developers, including faculty development centers, is to utilize signature pedagogies (Shulman, 2005) or discipline-specific knowledge when providing professional learning opportunities. Professional development to improve instruction can be a one-size-fits-all model. More research is needed to understand and disseminate unique instructional strategies effective in distinct disciplines.

Future research is recommended to compare individual evidence-based instructional strategies with themselves, rather than to traditional lecture. Seminal researchers such as Wieman (2014), who have led the conversation regarding changes in STEM instructional practices, have made the point that traditional lecture, still prominent in undergraduate STEM education, has been all but proven ineffective.

Moving forward, research comparing each of the ten or so EBIS within the context of signature pedagogy could bring focused instructional change more quickly.

Finally, future research is also recommended as a follow-up to this particular case study to discover if faculty members are continuing to implement the changes they made. Faculty members created 32 modules and shared resources amongst a national network of Engineering educators. It would be helpful to understand if they were still using the modules or created new ones without the professional learning program's support at some point in the future.

Conclusion

A national shortage of science, technology, engineering, and mathematics professionals impacts the U.S. economy, and calls to reform university teaching and learning are underway. Students are dropping out of STEM majors, particularly women and students of color, at a higher rate than their white counterparts, causing an even greater talent scarcity. There is pressure to change teaching and learning towards using evidence-based instructional strategies that involve students in the learning process. Efforts to change instructional strategies present mixed results (Chen, 2014; NCES, 2019).

These research findings revealed that faculty members desire a sense of belonging in a profession that asks them to spend much of their time teaching, yet does not prepare them adequately. This can lead to isolation and many yearn to work more closely with their colleagues. When supported with ongoing coaching, proof of effectiveness, and some accountability measures, faculty members can adopt and sustain evidence-based instructional strategies. Collegial support and time for reflection also were beneficial to sustained change. In addition, the scholarship of teaching and learning should be recognized and rewarded on par with discipline-based research, particularly since faculty members spend the majority of their time teaching.

Engineering faculty members are experts in their field. At the university level, these professors are at the academic pinnacle of their careers. Therefore, it may be difficult for highly educated and respected professionals to acknowledge a need for a change in instructional practice. Educational reformers seek quick fixes, programs, and strategies that may not persist over time. Change theory maintains that change is highly personal and individualistic (Hall et al., 1974; Hord, et al., 1987). Belief about the change may be more important than the actual innovation itself.

Evidence-based instructional strategies seek to place the students as the main actors in the class. Students are responding to curricula relevant to their lives, involving problem solving and collaboration with their peers. This form of applied learning could be the key to increasing student engagement, retention, and increasing the supply of STEM professionals needed.

References

Aguilar, E. (2013). *The art of coaching*. San Francisco: Jossey-Bass.

American Association of Universities (2017). *Progress towards achieving systemic change. A five-year status report on the AAU undergraduate STEM education initiative.* Washington, DC.

Amundsen, C., Abrami, P., McAlpine, L., Weston, C., Krbavac, M., Mundy, A., & Wilson, M. (2005). The what and why of faculty development in higher education: An in-depth review of the literature. *American Education Research Association*, (1989), 1–19.

Baumeister, R. & Leary, M. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *American Psychological Association Bulletin, 117*(3), 497-529.

Bok, D. (2014). Perspectives: The questionable priorities of university presidents. *Change: The Magazine of Higher Learning*, *46*(1), 53–57. doi:10.1080/00091383.2014.867214

Bonner, E., Marone, V., Yuen, T., Nelson, R., & Browning, J. (June, 2020). Lessons learned: Integrating active learning into undergraduate engineering courses. *American Society of Engineering Educators*. Paper # 28984.

Borrego, M., Cutler, S., Prince, M., Henderson, C., & Froyd, J. E. (2013). Fidelity of implementation of research-based instructional strategies (RBIS) in engineering science courses. *Journal of Engineering Education*, *102*(3), 394–425. doi:10.1002/jee.20020

Bowen, C. W. (2000). A quantitative literature review of cooperative learning effects on high school and college chemistry achievement. *Journal of Chemical Education*, *77*(1), 116. doi:10.1021/ed077p116

Burgan, M. (2006) In defense of lecturing. *Change: The Magazine of Higher Learning*, *38*(6), 30-34, doi:10.3200/CHNG.38.6.30-34

Calvery, L. (2016). *Moving from compliance to agency: what teachers need to make professional learning work.* Oxford, OH: Learning Forward.

