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Exploring the Curriculum and Institutional Contexts of STEM Future Faculty Programs

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by

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Abstract

While there are a multitude of contributing factors, under-represented student success in STEM appears to be critically interdependent with teaching and learning practices that are responsive to diverse epistemologies and inclusive pedagogies. However, the professional literature has yet to identify a set of faculty development best practices that might guide the field. Furthermore, the institutional supports required to drive the success of STEM-oriented future faculty programs remain unknown. This inquiry proposal intended to address these concerns through a critical comparative qualitative study in seeking evidence-based practices and institutional elements of STEM faculty professional development programs that support diverse graduate and postdoctoral scholar success. The findings revealed a new STEM faculty professional development model that critically re-imagines constructivist teaching and learning, deconstructed socialization, organizational advocacy, and iterative assessment in supporting diverse graduate and post doctoral scholar success.

ACKNOWLEDGEMENTS

Early in this program we were asked to read dissertations as a way of understanding how they look and sound. I remember reading an acknowledgement that shared the author's background and his amazing journey to a doctorate. Similarly, I want to share that I am a first-generation college graduate from a working-class upbringing. I was a high school dropout and spent much of my teenage years and early twenties homeless. I started community college at 23 after passing the GED. I survived on financial aid, food service jobs, and lived cheaply in my friend's garage. Even after earning my bachelor's degree and then a master's degree, I struggled with overwhelming student debt and the unreliability of adjunct work, and thought those things would prevent me from ever pursuing a doctorate. I am happy to say they have not, but they are major barriers in higher education that leaders need to solve (myself included).

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CHAPTER 1: INTRODUCTION

The U.S. Department of Education defines STEM as including four broad disciplinary categories: science, technology, engineering, and math (U.S. Department of Education, n.d.). STEM education is often framed as a pathway to innovation: a future of economic prosperity, technological improvement, and even cures for disease. In 2012, the President's Council of Advisors on Science and Technology US (PCAST) released a report on STEM that found economic need for 1 million more graduates in STEM education (PCAST, 2012). Unfortunately, undergraduate students leave STEM fields in droves. One explanation they give for leaving is poor teaching and unwelcoming environments in math and science courses. In their massive study of 10,000 STEM undergraduates, Seymour and Hunter (2019) found that students in STEM experience "push" factors like poor teaching and a gatekeeping environment and "pull factors" like engaging teaching in other disciplines.

As many in the field of education are aware, STEM is known for its difficulty retaining students, particularly women and students of color and promoting diverse faculty. In their 2020 Visioning Report, the NSF admitted that among US-born academics, there is a critical lack of women, people with disabilities and African Americans, Hispanic Americans, and Native Americans in STEM. Many historically marginalized and excluded students pursue STEM fields but despite a decade of concerted efforts at recruitment and retention, 60-65% will leave STEM in their undergraduate education in favor of other majors (Eagan et al., 2014). Only 9% of faculty in STEM and 4% in health sciences are from historically marginalized and excluded groups (National Science Foundation, 2019). This rate of loss not only deprives STEM fields of historically marginalized and excluded students' contributions to their fields but also prevents their movement into faculty positions, where they might affect change.

In addition to a lack of diversity, researchers have found that graduate students in STEM are not prepared for the various responsibilities of academic work which include research, teaching, and mentoring and other forms of service. Within STEM fields, graduate students spend much of their time working in research labs where training in research is more highly valued than training in teaching (Baiduc et al., 2016). It is not uncommon for a graduate student in STEM to spend their entire graduate career as a research assistant and teach only a little or not at all. Despite a lack of training, about 50% of PhDs in STEM will teach within five years of finishing their degree (Connolly et al., 2018), some of them at teaching-intensive schools like liberal arts and community colleges, with a lot of training as researchers but sometimes very little in teaching or mentoring. This calls for widespread, deliberate teaching development for STEM graduate students and postdoctoral scholars.

This chapter will start by describing past efforts to change STEM teaching at the undergraduate level. Next, it will discuss the challenges of creating change through professional development of already established faculty. Then a history of future faculty programs in the US, followed by a discussion of STEM-oriented programs. Next it will introduce a critical lens through which this study will view future faculty programming. Finally, this chapter will explain the purpose and significance of the study.

Background of Efforts to Change STEM Education

There have been multiple efforts since the late 1990s to improve teaching and learning in STEM. Seymour and Hunter (2019) conducted a large qualitative study of

10,000 students in STEM in 1997 (and again about 10 years later) to explore reasons so many STEM undergraduates leave STEM majors in favor of other fields. The study called for dramatic changes to STEM curriculum, teaching practices, and student supports. The PCAST report was released in 2012 and identified the same problems with the STEM pipeline as Seymour and Hunter in their original study. It identified five recommendations to improve STEM education: widespread use of evidence-based teaching; a move toward discovery-based learning; experiments in postsecondary math to bridge achievement gaps; partnerships to create new pathways to STEM careers; establishment of a national leadership to steer “transformative and sustainable change” (p. 7). In the ensuing years, many colleges and universities created STEM teaching and learning initiatives, created positions in STEM pedagogy, and formed faculty institutes to train educators in evidence-based practices (Durham et al., 2020; Miller et al., 2021). Overall, there is a trend toward increased use of evidence-based teaching in STEM. For example, Freeman et al. (2014) conducted a meta-analysis of 225 articles on active learning in STEM courses, and while some of these examples may have used as little as 10% active learning, the presence of 225 articles on the topic is significant.

And yet, studies have found that by and large, professional development of STEM faculty has brought about very little change in STEM education, particularly in terms of retention of marginalized and excluded students (Miller et al., 2021; Seymour & Hunter, 2019). Increasingly, future faculty programs, which provide pedagogical training to graduate students and postdocs, are being considered as sites for this change. One example is University of Maryland Baltimore County (UMBC), where institution-wide efforts geared toward STEM students closed the achievement gap and created a strong pathway from undergraduate through graduate school for historically marginalized and excluded students into STEM careers (Hrabowski et al., 2019). UMBC is significant not only for its successes in terms of students but also in their faculty commitment to the project. Similarly, Bowman et al (2020) found “one of the most effective ways to cultivate a culture of effective undergraduate education in STEM is to provide pedagogically-focused professional development for graduate students and postdoctoral fellows throughout their training” (p. 156-57). Multiple studies support this assertion. Ebert-May (2017) found that the changes needed in STEM education that will bring about higher retention, like student-centeredness rather than knowledge-centeredness, are more easily realized through future faculty programs. Connolly et al (2018) studied PhD students in STEM who participated in future faculty programs and found significant gains in course planning and teaching methods. Not only do they experience growth in feelings of self-efficacy, but alumni of STEM future faculty programs also report that they go on to use both effective teaching strategies and education scholarship in their roles as faculty (Mutambuki et al., 2020). Clearly, there is great potential for future faculty programs to positively impact the teaching and learning in STEM fields.

Future Faculty Programs

Faculty roles and responsibilities are usually expressed as research, teaching, and service. Boyer (1990) established that while faculty roles have trended toward prioritizing research over teaching, he suggested the three areas need to be equally considered. Boyer even thought to re-categorize them as scholarship of application, scholarship of discovery, scholarship of integration, and scholarship of teaching. He noted that even our understanding of research is flawed by focusing largely on scholarship of discovery, or the creation or discovery of new knowledge, over other areas of scholarship like research to solve societal problems (application) or to make connections across disciplines (integration). He also argued that academics are also taught not to see the interconnectedness of research and teaching: the ways new knowledge is shared through teaching and how teaching can create new knowledge. This imbalance, if you will, has caused STEM fields, in particular, to overemphasize research while de-emphasizing teaching, which has led to a gap in graduate student and postdoc pedagogical professional development.

In response to studies calling for structured professional development in teaching, in 1993 Preparing Future Faculty (PFF) was created by the Council of Graduate Schools and Association of American Colleges and Universities, and eventually 17 institutions were chosen to pilot the program (Rozaitis et al., 2020). Preparing Future Faculty did not necessarily prioritize teaching over research and service but saw them as equally important. They sought to integrate pedagogical training into graduate schools through discussions of teaching and learning and its core course, *Teaching in Higher Education* (Rozaitis et al., 2020). Doctoral granting institutions were required to partner with diverse institutions to give participants experience working and teaching in different settings. Lastly, participants were connected with multiple mentors from whom they received feedback. The grant funding of PFF ended in 2003, but many of these programs are still running (Phelps, 2010).

While not all future faculty programs have grown out of the PFF initiative, they tend to offer similar kinds of experiences. There is usually an opportunity to engage with scholarship of teaching and learning, chances to be observed teaching and given feedback, instruction in student-centered teaching strategies, and possibly training in inclusive teaching. They also include programming that will help them in all their faculty roles, including grant writing and publishing, and discussions of balancing the responsibilities. The modality, format, and time spent on each of these components varies. But one aspect that is consistent is that most graduate students and postdocs are adding this curriculum on top of their other duties and studies.