Carbone, R. E. (2000). Collaborations between the College of Arts and Sciences and the College of Education at Clarion University of Pennsylvania. *Paper Presented at the Annual Meeting of the American Association of Colleges for Teacher Education, (52nd), Chicago, IL, February 26-29, 2000*.

Chen, X. (2014). STEM attrition: College students' paths into and out of STEM fields. In *Attrition in Science, Technology, Engineering, and Mathematics (STEM) Education: Data and Analysis* (pp. 1–96).

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher development. *Teaching and Teacher Education*, *18*, 947–967. doi:10.1016/S0742-051X(02)00053-7

Cole, D., Ryan, C., Serve, P., & Tomlin, J. (2001, June). *Collaborative structures between the colleges of education and human services and science and mathematics.* Conference Paper: American Association of Colleges for Teacher Education.Washington, DC.

Condon, W., Iverson, E., Manduca, C., Rutz, C., & Willett, G. (2016). *Faculty* *development and student learning : Assessing the connections*. Bloomington: Indiana University Press.

Creswell, J. (2011). *Qualitative inquiry and research design: Choosing among five approaches (3rd ed).* Thousand Oaks, CA: Sage.

Desimone, L. M., & Pak, K. (2017). Instructional coaching as high-quality professional development. *Theory Into Practice*, *56*(1), 3–12. doi:10.1080/00405841.2016.1241947

Dewey, J. (1910). *How we think.* Chicago, IL: D.C. Heath.

Dierking, L. D. (2010). A comprehensive approach to fostering the next generation of science, technology, engineering, and mathematics (STEM) education eeaders. *New Educator*, *6*(3–4), 297–309. doi:10.1080/1547688X.2010.10399607

Donovan, B., Moreno Mateos, D., Osborne, J., & Bisaccio, D. (2014). Revising the economic imperative for US STEM education. *PLOS Biology*, *12*(1). doi.10.1371/journal.pbio.1001760

Ebert-May, D., Dertling, T., Hodder, J., Momsen, J., Long, T., Jardeleza, S. (2011). What we say is not what we do: Effective evaluation of faculty professional development programs. *BioScience, 61*, 550-558.

Ellett, C. D., Demir, K., & Monsaas, J. (2015). Science and mathematics faculty responses to a policy-based initiative: Change processes, self-efficacy beliefs, and department culture. *Innovative Higher Education*, *40*(2), 127–141. doi:10.1007/s10755-014-9299-y

Eagan, K., Lozano, J. B., Hurtado, S., & Case, M. H. (2013). *The American freshman: National norms in 2013*. Los Angeles: Higher Education Research Institute, UCLA.

Fairweather, J. (2008). Linking evidence and promising practices in science, technology, engineering, and mathematics (STEM) undergraduate education. *Practice*, 70.

Felder, R., Felder, G., & Dietz, E. (2013). A longitudinal study of engineering student performance and retention: Comparisons with traditionally-taught students. *Journal of Engineering Education*, *87*(4), 469–480.

Felder, R. (2009). Active learning: An introduction. *American Society of Quality Higher Education Brief (2).*

Felten, P. (2013) Principles of good practice in SoTL. *International Society of Scholarship of Teaching and Learning Journal, 1*(1), 121-125.

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(23), 8410–8415. doi:10.1073/pnas.1319030111

Froyd, J., Borrego, M., Cutler, S., Henderson, C., & Prince, M. (2013). Estimates of use of research-based instructional strategies in core electrical or computer engineering courses. *IEEE Transactions on Education*, *56*(4), 393–399. doi:10.1109/TE.2013.2244602

Fullan, M. (2001). The New Meaning of Educational Change. In *The New Meaning of Educational Change*. doi:10.4324/9780203986561

Fullan, M., & Knight, J. (2011). Coaches as systems leaders. *Educational Leadership*.

Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon, K. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915–945. doi:10.3102/00028312038004915

Gelles, L. (2020, June). *Lessons learned about fostering curricular chang*e. Paper presented at the American Society of Engineering Education, Montreal, CN. Conference Paper #30187

Haak, D., HilleRisLambers, J., Pitre, E., Freeman, S., & Shepard, L. (2011). Increased structure and active learning reduce the achievement gap in introductory biology. *Science*, *332*(6034), 1213–1216. doi:10.1126/science.1204820

Hake, R. (1998). Interactive engagement versus traditional methods: A six-thousand student survey of mechanics tests data for introductory physics courses. *American Journal of Physics 66*(64). doi: 10.1119/1.18809

Hall, G., Wallace, R., & Dossett, W. (1973). *A developmental conceptualization of the adoption process within educational institutions.* Retrieved from Texas University, Research and Development Center for Teacher Education.

Hall, G. (February, 1974). *The concerns-based adoption model: A developmental conceptualization of the adoption process within educational institutions.* Paper presented at the Anuual Meeting of American Educational Research Association, Chicago, IL.

Hanushek, E. (2019, November 10). What do test scores really mean for the economy? *Education Week*.

Hanushek, E., Ruhouse, J., & Woessmann, L. (2016). It pays to improve teacher quality. *Education Next*, *16*(3), 53–60.

Hargrove, R. (2003). *Masterful Coaching*. San Francisco: Jossey-Bass.

Henderson, C., Beach, A., & Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, *48*(8), 952–984. doi:10.1002/tea.20439

Henderson, C., Dancy, M., & Niewiadomska-Bugaj, M. (2012). Use of research-based instructional strategies in introductory physics: Where do faculty leave the innovation-decision process? *Physical Review Special Topics - Physics Education Research*, *8*(2). doi:10.1103/PhysRevSTPER.8.020104

Henderson, C., Khan, R., & Dancy, M. (2018). Will my student evaluations decrease if I adopt an active learning instructional strategy? *American Journal of Physics*, *86*(12), 934–942. doi:10.1119/1.5065907

Heron, J. (2001). *Helping the Client* (5th ed.). Thousand Oaks, CA: Sage.

Holdren, J., & Lander, E. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. *Science*.

Hord, S., Rutherford, W., Huling-Austin, L., & Hall, G. (1987). *Taking charge of change*. Austin: Southwest Educational Development Laboratory.

Hurtado, S., Eagan, H., Pryor, J., Whang, H., Tran, S. (2011). *Undergraduate teaching faculty: The 2010 HERI faculty survey.* Los Angeles, CA: Higher Education Research Institute.

Hutchings, P., Huber, M., & Ciccone, A. (2011). Feature essays: Getting there: An integrative vision of the scholarship of teaching and learning. *International Journal for the Scholarship of Teaching and Learning*, *5*(1). doi:10.20429/ijsotl.2011.050131

Johnson, D., Johnson, R., & Smith, K. (2006). *Active learning: Cooperation in the college classroom (*3rd ed). Edina, MN: Interaction Book Company.

Kern Entreprenuerial Engineering Network (2020). Retrieved from https://engineeringunleashed.com

Kern Family Foundation (2021). Retrieved from https://www.kffdn.org

Kezar, A. (2014). Higher education change and social networks: A review of research. *Journal of Higher Education*, *85*(1), 91–125. doi:10.1353/jhe.2014.0003

Kezar, A., Miller, E., Bernstein-Serra, S., & Holcombe, E. (2019). The promise of a "Network of Networks" strategy to scale change: Lessons from the AAU STEM initiative. *Change: The Magazine of Higher Learning*, *51*(2), 47–54. doi10.1080/00091383.2019.1569973

Knight, J. (2006). Instructional coaching. *School Administrator*, *63*(4), 5.

Knight, J. (2011). *Unmistakable impact: A partnership approach for dramatically improving.* Google Books. Thousand Oaks: Corwin.

Langdon, D., Mckittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *STEM: Good* *jobs now and for the future. Recent and projected growth in STEM and non-STEM employment source: ESA calculations using current population survey public-use microdata and estimates from the employment projections program of the bureau*.

Lincoln, Y., & Guba, E. (1985). *Naturalistic inquiry*. Thousand Oaks, CA: Sage.

Lundberg, M., & Yadav, A. (2006). Assessment of case study teaching: Where do we go from here? *Journal of College Science Teaching, 35*(5), 10-13.

Lyle, J. (2003). Stimulated recall: A report on its use in naturalistic research. *British Educational Research Journal, 29*(6), 861-878.