After Preparing Future Faculty, future faculty programs were created at a variety of institutions. Of importance to STEM was the development of the Center for Integration of Research, Teaching, and Learning network (CIRTL), created by the National Science Foundation in 2003 (Mathieu et al., 2020). CIRTL's mission is to "enhance excellence in undergraduate education through the development of a national faculty committed to implementing and advancing effective teaching practices for diverse learners as part of successful and varied professional careers" (CIRTL, 2020, para. 4). The three main pillars of CIRTL are Teaching as Research, Learning Communities, and Learning Through Diversity. Some of the most notable future faculty programs have adopted the CIRTL pillars as foundations for their curriculum: Scientific Teaching Fellows at University of Wisconsin-Madison (Austin et al, 2009), FAST at Michigan State University (Vergara et al, 2014), Tech to Teaching at Georgia Institute of Technology, and FIRST IV, a national institute for postdoctoral scholars. CIRTL membership costs institutions over $12,000 a year, so its member institutions tend to be large, research-intensive schools.

While STEM future faculty programs have been found to be effective at training educators, there are a few factors that influence their reach: 1. Not all doctoral-granting institutions have future faculty programs; 2. Institutions that have future faculty programs open to all graduate students sometimes have trouble recruiting STEM participants (some say this is due to the focus on research in STEM)(Brownell & Tanner, 2012); 3. Future faculty programs tend to be small because of limited resources (Connolly et al., 2018); 4. It is not clear how they are defining effective teaching and if their definitions include "learner-centered pedagogies" –active learning and inclusive teaching (Dewsbury et al., 2022, p. 2).

Future faculty programs are often compared to or confused with both teaching assistant training programs and faculty development programs. Teaching assistant training programs are more common than future faculty programs, are usually administered and taught by Center for Teaching and Learning (CTL) faculty, and time commitments vary wildly, between 2 and 100 hours per academic year (Schussler et al., 2015). Their curriculum often focuses on course policies, strategies for teaching discipline-specific content, and classroom management (Schussler et al., 2015), with the express purpose of preparing TAs to fulfill the duties of their role in the current term or semester. There is some attention to long-range goals of the student, but these are secondary to the immediate needs of the institution. TA training has more in common, at many institutions, with onboarding processes than with professional development.

Faculty development on pedagogical topics is quite common. It is offered by both CTLs and STEM departments, depending on the institution, the expertise in STEM departments, and the resources available. Development of current faculty, as opposed to future faculty—graduate students and postdocs—is the site of most pedagogical training in STEM. And while it has been found to increase "awareness and interest" in effective teaching, it does not always translate into a change in teaching practice unless accompanied by a close group of peers with whom to discuss teaching as well as a clear understanding of the teaching strategies and their outcomes (Borrego & Henderson, 2014, p. 229). Dewsbury et al. (2022) also found that faculty development in inclusive teaching (often experienced as an addition to current teaching practices) has not significantly changed STEM education because it requires expert level instructors to radically rethink their practices while enjoying departmental support in the effort. Very few STEM departments are up for this challenge. Too often a significant amount of energy is devoted to increasing faculty attendance and participation in pedagogical training and not necessarily to providing the other supports or following up on change in practice.

Future faculty programs are distinct from TA training and faculty development in a few important ways. Unlike TA trainings, which are focused on the institution's need for TAs to have quick knowledge of policies, learning management systems, etc., future faculty programs are focused on participants developing an evidence-based teaching practice. This practice is thought of as preparation for careers as faculty, so it is forward thinking and may not be of benefit to the institution. Studies have also identified future faculty (graduate students and postdocs) as occupying that perfect identity as both learner and instructor, and that dual perspective helping them to absorb and apply pedagogical concepts more effectively (Mutambuki et al., 2020). Due to this dual thinking, future faculty participants form their teaching practice around concepts taught in the program, like learner-centered pedagogies, instead of tacking them on later.

Purpose and Significance of the Study

This study seeks to explore ways in which STEM future faculty programs train their participants in learner-centered pedagogies. STEM fields have traditionally shown resistance to teaching professional development efforts aimed at student centeredness (Miller et al., 2021), so it is important to have a STEM focus in this study. This study also seeks to learn about the organizational and institutional dynamics that shape future faculty program curriculum and participation.

Many future faculty programs have studied the experience of engaging in their programs, largely by interviewing or surveying participants after completion. Their focus has mostly been on self-efficacy (Coles et al., 2020; Mutambuki et al., 2020; Rozaitis et al., 2020). Some have also used tools to measure the effectiveness of parts or all of their programming (Bowman et al., 2020; Branchaw et al., 2020). Many of these studies focus on a single program or when they have studied multiple programs, the sites studied do not have a STEM focus or pathway. Hill et al. (2019) studied eight CIRTL network programs, but with a broad focus on organization and leadership rather than curriculum and its relationship to institutional contexts. There was a need to examine multiple STEM future faculty programs and explore the similarities and differences in how they approach pedagogical professional development as well as learn about institutional benefits and barriers to these programs.

Summary

There is great demand in industry and academia for graduates trained in STEM fields, but many students in STEM fields change majors, particularly students who have been historically marginalized and excluded from these fields. A primary reason for changing is poor teaching and an unwelcoming environment. Unlike teaching assistant training programs, which serve the institution’s immediate needs, and faculty development, which is marginally successful at changing STEM education, future faculty programs hold great promise for developing a diverse professoriate skilled in learner-centered, evidence-based teaching. They have the ability to address STEM’s persistence problem, but they have not been studied thoroughly. This study seeks to fill the gap by learning more about the curriculum and context of STEM future faculty programs.

Chapter 2: Literature review

The literature review begins with a thorough look at issues that affect persistence in STEM fields at both the undergraduate and graduate levels: teaching, unwelcoming or gatekeeping environments, and a lack of pedagogical professional development for graduate students. These dynamics are also considered in the decisions of HME students to persist or switch. Next, STEM's focus on research and research funding, the ways graduate students and postdocs are socialized and mentored. This is followed by a discussion of the pedagogical considerations in examining this topic, both the strategies researchers have found to alienate students and those that lead to student success. Then the theoretical frames are introduced: organizational—what organizational frameworks are useful in considering the constraints and opportunities of future faculty programs; teaching and learning—what does teaching and learning theory help us understand about making change in STEM education; and critical theories—how can critical theory be used to critique current STEM education and provide a path forward for STEM future faculty programs.

STEM Student Success

The persistence of undergraduates and graduate students in STEM is interconnected. Students leave STEM fields at all points in their education, but the first two years of undergraduate work and the last few years of graduate work see the largest departures (Seymour & Hunter, 2019; NSF, 2020). Speaking generally, these trends are based in lack of supports, particularly for historically marginalized and excluded students. In undergraduate years, the lack of persistence is often associated with poor, instructor-centered teaching and aspects of STEM education that are exclusionary and unwelcoming (Seymour & Hunter, 2019). In graduate years, the lack of persistence is associated with a dearth of helpful mentors, financial stresses, as well as some of the same cultural issues as found in undergraduate experiences (Rohlfing et al., 2022).

Lack of Diversity and Career Preparedness in STEM Education

As many in the field of education are aware, STEM is known for its difficulty retaining students, particularly women and students of color and promoting diverse faculty. In their 2020 Visioning Report, the NSF admitted that among US-born academics, there is a critical lack of women, people with disabilities and African Americans, Hispanic Americans, and Native Americans in STEM (p. 8). Many historically marginalized and excluded students pursue STEM fields but despite a decade of concerted efforts at recruitment and retention, 60-65% will leave STEM in their undergraduate education (Eagan et al., 2014). Only 9% of faculty in STEM and 4% in health sciences are from historically marginalized and excluded groups (National Science Foundation, 2019).

Persistence Problems Connected to Teaching

Persistence, rather than retention, is the word used to describe “a spectrum of student behavior focused on the effort to continue in the major that they originally chose” (Seymour & Hunter, 2019, p. 7). Persistence continues to be a challenge in STEM undergraduate education as students experience a “push-pull” dynamic of STEM experiences pushing them out of the majors while learning experiences in other disciplines pull them. Seymour and Hunter (2019) found that there were certainly other factors at play in this push-pull besides teaching and learning, namely a realization that one is not as interested in STEM as they thought they would be. But the teaching and learning experiences were strongly influential: issues with faculty teaching contributed to 36% of all switching decisions (“switching” refers to students who switch majors but stay enrolled in college), complaints about poor teaching were mentioned as an almost universal concern by 90% of switchers, and even among students who persisted, 74% of them mentioned poor teaching as a problem in their major (Seymour & Hunter, 2019). Persistence in STEM fields has been connected to two instructional factors experienced by undergraduates: the teaching abilities of their instructors, particularly those teaching first and second year courses, and experiences related to inclusion in their classes.

In the PCAST report to the president, the advisors wrote “high-performing students frequently cite uninspiring introductory courses as a factor in their choice to switch majors" (PCAST, 2012, p. 9). In their study of 10,000 undergraduates at seven institutions (public and private), Seymour and Hunter (2019) discovered that 90% of students who switched majors out of STEM cited poor teaching as a primary cause for switching. Students mentioned classes where lecture was the only strategy used, day in and day out, for an entire semester and environments where questions were not welcomed. STEM courses use lecture as the primary form of teaching far more often than other fields. Seymour and Hunter (2019) elaborated on this in their findings:

> Their most common complaints were that lessons lacked preparation, logical sequencing, or coherence, and that little attempt was made to check that students were understanding class content. Students were frustrated by instructors who seemed unable to explain their material sequentially, coherently, or break it down into sequences that would enable conceptual grasp. “Poor” teachers did not appear to understand the relationship between the amount of material which can be

> presented in a single class and the level of comprehension and retention which they could expect from students. Nor did they pitch their class materials or test questions at a level which was appropriate for students at their stage of conceptual understanding. Students looked for, and mostly did not find, illustration, application, and discussion of the implications of material being taught. They also found it hard to retain their interest in the subject where their instructors failed to present the material in a stimulating manner. STEM classes were often faulted for their dullness of presentation—predominantly straight lecture—and over-focus on memorization. (p. 10)

Additionally, a 2013-14 survey of STEM faculty showed 51% as relying on the lecture, with the caveat that faculty often over-report their use of active learning strategies (Malcom & Feder et al., 2016). As a result, many have called for dramatic, sustained changes to the way STEM courses are taught and how faculty are trained (Miller et al., 2021; President's Council of Advisors on Science and Technology US, 2012; Seymour & Hunter, 2019). These changes range from incentivizing faculty to improve their teaching (Miller et al., 2021), funding agencies like NIH and NSF requiring pedagogical training for trainees on their grants (President's Council of Advisors on Science and Technology US, 2012), and developing discipline-specific teaching institutes (Crowder & Monfared, 2020). But in terms of teaching strategies, nearly all solutions mention active learning, course planning, group learning/projects, and approaching teaching as research as necessary to improve the learning experience for STEM students. One study found that active learning practices increased students' science self-efficacy, and this led to improved academic performance for historically marginalized and excluded students (Ballen et al., 2017).

The PCAST report also found that “many students, and particularly members of groups underrepresented in STEM fields, cite an unwelcoming atmosphere from faculty in STEM courses as a reason for their departure" (p. 9). Women and students of color (historically marginalized and excluded) students earn STEM degrees at about half the rate of white men, and still do not persist in STEM in numbers related to their representation in the population (Seymour & Hunter, 2019). Students in Seymour and Hunter’s (2019) study told of instructors ridiculing them for asking questions, comments from deans that only one in four of them will make it to graduation, and a general feeling of having to “get with the program” to succeed. These messages had a particularly acute meaning to historically marginalized students, who were already made to doubt their abilities in STEM.

Malcom and Feder (2016) found that foundational math and science “gateway” courses were known for highly competitive environments that lacked peer support and instructor interaction. Indeed, Seymour and Hunter (2019) described the environment: “Comparing teaching styles encountered in STEM courses with those experienced in courses outside of STEM disciplines were marked by dichotomies: coldness versus warmth, elitism versus democracy, aloofness versus openness, and rejection versus support” (2019, p. 11). Students were made to feel that learning was squarely on their shoulders and not on the shoulders of their instructors, and if they were struggling, it must be because the students are deficient.

Despite years of faculty development and funding provided by the NSF and other funding bodies, many undergraduate students in STEM still experience classrooms and professors that are almost exactly as they were 20 or 30 years ago: taught by white men and a few white women, lecture-style, and with very little awareness of effective teaching practices. This calls for teaching development that is both evidence-based and that follows inclusive principles.

Graduate Student and Postdoc Socialization

In addition to a lack of diversity, researchers have found that graduate students in STEM are not prepared for the various responsibilities of academic work which include research, teaching, and mentoring and other forms of service (Austin et al., 2009). Research is a priority in STEM, both in terms of training and funding. Many STEM faculty need to generate a significant amount of grant funding to run their labs and pay their salaries. Not surprisingly, graduate students spend much of their time working in research labs where “a common theme is the higher value placed on research accomplishment as compared to the value ascribed to pedagogical training for future faculty members” (Baiduc et al., 2016, p. 238). The money sets the priorities. The amount of money flowing into research institutions from NIH and NSF grants is a perfect example of what O’ Hagan et al. (2019) described as STEM’s perfect fit with the neoliberal enterprise" due to the "commercial potential of science" and the "market-like competition among faculty and institutions for resources" (p. 206).

Brownell and Tanner (2012) found that students in the sciences are acquainted as early as undergraduate years to the ways of labs and research, and as they moved into graduate school, they "adopt the values, attitudes, and professional identities of the scientists who trained them" (p. 341). One of these lessons is that research is prestigious (which is proven by grant dollars) while teaching is its lesser cousin. This divide between teaching and research is often reinforced by the fact that future faculty programs are usually housed in Centers for Teaching and Learning (CTLs), which are quite separate from research groups at large research institutions (Crowder & Monfared, 2020). Brownell and Tanner (2012) also found that there are sometimes negative consequences for showing interest in teaching, including mentors who will not allow students to gain pedagogical training and those who will spend less time mentoring students who express interest in teaching. This is at least partly due to the misguided idea that engaging in pedagogical professional development will negatively affect their careers as researchers, which was disproved by Shortlidge and Eddy (2018). Of course, this way of thinking has been in place for a long time, so when thinking about changing priorities, culture change is necessary.

Mentoring

If we consider that providing teaching professional development is one part of a mentoring process, a mentoring system that is research oriented and has few rules or requirements would in most cases lead to very little teaching professional development (and other forms of mentoring). Faculty are not usually trained in mentorship and time spent on mentoring can have negative effects on their promotion (Kezar & Posselt, 2020, p. 97). Furthermore, the approaches to mentoring most seen in STEM are quite informal and seem to hold a “survival of the fittest” mentality (Thakore et al., 2014). These political dynamics are particularly dangerous to students of color, who already struggle to identify mentors who can help them overcome barriers of white supremacy within many graduate programs but particularly in STEM (Kezar & Posselt, 2020). Thus, the lack of diversity in most STEM PhD programs and faculty roles has its roots at least partially in graduate socialization. Women and historically marginalized and excluded graduate students in STEM said they experience unwelcoming environments, are less likely to receive mentoring, and question their ability to finish their degrees (Rohlfing et al., 2022).

Mentorship in STEM can also be understood through the power imbalance between faculty and graduate students. Manning (2018) recognized “access to information, expectations about consultation regarding decisions, and ability to exercise voice” (p. 164) as privileges not extended to people low in the hierarchy, which includes graduate students and postdocs. This lack of access to information might include knowledge about faculty roles and professional development in teaching, as well as limiting the range of mentoring discussions. This is not to say graduate students can’t have great mentoring experiences and even gain teaching development in the process. Indeed, either because they get lucky and have a great mentor, or because they “connect” with their mentor (an experience more likely if white and male), this relationship can be particularly beneficial. But both of these situations rely on a relationship to form, not on a systematic approach to training future faculty. Additionally, the current situation also puts most if not all the responsibility on faculty and is not shared by school administration and staff (Kezar & Posselt, 2020, p. 98).

Postdocs

Postdocs with HME identities are less likely to pursue academic careers if they doubt their abilities to succeed in academia (Yadav & Seals, 2019). The lack of professional development for postdocs causes many of them to feel this doubt. As explained by Yadav and Seals (2019):

> postdocs feel they are invisible as they fall in the ignored space between graduate students and faculty, which is exacerbated by the lack of quality institutional infrastructure to uniformly and comprehensively support postdocs. (p. 3)

Most efforts have been toward attracting increased numbers of diverse graduate students in the sciences, not helping them persist at the doctoral or postdoc stages (Yadav & Seals, 2019). Postdocs are also caught in the demands of the 40-hour work week as researchers, which does not leave much time for professional development in other areas. And yet, the effects of supporting postdocs with pedagogical professional development are impressive. For example, postdocs who participated in a mentoring program that included research and teaching were three times more likely to enter the professoriate (Rybarczyk et al., 2016). Women who participated in the program entered faculty positions at 69%, a much higher rate than the national average of 34% and HME participants entered at a rate 3x higher (29% and 9.5%) (NSF). They cited the teaching aspect of their training as key to their success. Additionally, the SPIRES program, which focuses on HME STEM postdocs, reported that participants have gone on to have significant impacts on undergraduates in STEM in teaching and mentoring (Rybarczyk et al., 2016). Clearly, pedagogical professional development helps postdocs to succeed in all areas of faculty life. This next section describes the teaching and learning issues important to understanding a way forward with STEM education.

Teaching Issues

The literature includes discussion of evidence-based teaching (EBT) identifying a set of practices that will improve STEM teaching in higher education. EBT includes student-centered strategies such as the use of clickers, Socratic discussion, and case studies as well as the two areas of focus in this study: active learning and inclusive teaching. Goodwin et al. (2018) found that graduate students are more receptive to EBT than their faculty counterparts, likely because their professional identities are still forming. Another term of use, and a subset of evidence-based teaching, is learner-centered pedagogies, which includes a range of strategies and approaches, but most importantly includes active learning and inclusive teaching. The next few paragraphs will describe the relevant teaching and learning theories, with some attention to modalities. Finally, common teaching strategies will be described, which will also point to the need for an in-depth study of teaching strategies in their programs.