Macdonald, R., Manduca, C., Mogk, D., & Tewksbury, B. (2005). Teaching methods in undergraduate geoscience courses: Results of the 2004 on the cutting edge survey of U.S. faculty. *Journal of Geoscience Education*, *53*(3), 237–252. doi.10.5408/1089-9995-53.3.237

Mazur, E. (1997). *Peer instruction: A users manual*. Englewood Cliffs, NJ: Prentice-Hall.

McVey, M., Bennett, C., & Greenhoot, A. (2019). Impact of an embedded expert model on course transformation in engineering. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Meade, P., & McMeniman, M. (1992). Stimulated recall—An effective methodology for examining successful teaching in science. *The Australian Educational Researcher, 19*(3), 1-18.

Merriam, S. (2009). *Qualitative research*. San Francisco, CA: Jossey-Bass.

Mestre, J., Herman, G., Tomkin, J., & West, M. (2019). Keep your friends close and your colleagues nearby: The hidden ties that improve STEM education. *Change: The Magazine of Higher Learning*, *51*(1), 42–49. doi:10.1080/00091383.2019.1547081

Miles, M., & Huberman, A. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks, CA: Sage.

Mills, G. & Gay, L. (2016). *Educational research: Competencies for analysis and applications* (11th ed.). Essex, England: Pearson.

Muijs, D. (2016). *Doing quantitative research in education with SPSS.* Thousand Oaks, CA: Sage.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2007. *Rising above the gathering storm: Energizing and employing america for a brighter economic future*. Washington, DC: The National Academies Press. https://doi.org/10.17226/11463

National Center for Education Statistics (NCES). (2017). *Percentage of 2011–12 first time postsecondary students who had ever declared a major in an associate or bachelor degree program within 3 years of enrollment, by type of degree program and control of first institution: 2014.* (December 2017).

Olson, S., & Labov, J. (2012). Community colleges in the evolving STEM education landscape: Summary of a summit. *Community Colleges in the Evolving STEM Education Landscape: Summary of a Summit*, 1–156. doi:10.17226/13399

Organization for Economic Cooperation and Development (OECD). (2018). PISA

Worldwide Ranking – average score of math, science, and reading. In *Factsmaps*.

Owens, M. et al., (2018). Collectively improving our teaching: Attempting biology department-wide professional development in scientific teaching. *CBE Life Sciences Education, 17*(1), 17.

Park, J., Park, K., Jackson, K., & Vanhoy, G. (2020). Remote engineering education under COVID-19 pandemic environment. *International Journal of Multidisciplinary Perspectives in Higher Education, 5*(1), 160-166.

Patton, M. (2001). *Qualitative evaluation and research methods* (3rd ed.). Thousand Oaks, CA: Sage.

Phuong, T., Cole, S., & Zarestky, J. (2018). A systematic literature review of faculty development for teacher educators. *Higher Education Research and Development*, *37*(2), 373–389. doi:10.1080/07294360.2017.1351423

Prince, M., Borrego, M., Henderson, C., Cutler, S., & Froyd, J. (2013). Use of research-based instructional strategies in core chemical engineering courses. *Chemical Engineering Education*, *47*(1), 27–37.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(2), 223.

Reich, A., Rooney, D., Gardner, A., Willey, K., Boud, D., & Fitzgerald, T. (2015). Engineers' professional learning: a practice-theory perspective. *European Journal of Engineering Education*, *40*(4), 366–379. doi:10.1080/03043797.2014.967181

Reinholz, D. & Apkarian, N. (2018). Four frames for systematic change in STEM departments. *International Journal of STEM Education 5*(1).

Riegle-Crumb, C., & King, B. (2010). Questioning a white male advantage in STEM: Examining disparities in college major by gender and race/ethnicity. *Educational Researcher*, *39*(9), 656–664. doi:10.3102/0013189X10391657

Reimer, L., Schenke, K., Tutrang, N., O'Dowd, D., Domina, T., Warschauer, M. (2016). Evaluating promising practices in undergraduate STEM lecture courses. *Journal of Social Sciences (2)*1, 212-233. doi: 107758/RSF.2016.2.1.10

Rhodes, C. (2000). Doing knowledge at work: Dialogue, monologue, and power in organizational learning. In J. Garrick & C. Rhodes (Eds). *Research and knowledge at work: Perspectives, case studies, and innovation strategies* (pp. 217-231). London: Routledge.