Instructor-Centered Teaching in Current STEM Education

STEM fields largely use a “sage on the stage” model of teaching. Much of the instruction is in the form of lecture with slides or at a white board (Seymour & Hunter, 2019). Interaction in STEM classrooms is often limited to a question-and-answer session, what John Watson called stimulus and response. The expectation for students is that they be able to learn from the lecture, ask questions if they are confused, and show their learning in a paper or on an exam. Students who listen well and take good notes are rewarded with higher test scores. At times there may be a hands-on activity, like a lab, and holds a focus on observable skills. Merriam and Bierema (2014) related that "observable behavior, not internal mental processes or emotional feelings, determines whether learning has occurred" (p. 26).

STEM (and many other fields, to be honest) is also known for punishment in course policies. Zero scores for late work, grade drops for absences, and high stakes exams are all commonly seen. While many instructors have moved away from punishment-type policies, this is one persistent aspect of STEM education that might be viewed as gatekeeping and lacking a student-centered approach. Even while trends in education move toward student-centered approaches with UDL and trauma-informed strategies for teaching and course policies, these moves are not yet firmly established in STEM courses (Dewsbury et al, 2022; Brownell & Tanner, 2012).

Constructivist Strategies for Greater Persistence

STEM education is not as well acquainted with constructivist strategies as the arts and humanities. Constructivists see the learner as a dynamic actor seeking knowledge and meaning rather than as an empty vessel to be filled (Driscoll, 2005). Some qualities of constructivism are group learning concepts, active learning, recognizing and using students' previous knowledge, concepts of proximal zones of development, and experiential learning, among others. Constructivism asserts that participants enter with previous knowledge about teaching and learning based on their experiences as students and sometimes as teaching assistants. They are able build off that knowledge, sometimes contradicting it, and gradually introduce evidence-based teaching practices. One example of this is that many STEM students enter with little to no knowledge of active learning, which has its basis in constructivism. Over the course of their program, they will likely learn many active learning strategies like gallery walk and jigsaw discussions, and also a bit of the theory that supports them. Active learning is an important component of this study because it has been found to positively affect the retention of historically marginalized and excluded students in STEM (Dewsbury et al., 2022; Ballen et al., 2017).

Active Learning

Active learning is supported by many educational philosophies and theories, but Piaget's constructivism (1968) and Vygotsky's proximal development theory (1978) are two of the most important. Constructivists think of the learning process as a student taking in new information and either fitting it into a framework or making changes to the framework to allow for the new knowledge. Active learning strategies strive to create this experience for learners by not only setting the scene for learning but also for using higher order skills and helping learners to develop metacognition. Willingham (2021) added that active learning has the effect of helping learners to take their background knowledge and apply critical thinking skills, which helps them organize knowledge into useful configurations (p. 28), or packages that can easily be taken off a shelf. Some examples of active learning, from simple to increasingly complicated, are pause procedure, think/pair/share, group discussion, case studies, and the use of simulation technology. Of note is the inclusion of group work in this list, and here is where Vygotsky's proximal development theory (1978) supports active learning. Vygotsky found that learners learn from peers (and not just an instructor) and that they could often stretch beyond their individual knowledge when working with a group. Willingham (2021) also pointed out the value of peer learning and in creating a sense of belonging (through inclusive teaching) when he said the "emotional bond accounts for whether students learn" (p. 70). Too often bonds between students and with their instructors is not viewed as central to learning.

Experiential Learning

Experiential learning has been found to be important in the professional development of new faculty. One example of experiential learning is Kolb's Experiential Learning Cycle: concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 2014). For example, Mutambuki et al. (2020) examined the features of a successful future faculty program and identified "repeated opportunities to engage in evidence-based teaching approaches through experiential learning" (p. 59) as key to their effectiveness. These may come in the form of microteaching sessions, guest teaching, and TAing observed by a teaching mentor followed by a feedback session, and opportunities to create and practice learning activities. Borrego and Henderson (2014) suggested that this application or implementation part of student-centered teaching is crucial for the larger culture change process to take hold in STEM. In their study of postdocs who participated in future faculty programs, Ebert-May et al., (2017), the authors found that access to teaching opportunities and regular feedback from constructivist-minded mentors was key to sustained use of learner-centered pedagogies post-program.

Growth Mindset

Lastly, constructivism informs many of the thoughts around growth mindset, which is based in social learning theory but has constructivist values. Growth mindset is "the core belief that intelligence is malleable and can be improved via hard work" (Willingham, 2021, p. 203). Growth mindset can be held by a student, but is also powerfully realized through instruction. For example, a student may believe they can learn the content, but if an instructor does not believe, they will not take steps to teach the student and support them in their learning. It is vitally important in STEM that instructors have a growth instead of fixed intelligence mindset, particularly for the success of historically marginalized and excluded (HME) students. In a longitudinal study that included 15,000 STEM undergraduates and their instructors, Canning et al. (2019) found that students whose instructors had fixed mindset had larger racial achievement gaps while students whose instructors had growth mindset view of intelligence were similar in achievement. Similarly, the two approaches to teaching on which this paper focuses—active learning and inclusive teaching—both found to have significant positive effects on STEM students and persistence (Seymour & Hunter, 2019), are of a growth mindset orientation.

Learner-Centered Pedagogies

Instruction in the United States is increasingly learner-centered rather than instructor-centered. In the latter, content and ideas are filtered through the instructor and their worldview and are offered to students largely in the form of lecture. In the former, content and ideas are offered to students to consider in a variety of ways that might include a short lecture but will also include active learning or experiential learning, for example. The issue of "covering content," is often cited as the reason why STEM instructors do not include active learning techniques in their teaching (Petersen et al., 2020). They feel pressured to cover topics, which is assumed to be when the learning takes place, rather than in an active setting. This seems to be a significant barrier for instructors in foundational level science courses, who feel pressure to cover fundamental concepts. The science of cognitive development would assert that foundational courses are exactly where students need active learning. As Willingham (2021) explained it: the brain will not remember what it has not thought about, so instructors need to design lessons that have students think about the material, not just take notes from what is on a slide.

Learner-centered pedagogies include active learning (described above) and inclusive teaching practices. Both active learning and inclusive teaching strategies place the learner at the center of pedagogical choices. These learner-centered strategies have been found in multiple studies to lead to student learning and success but have also been found to be central to improving STEM teaching and learning and student persistence.

Inclusive Teaching Practices

Inclusive practices in teaching, for the purposes of this paper, are defined as having the awareness, knowledge, and skills for applying diversity, equity, and/or inclusion to teaching and learning (Hartwell et al., 2017). These strategies are sometimes also referred to as anti-racist teaching practices, depending on their attention to equity and white supremacy. They value diverse contributions to learning and seek to include all students in the learning process. Dewsbury and Brame (2019) added that inclusive teaching is dialogic:

> When instructors engage with their students' voices and acknowledge their students' agency in learning, it transforms the ways in which we construct STEM classrooms. Students' voices guide curricular choices, the support structures that

> help students succeed, and the tools that will promote a positive classroom climate. (2019, p. 3)

Inclusive instructors strive to understand and confront the foundations of education in white supremacy and provide ways to counter it in course policies, course design, lesson planning, assessment, and other course activities. One example of this is the recognition of scientists of color in lectures and in selected articles. Inclusive educators do not ask students to represent a group or teach the class about a group to which they belong. Inclusive teaching practices consider the unequal status of both instructor and students, and increasingly, incorporates multiple modes of assessment and flexibility in attendance and due dates. Finally, professional development focused on inclusive teaching should also include attention to "reflection, empathy, and awareness of social relations and interactions in the learning environment" (von Vacano et al., 2022, p. 7). Inclusive teaching fosters these social and reflective experiences as part of the learning process, not simply a movement of information from instructor to student. Maybe because of this deeper level of engagement, Dewsbury (2017) found that surface-level professional development on inclusive teaching has negative impacts on classroom experiences.

Educational literature is full of discussions of belonging and how to foster it. Inclusive practices are often shared as tools to create a sense of belonging among students. While these practices are important, relationship building and dialogue are key. Furthermore, it is difficult to teach faculty how to foster belonging if they are not talking about the various paths to belonging and a clearer definition of what they belong to (Dewsbury, 2017). For example, an instructor would need to recognize the hierarchies and white supremacist traditions in which they work to fully create belonging in a course.

Freire said that instructors need to enter into dialogue with students and that this dialogue is what will lead to inclusive, emancipatory education. Dewsbury (2017) echoed this is asserting that truly inclusive teaching is about relationships. Interestingly, Ballen et al. (2017) found a connection between the use of active learning strategies with sense of belonging in HME science students.

Modalities

The last 20 years have seen a move toward increasing use of technology in teaching. Even before the COVID pandemic, universities like Arizona State and Oregon State University had fully online departments and degrees. The pandemic had the effect of pushing all learners online for varying amounts of time and illuminated the need for faculty to gain skills in teaching in online and hybrid formats. In addition to the basic skills of teaching on Zoom and fundamentals of instructional design, faculty are learning about Universal Design for Learning (UDL), which provides a blueprint for fully accessible online teaching (that also meets many of the requirements for inclusive teaching). It remains to be seen how STEM future faculty programs have included training in various modalities and digital accessibility as part of their curriculum. Additionally, this is an area of interest because online education more often features learner-centered course design, highlighting “integration and sustained inquiry…the development of cohesion and sense of community” (Voegele, p. 177, 2012).