Rising above the gathering storm: Energizing and employing America for a brighter economic future. (2007). In *The National Academies Press*. doi:10.17226/11463

Rutz, C., Condon, W., Iverson, E., Manduca, C., & Willett, G. (2012). Faculty professional development and student learning: What is the relationship? *Change: The Magazine of Higher Learning*, *44*(3), 40–47. doi.org/10.1080/00091383.2012.672915

Saldaña, J. (2016). *The coding manual for qualitative researchers* (3rd ed.). Thousand Oaks, CA: Sage.

Schneider, R., & Pickett, M. (2006). Bridging engineering and science teaching: A collaborative effort to design instruction for college students. *School Science and Mathematics*, *106*(6), 259–266. doi:10.1111/j.1949-8594.2006.tb17914.x

Sechrist, C., Batchman, T., Feisel, L., Gmelch, W., Gorham, D., & Stoler, B. (2002). *IEEE Transactions on Education*, *45*(2), 118.

Senge, P. (1994). *The fifth discipline fieldbook: Strategies and tools for building a learning organization*. New York: Doubleday.

Sevo, R. (2009). Literature overview : The talent crisis in science and engineering. *Applying Research to Practice (ARP) Resources*, *NSB*, 1–15.

Sharkey, S., & Weimer, M. (2003). Learner-centered teaching: Five key changes to practice. *Teaching Sociology*, *31*(2), 251. doi:10.2307/3211318

Showers, B., & Joyce, B. (1996). *The evolution of peer coaching today: Peer coaching study teams enhance staff development efforts and offer support for teachers implementing new strategies* (Vol. 53).

Shulman, L. (2005). If not now, when? The timeliness of scholarship of the education of engineers. *Journal of Engineering Education,* p.12.

Smith, C., Hofer, J., Gillespie, M., Solomon, M., & Rowe, K. (2003). How teachers change: A study in professional development in adult education. *National Center for the Study of Adult Learning and Literacy*, 22–38.

Smith, M., Vinson, E., Smith, J., Lewin, J., Stetzer, K. (2014). A cmpus-wide study of STEM courses: New perspectives on teaching practices and perceptions. *CBE Life Science Education 13*, 624-635.

Stake, R. (1995). *The art of case study research.* Thousand Oaks, CA: Sage.

Steinert, Y., Mann, K., Anderson, B., Barnett, B. M., Centeno, A., Naismith, L., … Dolmans, D. (2016, August 2). A systematic review of faculty development initiatives designed to enhance teaching effectiveness: A 10-year update: BEME Guide No. 40. *Medical Teacher*, Vol. 38, pp. 769–786. doi:10.1080/0142159X.2016.1181851

Stupinsky, R., BrckaLorenz, A., Yuhas, B., & Guay, F. (2018). Faculty members' motivation for teaching and best practices: Testing a model based on self-determination theory across institution types. *Contemporary Educational Psychology, 53*(4), 15-25.

Tagg, J. (2012). Why does the faculty resist change? *Change: The Magazine of Higher Learning*, *44*(1), 6–15. doi:10.1080/00091383.2012.635987

Terenzini, P.. Cabrera, A., Colbeck, C., Parente, J., & Bjorklund, S. (2001). Collaborative learning vs. lecture/discussion: Students' reported learning gains. *Journal of Engineering Education*, *90*(1), 123–130. doi:10.1002/j.2168-9830.2001.tb00579.x

Thomas, D. (2006). A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation, 27*(2), 237-246. doi:10.1177/1098214005283748

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Cambridge: Harvard University Press.

Wagner, T. (2014). The global achievement gap. *Assessment*, 20–21.

Walter, E., Henderson, C., Beach, A. & Williams, C. (2016). Introducing the postdecondary instructional practices survey (PIPS): A concise, interdisciplinary, and easy-to-score survey. *CBE Life Science Education, 15*(4).

Webster-Wright, A. (2009) Reframing professional development through understanding authentic professional learning. *Review of Educational Research 79*(2), 702-739. doi: 10.3102/0034654398330970

Wieman, C. (2014, June 10). *A large-scale comparison of science teaching methods sends a clear message.* Proceedings of the National Academy of Sciences of the United States of America, Vol. 111, pp. 8319–8320. doi:10.1073/pnas.1407304111

Wieman, C., Perkins, K., & Gilbert, S. (2010). Transforming science education at large research universities: A case study in progress. *Change: The Magazine of Higher Learning*, *42*(2), 6–14. doi:10.1080/00091380903563035

Winberg, C., Adendorff, H., Bozalek, V., Conana, H., Pallitt, N., Wolff, K., … Roxå, T. (2019). Learning to teach STEM disciplines in higher education: a critical review of the literature. *Teaching in Higher Education*, *24*(8), 930–947. doi:10.1080/13562517.2018.1517735

Woods, D. (2012). PBL: An evaluation of the effectiveness of authentic problem-based learning. *Chemical Engineering Education*, 46, 135.

Wright, M. (2002). Always at odds. *The Journal of Higher Education*, *76*(3), 331–353. doi:10.1080/00221546.2005.11772285

Yin, R. (2018). *Case study research and applications: Design and methods* (6th ed.). Thousand Oaks, CA: Sage.

Appendix A

Written Information Sheet (survey)

This survey is part of a research study conducted by Rebecca Levison, as part of the [program]. I hope to learn how engineering faculty perceive changes to their teaching practice and implement pedagogical shifts over time. If you agree to participate, please complete the survey below. If you do not want to participate, please do not complete this survey.

All data will be kept in a password protected computer without any link to your name. There are no anticipated risks to your participation in this survey, however, it is unlikely yet possible that a data breach could occur with the Qualtrics survey and that the data may be compromised.

Participating in this research may help improve what we know about perceptions and beliefs on the utilization of new teaching strategies and may be published anonymously in a conference or journal paper. However, we cannot guarantee that you personally will receive any benefits from this research. Your participation is voluntary, and your decision whether or not to participate will not affect your relationship with [University]. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions about the study, please feel free to contact me, Rebecca Levison (XXX) [XXX-XXXX] or [email address] or my faculty advisor Dr. Nicole Ralston at [email]. If you have questions regarding your rights as a research subject, please contact the IRB (IRB@up.edu).

Online Survey: Postsecondary Instructional Practices Survey (PIPS) and Open-Ended Questions

INFORMATION

This survey consists of two parts: a 24 item teaching practices survey and 7 item short answer survey. The first part was designed by researchers at California State University at Fresno and Western Michigan University and the second was designed by a researcher at the University of Portland to collect self-reported teaching practices from individuals teaching at institutions of higher education.

INSTRUCTIONS

The survey has 24 teaching practice items and 7 short answer questions. It should take about 15 minutes to complete.

Each teaching practice item is a statement that may represent your current teaching practice. As you proceed through the survey, please consider the statements as they apply to teach your ***lowest level*****, the** ***largest enrollment undergraduate course taught in the last two years*****.**

Please read each statement, and then indicate the degree to which the statement is descriptive of your teaching. There are no "right" or "wrong" answers. The purpose of the survey is to understand how you teach, not to evaluate your teaching.

0 - Not at all descriptive of my teaching 1 - Minimally descriptive of my teaching 2 - Somewhat descriptive of my teaching 3 - Mostly descriptive of my teaching
4 - Very descriptive of my teaching

I: Teaching Practice Statements

Please indicate the degree to which the following statements are descriptive of your teaching at your *lowest level, the largest enrollment undergraduate course taught in the last 2 years.*

	Not at all descriptive of my teaching	Minimally descriptive of my teaching	Somewhat descriptive of my teaching	Mostly descriptive of my teaching	Very descriptive of my teaching
P01. I guide students through major topics as they listen and take notes.	0	1	2	3	4
P02. I design activities that connect course content to my students' lives and future work.	0	1	2	3	4
P03. My syllabus contains specific topics that will be covered in every class session.	0	1	2	3	4
P04. I provide students with immediate feedback on their work during class (e.g., student response systems, short quizzes)	0	1	2	3	4
P05. I structure my course with the assumption that most of the students have little useful knowledge of the topics.	0	1	2	3	4
P06. I use student assessment results to guide the direction of my instruction during the semester.	0	1	2	3	4
P07. I frequently ask students to respond to questions during class time.	0	1	2	3	4
P08. I use student questions and comments to determine the focus and direction of classroom discussion.	0	1	2	3	4