CIRTL Curriculum

CIRTL is easily the most well-known source for future faculty programming in STEM. There are three main pillars of CIRTL: Teaching as Research, Learning Communities, and Learning Through Diversity. Many STEM future faculty programs use the CIRTL pillars to structure their curriculum and their course and workshop offerings seem to be a mix of national CIRTL sessions and local, institutionally-based sessions and courses. Of note, CIRTL's three pillars do seem to address at least thematically some of the issues identified in the literature review regarding teaching in STEM: the pressure to dichotomize teaching and research, the need for communities of practice for successful faculty development, and the need for inclusive teaching in STEM fields. CIRTL offers a few regularly offered MOOCs as well, one titled *An Introduction to Evidence-Based STEM Undergraduate Teaching* and *Advanced Learning Through Evidence-Based STEM Teaching.* At first glance, CIRTL seems to be the answer STEM leaders have been looking for, but its reach is limited. One reason CIRTL does not have a larger role in transforming STEM education is the cost of access: member institutions pay $12,000 a year to access CIRTL's programming. The argument to put this amount of money into graduate student and postdoc professional development is a tough one, particularly at smaller universities. Institutions also need to have the local resources and staff to promote and support CIRTL engagement. Secondly, the MOOC model of professional development is inconsistent in engagement. Goopio and Chung (2021) found that while initial MOOC registration is high, a significant portion drop out after the first week, and most of the rest will drop out before the end of the course, which also means that few if any will complete the course. If programs are hoping to replace local programming with reliance on MOOCs, they may find that those learning goals are not being met. Despite these challenges, many effective, well-established STEM future faculty programs are CIRTL members and take advantage of both their organizing pillars and their curriculum.

Organizational and Critical Analysis

When considering the issues that arise around pedagogical professional development, teaching and learning in STEM undergraduate courses, and the role of future faculty programs in affecting change, it is useful to apply organizational lenses in analysis. Because this issue finds its persistence in inequities, a critical lens is needed to identify problems and seek solutions in persistence, teaching and learning, and organizations.

Organizational Analysis

Organizational theories provide a lens through which to view the institutional contexts of future faculty programs in STEM. Manning's (2018) political model of organizational theory provides insight into the power inequities of graduate student and postdoc experiences. The political model describes a hierarchy where they occupy the bottom rungs and a landscape of mentoring and career development that can often be unpredictable and informal. In contrast, Eddy and Kirby's networked leadership models are useful in thinking about the ways future faculty programs recruit institutional resources in service of professional development for graduate students and postdocs.

Political Model

In Kathleen Manning's *Organizational Theories for Higher Education* (2018), the author asserted, "the dynamics and relationships between people are where the political model is most explanatory and insightful" (p. 159). Indeed, the teaching professional development landscape for STEM graduate students is a jungle of conflict, competing priorities, privilege, and detachment. Connolly et al. (2018) found that teaching professional development leads to increased feelings of efficacy in early career scholars. Yet, the professional development opportunities (or lack of) are subject to the inconsistencies of politics.

The political organizational lens is useful for describing the teaching professional development and mentoring landscape experienced by many STEM graduate students. It is an effective lens because it highlights the inequities and inconsistencies of training and the need for systemic, informed mentorship and teaching professional development. It recognizes, though, that when strong, productive relationships are formed between mentor and mentee, the mentee benefits significantly.

Networked Leadership

Networked leadership is a form of connected leadership that strives to create long-term connections and affect change within the organization (Eddy & Kirby, 2020). It involves both positional leaders and those not in positional leadership in collaborations than span the institution. Individual players can move in and out of leadership in the collaboration because the focus is on an identified problem to solve or service to provide (Eddy & Kirby, 2020). Networked leadership is useful for considering the leadership requirements of leaders of future faculty programs. Hill et al. (2019) studied eight CIRTL network future faculty programs and in interviews with program faculty and staff, these leadership themes emerged: 1. The ability to connect with people and programs across the institution to encourage buy-in; 2. Acting as a champion for the program and for graduate student and postdoc professional development in general; 3. Inspiring excitement for the program to garner fiscal support and other resources. Despite finding these three themes, the authors assert that the first—the ability to connect with people across the university—was the most often mentioned.

Partnerships for Shared Resources and Opportunities

One feature of networked leadership is partnerships. Eddy and Kirby (2020) argued that partnerships are important in our current context of “declining funding and increasing complexity of institutions” (p. 199). For example, one office may not have the expertise to conduct all the workshops in a program, so leaders reach out to faculty and staff that do. Bowman et al. (2019) found that many institutions do not have the resources to support future faculty programs, which is why partnerships become important. A future faculty program at University of California, San Francisco, creates partnerships with local undergraduate institutions because the school does not have undergraduates, and thus, lacks teaching opportunities. These partnerships enable programs to explore “innovative or new programs and ideas, but without ties to the institutional structure” (Eddy & Kirby, 2020, p. 198). Partnerships can also exist within an institution. For example, future faculty programs often collaborate with diversity initiatives and career development offices to meet the needs of graduate students and postdocs as they think about their careers. Advisory boards are another example of how inter-institutional partnerships can support future faculty programs, both by helping with decision making and by garnering support from various departments and central leadership (Hill et al., 2019).

Boundary Spanning to Support Future Faculty Programs

In addition to partnerships, boundary spanning is a beneficial characteristic of networked leadership. Boundary spanning is when people work across silos or divisions in an institution. The stronger the boundaries, the greater challenge is presented to networked leadership. One asset of boundary spanners is that they are able to understand and translate different groups' perspectives. Faculty and staff who coordinate future faculty programs are boundary spanners partly due to the broad goal of including graduate students and postdoctoral scholars from a variety of departments, and partly due to the needs of the program for trainers, facilitators, board members, and observers. For example, the FAST program at Michigan State University uses graduate fellows, science faculty mentors, and trainings from the Graduate School to piece together their STEM-focused future faculty program (Vergara et al., 2016). Another example is seen with many future faculty programs that are members of CIRTL. There is often a local faculty or staff that acts as a liaison between the CIRTL network and their institution (Hill et al., 2020).

Boundary spanners are also an example of how networked leadership leads from the middle rather than above (Eddy & Kirby, 2020). The people doing the boundary spanning are rarely the people at the top of their respective hierarchies. More often they are CTL faculty or staff or a few faculty members leading the effort. Lastly, when we think of networked leadership and the broad network it creates, it is important to note the diversity of knowledge and experience brought to bear on future faculty programs (Eddy & Kirby, 2020). Boundary spanning might connect them with peer mentors, career opportunities, and other collaborations outside of their normal sphere of research lab and academic department. Interestingly, boundary spanning can provide a lens through which to view STEM-focused future faculty programs. Specifically, by focusing only on scientists in training, these programs might miss out on the diversity of experiences and knowledge shared in a campus-wide future faculty program.

Organizational Challenges

According to multiple studies, there is significant variation in future program design and components (Crowder & Monfared, 2020; Mutambuki et al., 2020). Some programs have a pick-and-choose approach, where participants are not moving through the program in cohorts and there is not a guaranteed number of hours they might engage with the curriculum. Other programs have a cohort model fed by applications and some offer fellowship money to support the time spent. Similarly, programs that are part of the CIRTL network seem to vary in how much CIRTL programming makes up their program. Some programs rely on CIRTL for nearly all their STEM-specific programming (Hill et al., 2019). Others offer quite a bit of local curriculum in the form of courses, workshops, teaching observations, and use CIRTL as a guiding set of principles rather than as content or curriculum. Due to this variation, it seemed clear that more needed to be learned about the curricular decisions made by programs and the extent to which programming is based in their institutional contexts.

STEM-focused future faculty programs are largely based at research-heavy institutions (Crowder & Monfared, 2020). Many are at large land grant institutions that have significant resources to devote to graduate students. Some are at smaller institutions that have STEM or biomedical sciences focuses, like academic health centers. In their study of eight CIRTL programs, Hill et al. (2019) found four key features of future faculty programs: 1. Campus support for teaching and learning in general and professional development of graduate students and postdocs in particular; 2. Programs had access to central support services and many connections to people and resources across campus, regardless of their organizational location; 3. Leaders of these programs were good at reading the landscape of the institution and connecting with stakeholders; 4. Programs were strong programmatically—they had good teams, functional space, access to money and resources, and had strategic marketing. The converse of these four features should also be considered: what are the consequences of having three of the four features? What if that feature is adequate funding or support for graduate student and postdoc professional development? While these four features all seem important, they beg the question of if this list should be ranked. Or, alternately, can a dynamic leader with great connections across the institution make up for a lack or two in another area?

The field of graduate student and postdoc professional development also needs to consider the barriers and opportunities of institutions without future faculty programs. As mentioned earlier, not all institutions have a future faculty program, much less a STEM-focused program. There are many reasons for this: multiple studies have found that some institutions do not have the funding or FTE to devote to such a program (Bowman et al., 2020; Connolly et al., 2018). Early Preparing Future Faculty programs were funded through a grant, but that grant has since expired and some programs went with it (Rozaitis et al., 2020). Many institutions fund shorter, more immediate teaching assistant training. This training is justified because it prepares TAs for their short-term duties, which serve the interests of the institution and do not require the same commitments of resources as future faculty programs (Branchaw et al., 2020; Fong et al., 2019; Lang et al., 2020).

Another barrier to developing future faculty programs in STEM is the persistent focus on research (which is constantly reinforced by grant funding) and how this focus harms efforts to professionalize teaching among scientists. There are a few ways this manifests: at some institutions, graduate students in STEM are only given research positions and are not offered teaching assistantships. As mentioned earlier, even if teaching assistantships are offered, they are often told that these positions are less valuable than research positions (Rybarczyk et al., 2016; Yadav & Seals, 2019). Another way this is manifest is that pedagogical professional development is not often integrated into the standard curriculum of graduate students or the duties of postdocs. It is usually an add-on that must be done in one's "free time" and quite often against the wishes of one's principal investigator (Borrego et al., 2021). While not present in all contexts, the literature shows that there are significant barriers to future faculty programs and to participating in them (Borrego et al., 2021; Bowman et al., 2020; Connolly et al., 2018; Hill et al., 2019). Not surprisingly, these barriers inhibit the positive effects future faculty programs can have on STEM education at both the undergraduate and graduate levels.

Despite the barriers faced by future faculty programs, they persist in training graduate students and postdocs to be effective educators. They take advantage of already existing resources like the CIRTL network, science faculty with pedagogical expertise, and the resources and faculty of CTLs and graduate schools to create programming that truly prepares them for college teaching. This study sought to learn about their actual curriculum, what commonalities and differences exist between programs, and how their curriculum is affected by their institutional contexts.

Critical Analysis

Critical theory helps us understand both the context of the problem in STEM and future faculty programs' attempts to answer the problem. First, historically marginalized and excluded (HME) students are often underserved and alienated by STEM teaching in foundational courses, which leads to a lack of persistence and lack of representation at the graduate, postdoc, and faculty level. Seymour and Hunter (2019) also found that students of color blamed themselves for not learning better in STEM courses. Clearly, STEM undergraduate education is not serving historically marginalized and excluded students and this lack of service is based in white supremacy culture. Furthermore, critical theory is informative when looking at the organizational contexts and policy landscape of STEM disciplines. It sheds light on how power is organized to protect the status quo in STEM education.

Critical Theories and the Classroom

The critical theory called community cultural wealth is also relevant to STEM future faculty programs. Too often in education we are trained to view historically marginalized and excluded students as deficient—in training, opportunities, supports, etc. and these are used as explanations for poor academic performance (Yosso, 2005). Conversations around HME persistence used to center on preparedness, with the implication that HME students were deficient, not the education systems that failed to help them prepare. In contrast, community cultural wealth theory helps faculty and future faculty to comprehend the resources, abilities, and contacts historically marginalized and excluded students come with—of community, family, cultural and religious traditions, among others. For example, Hofstra et al. (2020) conducted a broad survey of scientific articles and dissertations using machine learning and found that historically marginalized and excluded scientists are more innovative than their white counterparts. The authors attribute their scientific novelty to their ability to see and connect ideas and concepts differently. The study also found that their ideas, however novel, are not adopted at the same rate as their white counterparts. Community cultural wealth theory helps illuminate the lost opportunities and knowledge when students from HME groups are kept out of faculty roles.

Critical Race Theory helps us understand problems in STEM education as part of white supremacy culture. Von Vacano et al. (2022) asserted that white supremacy in STEM is "historical, cultural, and institutional" (p. 4). For example, nearly 90% of faculty are white and 65% are male (Bennett et al., 2020), the textbooks and lectures feature the thoughts and work of white men, and introductory level courses are described as "cold" and "cutthroat" (Hrabowski et al., 2019, p. 114). Yosso (2005) adds another interesting point about the "racialized assumptions" made of HME students: they often lead to banking style instruction because students are seen as empty or deficient (p. 75). Furthermore, historically marginalized and excluded students are made to feel like outsiders to science, their identities as scientists questioned in what Seymour and Hunter (2019) call "a normalized process of structured wastage" (p. vii).

Indeed, many future faculty programs may need to take extra steps to help participants unlearn traditional teaching methods like relying on lectures and question and answer sessions, particularly considering the dynamics of "banking" style instruction.

For example, STEM-focused future faculty programs might emphasize discipline-specific teaching methods over student-centered approaches. More often than not, STEM faculty are content-focused rather than student-focused (Dewsbury et al., 2022). They believe their job is to relay content and that the lecture with pre-made slides or with a whiteboard is what works to relay it (Seymour & Hunter, 2019). Conversely, some future faculty programs seem to have taken steps to include a critical approach to teaching, at least as far as training participants to teach to a diverse student population (Bowman et al., 2020; Rozaitis et al., 2020; Vergara et al., 2014). To take it a step further, STEM future faculty programs might begin to consider how they are talking about power and inequities in the classroom and what future faculty can do to develop critical teaching and learning spaces. Diggs and Mondisa (2022) found that many future faculty programs do not consider the needs and desires of HME participants in their programs. They do not offer workshop topics that attend to these needs; likewise, the credit courses offered do not necessarily have HME challenges and benefits included (Diggs & Mondisa, 2022). Conversely, many participants in future faculty programs said they experience greater community by participating and that they enjoy the diversity of the programs (Mahavongtrakul et al., 2021). They also mentioned that they enjoy the peer support for their interest in pedagogy. They shared that sometimes their cohorts in their home departments are toxic and competitive, while their future faculty cohort was welcoming and supportive.

Critical Approach to Organizations

The literature confirms that future faculty programs in STEM have great potential to facilitate change in STEM classrooms and help fix the pipeline of historically marginalized and excluded students. Studies have found that they successfully train instructors who experience self-efficacy in many areas of student-centered teaching and will likely go on to teach using student-centered, evidence-based approaches in their faculty careers. It is not clear if they see themselves as part of culture change in STEM. And if they do feel a part of the change, this study sought to know more about how they enact it in their programs and what abilities/opportunities they add to the effort of changing STEM education. Lastly, research is needed on future faculty programs playing a role in developing critical approaches to policies that govern graduate student and postdoc professional development.

There are significant, historical barriers to making change in STEM education. A critical lens shows

> multiple broad influences on STEM education that affect its participants – both instructors and learners – deeply yet invisibly, by guiding and constraining the choices, opportunities, and psychologies of individual actors. Importantly, these processes are historical, cultural, and institutional, their influences are invisible – that is, they are "baked in" to the structure of the system. (von Vacano et al., 2022, p. 5)

The values that are "baked in" include STEM education as social reproduction rather than social mobility, reinforcement of status hierarchy, and assumptions about effective teaching. Students and postdocs occupy the lower rungs of the hierarchy and "shield faculty from criticism, reflections, responsiveness, or self-awareness" regarding the roles they play as instructors and mentors (von Vacano et al., 2022, p. 6). Meanwhile, the pressures of academic capitalism have faculty focused on bringing in grant funding over any other faculty role or responsibility. These dynamics seem to put STEM future faculty programs in uncomfortable positions of advocating for graduate student and postdoc autonomy, possibly distracting them from grant writing and lab work, and attempting to train them in teaching strategies that might feel new and possibly threatening. On the other hand, some programs might enjoy a closer relationship to STEM departments and might view their domain as simply improving the teaching and providing future faculty with much-needed professional development rather than as change agents working to transform STEM.

Paradigmatic Framework

Faculty development is often informed by a pragmatist worldview for its focus on problems, its orientation toward real-world practice, and its inclusion of multiple methods. In the pragmatist view, both the individual and the world are constantly changing and responding to action and consequences. As Kaushik and Walsh (2019) explain, "the world is also not static—it is in a constant state of becoming." (Kaushik & Walsh, 2019, p. 3). This focus on action and change is a useful lens through which to view the efforts of future faculty programs, which function on the belief that the actions of the program will bring about learning in the participant, who will then go out and teach differently because of the training. It also informs the perspective of this study, which sought to explore how STEM future faculty programs are answering the question of learner-centered pedagogy and institutional supports while recognizing that all of their answers are in flux and context-dependent, two features of a pragmatist lens (Creswell & Creswell, 2018). Additionally, Wallin (2003) asserts that faculty development's nonlinearity, its focus on individual growth and skills, and its lack of a grand or unifying theory, call for a pragmatic approach to research for its problem-solving orientation and flexibility. Like traditional faculty development, future faculty programs in their very nature are pragmatist: they focus most of their energy and time on strategies that will create better teaching and learning experiences, and engagement with educational scholarship and theories, while important, is usually secondary.

The pragmatist worldview calls for real-world solutions to problems. In the case of future faculty programs in STEM, the review of literature showed that teaching and learning practices, socialization in the sciences, and organizational facets all influence programs and participants' access to them. The model below shows how these areas intersect and how learning about them is both interconnected and better understood using a critical lens.