	Not at all descriptive of my teaching	Minimally descriptive of my teaching	Somewhat descriptive of my teaching	Mostly descriptive of my teaching	Very descriptive of my teaching
P09. I have students use a variety of means (models, drawings, graphs, symbols, simulations, etc.) to represent phenomena.	0	1	2	3	4
P10. I structure the class so that students explore or discuss their understanding of new concepts before formal instruction.	0	1	2	3	4
P11. My class sessions are structured to give students a good set of notes.	0	1	2	3	4
P12. I structure the class so that students regularly talk with one another about course concepts.	0	1	2	3	4
P13. I structure the class so that students constructively criticize one another's ideas.	0	1	2	3	4
P14. I structure the class so that students discuss the difficulties they have with this subject with other students.	0	1	2	3	4
P15. I require students to work together in small groups.	0	1	2	3	4
P16. I structure problems so that students consider multiple approaches to finding a solution.	0	1	2	3	4
P17. I provide time for students to reflect on the processes they use to solve problems.	0	1	2	3	4
P18. I give students frequent assignments worth a small portion of their grade.	0	1	2	3	4
P19. I require students to make connections between related ideas or concepts when completing assignments.	0	1	2	3	4
P20. I provide feedback on student assignments without assigning a formal grade.	0	1	2	3	4
P21. My test questions focus on important facts and definitions from the course.	0	1	2	3	4

P22. My test questions require students to apply course concepts to unfamiliar situations.	0	1	2	3	4
P23. My test questions contain well-defined problems with one correct solution.	0	1	2	3	4
P24. I adjust student scores (e.g. curve) when necessary to reflect a proper distribution of grades.	0	1	2	3	4

II: Additional Questions

Faculty members of the [University] may have participated in a grant-funded program. Professional development opportunities such as trainings, one on one support and data analysis were provided in partnership with [University's] School of Education. Please answer the following questions to understand the extent to which you participated in [program].

1. **Please check all that apply.**

___ I participated in at least one local [program] training on the University campus.

___ I attended at least one national [program] training or conference or training

___ I developed at least one [program] module and published it on the [program] Engineering website.

___ I met at least once with an education doctoral student [Names of three doctoral students] from the School of Education to plan and discuss ideas to develop my module.

___ An education doctoral [Names of three doctoral students] observed my class at least once while I was teaching from my module.

___ I met at least once with an education doctoral student [Names of three doctoral students]AFTER I completed my module to obtain feedback.

___ I did not participate in any aspect of the [Program].

2. Now think about these [Program] related experiences you've had. Have you made any changes to your instruction due to these experiences? Can you provide a specific example?

3. Are there any teaching strategies you adopted that you attribute to participating in the [Program] program? If so, which ones?

4. If you did adopt a new strategy or change your teaching practice as a result of your participation in the [Program], are you still using it or plan to use it this year? Why or why not?

5. When thinking about adopting a new teaching strategy, what are some of the conditions you need to make that change in your teaching practice?

6. Is there anything else we need to know about participating in the [Program] program?

7. Including this year, how many years have you been teaching engineering to college students?

Appendix B

Written Information Sheet for Interviews

This interview is part of a research study conducted by Rebecca Levison, as part of the UNIVERSITY OF PORTLAND School of Education doctoral program. I hope to learn how engineering faculty perceive changes to their teaching practice and implement pedagogical shifts over time. You were selected for an interview because you offer a unique perspective on the impact of the [program] due to your level of involvement.

This form includes detailed information on the research to help you decide whether to participate. Please read it carefully and ask any questions you have before you agree to participate.

If you decide to participate, you will be contacted to set up a 30-minute interview on ZOOM to understand the extent to which you participated in the [program], your perspective and experience in the program and in using new teaching strategies. The ZOOM interview will be audio and video recorded.

There are no anticipated risks to your participation in this interview. Participating in this research may help improve what we know about perceptions and beliefs on the utilization of new teaching strategies and may be published anonymously in a conference or journal paper. However, I cannot guarantee that you personally will receive any benefits from this research.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Subject identities will be kept confidential by assigning a pseudonym to each interview participant and a numerical code. Identifiers will be removed from identifiable information. All data will be kept in a password protected computer without any link to your name. After identifiable private information is removed, the information may be used for future research studies.