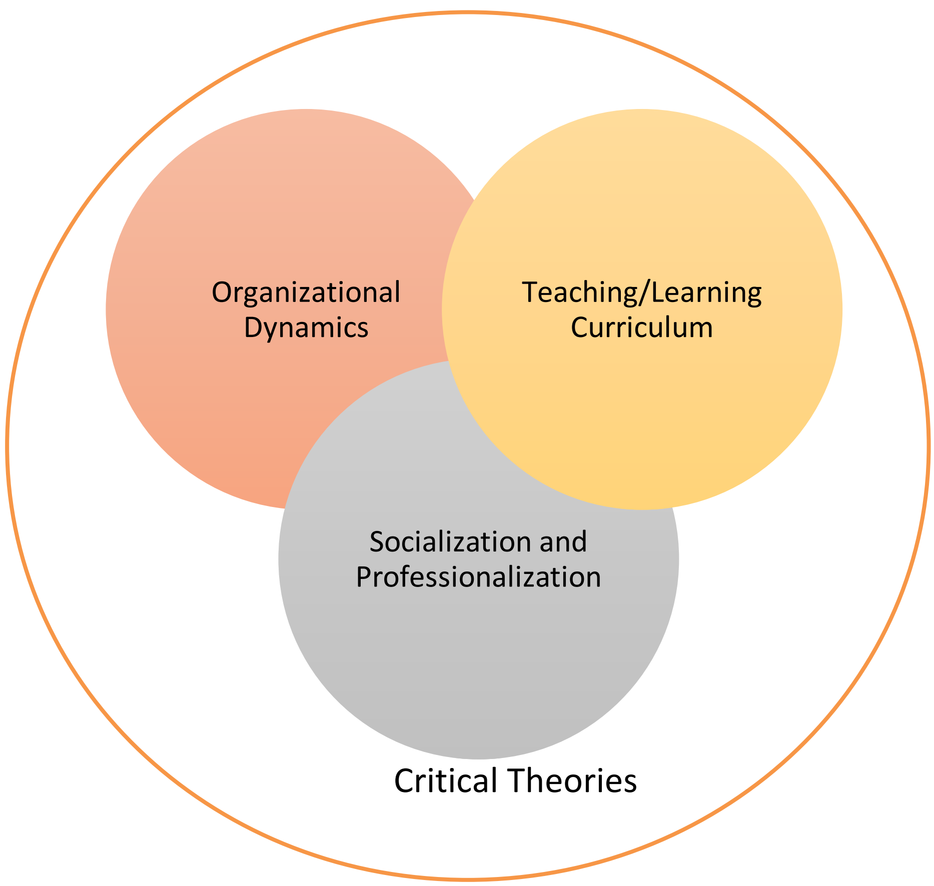

Figure 1: STEM Future Faculty Conceptual Framework

Grant and Osanloo (2016) define a conceptual framework as “the researcher’s understanding of how the research problem will best be explored, the specific direction the research will have to take, and the relationship between the different variables in the study” (17). The framework above shows the overlapping effects of teaching and learning theories and approaches, STEM socialization and cultural aspects, and organizational theories as lenses through which future faculty programs might be explored. For example, even while a future faculty course is training a graduate student in teaching strategies, it is also socializing them to faculty roles and responsibilities (often in ways not found in their departments or labs). Similarly, the programming and support offered by a future faculty program should be viewed as intersecting with institutional issues like fiscal funding and access to fellowships. Additionally, critical theories are overlaid on all the spheres because they are the overarching lens through which each domain is viewed. Future faculty programs are located at the very center of this diagram, where these lenses all overlap. The three primary areas of interest in this study are the teaching and learning approaches, the interplay between graduate student socialization/professionalization and future faculty programs, and the organizational contexts that affect the curriculum and structure of future faculty programs.

Critical theories shed light on the ways power and privilege work against STEM persistence. Dewsbury (2017, 2022) and von Vacano et al. (2022) argued that STEM education has a pernicious inequality, seen from the smallest moments of instructor/student interactions all the way up to the departmental, institutional, and national level. As von Vacano et al. (2022) wrote, “meso level interventions [including inclusive pedagogical development for future faculty] that include a critical approach to faculty and peer instructor development may be key to addressing STEM disparities, given that meso level processes plan a mediational role between macro and student-level factors" (p. 2). The authors situate future faculty programs and other interventions, like universal design for learning and student self-empowerment, at the crux of change. Thus, it is vital that attention is called to how power and privilege are enacted in STEM while also training future faculty to confront and counter them. Not surprisingly, power and privilege play a large role not only in STEM classrooms but also in the training of graduate students and postdocs and their ideas about continuing into faculty positions, so it is important to look at these three areas with a critical lens.

Summary

This chapter began by describing the problems in persistence in undergraduate and graduate STEM education that are particularly acute for historically marginalized and excluded students. It discussed the mentoring and socialization of graduate students and postdocs toward careers as researchers rather than teachers. Next, considerations of teaching and learning were discussed in light of STEM education and the work of future faculty programs. Lastly, the various forms of analysis—organization, pedagogical, and critical were applied to the topic. Specifically, this chapter described the current understanding of STEM education at the undergraduate, graduate, and postdoc levels and the cultural features that not only make change difficult but also point to a gap in the literature regarding the role of future faculty programs in creating change. Finally, the theoretical framework, pragmatism, and the conceptual framework were discussed to describe the larger assumptions that shape this study. In the next chapter, the methodology of the study is explained, including how the researcher came to the research questions based on the aforementioned frameworks.

CHAPTER 3: METHODOLOGY

Future faculty programs that seek to provide pedagogical professional development to STEM graduate students and postdocs are increasingly viewed as important sites to the project of improving STEM education and diversifying its students and faculty. To date, however, the professional literature has yet to identify a set of faculty development best practices that might guide the field in growing graduate students and postdoctoral scholars as educators. Furthermore, the literature has yet to describe the institutional supports required to drive the success of STEM-oriented future faculty programs. This study intended to address this need through a comparative qualitative study in seeking evidence-based practices and institutional contexts in STEM future faculty programs. This chapter describes the purpose of the study, research questions, and data collection and analysis.

Research Questions

A review of the literature suggests that more needed to be learned about STEM-focused future faculty programs. In the teaching and learning domain, multiple studies have shown that future faculty programs have increased the self-efficacy in teaching of their participants and that these programs are preparing them for all the roles of faculty life, largely by interviewing current and previous program participants or by using instruments to measure their use of effective teaching strategies in class sessions. While much has been published about their overall efficacy, very little has been published about their efforts to train inclusive instructors. Additionally, to date, there are few studies that sought to learn about STEM future faculty programs from the managers of such programs and understand the pedagogical, professional developmental, and organizational thinking that went into creating and sustaining these programs.

There was a need to learn about the role of future faculty programs in new efforts to socialize and professionalize STEM graduate students and postdocs. Studies suggest future faculty programs might be key to improving persistence in STEM undergraduate education and to diversifying STEM faculty. Still, very little has changed in STEM teaching, so more needed to be learned about the curriculum of these programs (teaching and learning area) and their institutional contexts (organizational dynamics). Organizational dynamics also led to questions of the benefits and/or challenges these programs face based on their location in the institution, their organizational structure, and their fiscal support, to name a few possible factors.

The research questions included:

1. What pedagogical approaches and professional development processes are utilized by effective STEM future faculty programs?

   1a. How are participants trained in learner-centered pedagogies?

   1b. How are participants acquainted with issues of power and privilege in pedagogical practices?

2. What organizational or institutional benefits and barriers exist to providing pedagogical training to graduate students and postdocs?

Population and Site Selection

To effectively answer these questions, the researcher needed to first establish criteria for what constitutes an "effective program" and identify programs that would answer questions about STEM future faculty programs. The researcher conducted an initial review of program websites to identify programs that met the criteria for effectiveness. The researcher sought to study three programs and identified alternates.

Study sites were selected based on meeting these criteria:

1) It was a STEM-oriented future faculty program. This study was interested in the particular dynamics of STEM education, which are summarized as poor teaching in foundational courses, a growing emphasis on the importance of STEM programs to research and industry, and the increasing focus on future faculty as possibly the most effective site of teaching professional development. Future faculty programs were chosen over teaching assistantship training programs because they generally feature both depth and breadth of pedagogical knowledge and are oriented toward careers in academia (whereas TA trainings are satisfying the more immediate need to staff discussion groups and review sessions).

2) The program had a time commitment of 30 hours or more for completion. This time commitment is supported in the literature as a threshold for participant self-efficacy (Connolly et al., 2018).

3) The program had a history of robust program evaluation. Programs with evaluation and improvement processes were of interest to this study because they sought to evolve with participant needs.

4) Scholarly activity was prioritized in selection. Programs that engage in scholarly work based on features of their programs are adding to the field of understanding of future faculty program success. Sites were chosen after a review of online materials to establish the above criteria as well as access to people and materials for the case.

Site Selection

The researcher utilized the POD network, specifically the Graduate Student and Postdoc Professional Development Special Interest Group (GPPD SIG) to identify programs that met the selection criteria and were willing to participate. If a program manager was open to participation, the researcher scheduled a 30-minute Zoom call with them to tell them about the study and answer questions. At the end of the call, programs either committed verbally or said they needed to check with their supervisor, who would also participate. An initial group of three programs gave verbal agreements at the end of this first meeting. Within a few weeks, one of these programs said they could not participate because the supervisor told the program manager that the program manager did not have the time to participate. A second program declined to participate for similar reasons, but it was two months before they informed the researcher. Having two programs decline, the researcher continued to utilize contacts in the POD network and personal contacts in the field to learn about programs that would qualify. Both of the last two programs were referred to the researcher as high-quality programs worth replicating. They agreed to participate based on the information in the study information sheet and email communication with the researcher. They did not require an initial Zoom call. The researcher called them Central University, SW University, and NW University.