Your participation is voluntary, and your decision whether or not to participate will not affect your relationship with [University]. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions about the study, please feel free to contact me, Rebecca Levison at (XXX) XXX-XXXX or [email] or my faculty advisor Dr. Nicole Ralston at [email]. If you have questions regarding your rights as a research subject, please contact the IRB (IRB@up.edu).

Appendix C

Interview Questions / Protocol

Interview Script

Thank you for agreeing to participate in this interview to understand the impact, if any, of the [program], specifically the partnership between the [department] and the School of Education. This case-study seeks to understand the impact of the collaboration between the departments on teaching practices. This interview should take approximately 30 minutes. All interviews are audio and video recorded for later transcription. Do I have permission to audio and video record this interview?

Please see the written information sheet that was sent to you. It states that participation in this study is voluntary and confidential and you can withdraw at any time. Do you still want to participate in this interview?

Do you have any questions before we begin?

You were selected for an interview because you offer a unique perspective on the impact of the [program] due to your level of involvement. It's my understanding that you designed and implemented a module for one of the courses you taught, gathered assessment data, and posted a Card on the [National Network] website. One component of the [program] was the support from the School of Education in designing, implementing and assessing the modules. The following questions are designed to understand the impact, if any, on your teaching practice.

1. Can you tell me a little bit about what it was like to participate in [program]?
    a. How did you learn about [program]?
    b. Why did you decide to participate?

2. Thinking back, what was most impactful about the [program]? Why?

    a. What was least impactful? Why?

3. What changes have you made to your teaching practice, if any, as a result of participating in the [program]?
    a. Can you provide an example**? (If respondent only talks about changing the [program] module, rather than focusing on <u>teaching practice</u>, ask the question again with emphasis on teaching practice).**

4. A link to the module you created was sent to you electronically when you completed your survey. Thinking back to the process how did you decide to create this?
    a. What were the key components?
    b. How did it go?

5. Have you taught this same module again? Why or why not? If so, how did it go?

6. When thinking about making changes to your teaching practice, including the use of new strategies or the development of new modules, what supports are necessary for you?

    a. What do you need to be successful?
    b. What are the barriers? Why?

7. Was the partnership with the School of Education a helpful support? Why or why not?

8. Is there anything else you would like to add about your experience with the [program]?

Thank you so much for your time today. A transcript of this interview will be available and sent to you to check for accuracy.

Appendix D

[Program] Published Card on [National Network] Website

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Taking Action on Ethics

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Description

This module was designed to help students learn to develop an action plan for ethics. The book by Mary Gentile, "Giving Voice to Values" argues that most students already know that they should never build a bad bridge. However, when faced with the complexity of workplace politics they sometimes do not have a plan for properly articulating an ethical concern.

The module was designed to be added to an existing class project so students had context for building an action plan for ethics. The module was implemented in a heat transfer course, but was also implemented in a slightly different context/project in a fluids course. With small modifications it could be added to other classes.

Ethics Dilemma - The students worked the first half of the project to design a device to transport a vaccine and keep it cold for 48 hours. During the ethics module, students were then told that the company they work for has changed the plan, and the device will now be used to transport the vaccines for 5 days longer (7 days total) without the ability to refrigerate the vaccines in the interim.

Mindset Matters

Curiosity

- Explore a contrarian view of accepted solution

Connections

- Assess and manage risk

Creating Value

- Identify unexpected opportunities to create extraordinary value

Skillset

Design

- Analyze Solutions

Opportunity

- Evaluate Tech Feasibility, Customer Value, Societal Benefits & Economic Viability
- Assess Policy & Regulatory Issues

Engineering Disciplines

- Chemical Engineering
- Health Sciences & Medical
- Mechanical Engineering

Authors

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Appendix E

Excerpts from Codebook

Categories/Themes	Codes	Description
Sense of responsibility to impact change	impact students impact self impact engineering profession impact world/society	Faculty described feelings of responsibility as a teacher to impact change in a variety of settings (personal and professional)
Sense of belonging	untrained isolated seek collaboration	Faculty described the impact of the program as a need due to the lack of training in educational pedagogy and feelings of isolation
EBIS	group discussions relevant to students real world connections hands on activities flipped classrooms Gallery Walk Open-ended questions Think-Pair-Share	As described in the literature. Students are central actors in learning process