The three programs chosen for the study were two institutes of technology (Central and SW) and one research-intensive land grant university (NW). One institute of technology was located in the South (Central), the second institute of technology was on the West Coast (SW), and the land grant university was in the Pacific Northwest (NW). All three institutions were in major urban areas.

Central University was a STEM-only institution with 26,400 graduate students and approximately 19,000 undergraduates. It did not publicly share postdoc numbers. The future faculty program was managed by a Center for Teaching and Learning (CTL) and staffed by three staff members trained as educational developers, 8-10 graduate students, and occasional faculty fellows. It served 300-400 participants at any given time and was accessible to both graduate students and postdocs. Their programming for each group was different, with postdocs doing much of the work asynchronously and on individualized timelines while graduate students more often took credit courses. Central has been a member of the CIRTL network since 2016. It was active in gathering and sharing scholarship regarding its future faculty program at national conferences.

SW University was also a STEM-only institution with 1,400 graduate students, 1,000 undergraduates, and 650 postdocs. The future faculty program was administered from a CTL and staffed by two people, the supervisor and the program manager (who had a doctorate in a STEM field). SW's future faculty program was solely for graduate students and had 6-8 participants complete the certificate program per academic year (although they recently launched a postdoc program in January of 2024). This program was identified by experts in the field as having an innovative and effective program design. This program held membership in CIRTL but was not at the time of the study using it in their future faculty program.

NW University was a large land grant institution with multiple campuses and many non-STEM degrees and programs. It had 17,450 graduate students, 43,255 undergraduates, and approximately 900 postdocs. Their program was led by biology faculty members, one of whom was the program manager and the others served as mentors, and supported by staff in the college of biological sciences and school of medicine. The program director worked at one of the satellite campuses while faculty mentors primarily worked at the main campus. This program was limited to postdocs but had an offshoot of the program that was being re-developed for graduate students. Approximately 9-12 postdocs completed the program per year. This program not only engaged an outside evaluator to assess program effectiveness, it also published in peer-reviewed journals on program design and effectiveness. Fifty percent of their participants were offered tenure track academic positions.

Participant Selection

Program managers needed to have been in their position a minimum of two years to have great knowledge of the program curriculum and the theories and models used to create it. Their supervisors (associate deans, deans, assistant vice provosts) were chosen because they provided further information and contexts at the institutional level. Many studies have researched the experiences and training of future faculty programs from the perspective of the graduate students and postdocs participating in these programs. There was a gap in knowledge regarding the program and curriculum-level decisions and strategies.

This study used purposive sampling, which means the researcher selected participants that are most likely to provide insight into the phenomenon (Saldaña & Omasta, 2018), in this case, their future faculty programs. The researcher sent emails to the program managers of the three programs to ask for their participation, making sure to describe the study and its purpose, the requirements of involvement, and the data management plan. It was not possible to gain access to a supervisor for one of the programs; in this case, the researcher was directed to another leader with organizational knowledge of the site to participate in the supervisor interview.

Research Perspective (Methodology)

This study used a comparative qualitative approach to data collection and analysis. The use of qualitative multi-site studies arose in the 1970s in education research because they overcame some of the weaknesses of large quantitative studies while also not being limited to the particularities of just one case (Herriott & Firestone, 1983). Additionally, they respond to critiques that single-site case studies could not be used "for informing actions relevant and applicable to other settings" (Herriott & Firestone, 1983; Jenkins et al., 2018, p. 1969). While the purpose of this study was not to find a universal truth about STEM future faculty programs, it was interested in learning about features of these programs that might be replicated at other institutions and might inform a set of best practices.

Multi-site case studies have been often used "to better understand and measure program implementation" (Herriott & Firestone, 1983, p. 15), and while this study was not a traditional case study, it had the goal of better understanding future faculty programs in STEM. While these programs have been shown to produce effective instructors, very little is known about the various curricular and professional development approaches utilized by STEM future faculty programs. Hill et al. (2019) and Mutambuki et al. (2020) both used multi-site case studies to learn more about future faculty programs, about organizational factors that effect CIRTL programming in the former and about overall teaching skills in the latter (regardless of the program they completed). In this study, the goal was to better understand STEM future faculty programs, specifically their teaching and learning approaches and professional development processes, and their institutional contexts.

Case study design is suitable when a program's variable cannot be studied separately from its context (Merriam & Tisdell, 2016). While this study was not a traditional case study, it did benefit from some of the features of case study methodology, primarily in gathering multiple types of data and in employing some of the analysis tools used in case studies. Most future faculty programs are created at the institutional level, even if they later joined larger networks such as CIRTL, so their institutional contexts informed many of their choices regarding supports and curriculum. Studies such as Hill et al. (2019) showed that institutional contexts are important to understanding future faculty programs. Furthermore, networked leadership theory asserts that partnerships and boundary spanning are key to programs like future faculty programs, which rely on faculty across the institution and sometimes outside of it to be successful (Eddy et al., 2020).

Data Collection

Case studies are used when the researcher seeks to understand one thing well (Merriam & Tisdell, 2016). This quasi-case study sought to understand STEM future faculty programs, so multiple sources of data were deemed necessary. Data collected included documents (program materials, guides, workshop slides) from three STEM-oriented future faculty programs.

Collection focused on documents that could help the researcher learn about the four areas of the conceptual framework (teaching and learning, socialization/professionalization, and organizations, as well as the critical lens). Syllabi and workshop materials helped the researcher explore the pedagogical approaches and strategies that made up program curriculum (Merriam & Tisdell, 2016) as well as added to the researcher's understanding of professional development processes. These documents added detail and depth to semi-structured interviews with program managers and either deans, assistant vice provosts, or members of program steering committees. Baxter and Jack (2008) suggest that these multiple sources "add strength to the findings as the various strands of data are braided together to promote a greater understanding of the case" (Baxter & Jack, 2008, p. 554). Another way to understand the benefits of documents is that they provide stability. While people change their ideas of things regularly as they learn or interact with others (as in an interview), documents are a more objective record of a phenomenon (Merriam & Tisdell, 2016).

Interviews with leadership were important to understand the curricular and organizational aspects of future faculty programs. Yin (2011) suggests that interviewing key people in organizations have great value case study research. These "elite interviews" with leadership of these programs provided a depth of understanding not available with participants or affiliated faculty and staff (Yin, 2011). Program managers were interviewed for their intimate knowledge of the programs as well as their understanding of program design and leadership. Supervisors of program managers were interviewed because they had knowledge of how these programs are located and supported at the institutional level. In their study of CIRTL-related programs, Hill et al. (2019) found that program managers and other leaders were key to program success and their ability to share information about the program to people across the institution was an important benefit they added.

The collection of all of these various data provided the depth needed in a comparative multi-site qualitative design and helped in the comparative work in analyzing the similarities and differences between sites.

Program	Interview 1 (Program director)	Document gathering	Interview 2 (Supervisor or other leader)	Interview 2 (Program director)
Central	9/1/23	9/2-12/21/23	9/11/23	12/22/23
SW	9/28/23	9/29-12/21/23	10/7/23	12/21/23
NW	10/18/23	10/11-1/4/23	11/2/23	1/5/24

Table 1: *Data Collection Schedule*

Procedures

This section describes both the interview protocol and the collection of documentary materials. An initial review of program materials available on public-facing websites was completed to gather basic information about programs and to ensure they met selection criteria. These materials included program websites, syllabi for required courses, diagrams showing certificate requirements, event calendars that listed workshops, annual reports, and program applications. Materials that were relevant to the research questions were uploaded into Dedoose. Interviews with program managers and one other person in leadership were scheduled for a period after the initial review of documents to make efficient use of their time and to ask directed questions about program components and curriculum (managers) and institutional dynamics (supervisors). Following the 75-minute interviews, the researcher asked program managers what other program materials they had to share (and that were not easily available on public-facing sites). Lastly, follow-up 30-45-minute interviews took place with the program managers. This totals three interviews per site and nine interviews total.

Interview Protocol

Interview questions were based on the conceptual framework and designed to answer the study's research questions. They sought to learn about program curriculum, including learner-centered pedagogies and critical approaches to teaching, professional development processes, and institutional contexts. The researcher sent emails to the program managers and supervisors of the three programs to ask for their participation, making sure to describe the study and its purpose, the requirements of involvement, and the data management plan.

See appendix A for a complete list of interview questions.

The use of semi-structured interviews allowed the researcher to combine both highly structured questions, like demographic or other specific information, and loosely structured, open-ended questions topics of exploration (Merriam & Tisdell, 2016). Merriam (2001) asserted that interviews are the best technique to use when conducting studies of "a few selected individuals" (p. 72), or in this case, leaders of these programs.

Program Manager Interviews

Interview questions were piloted with an expert colleague to test their ability to answer the research questions. They were also workshopped with a member of the researcher's dissertation committee. They were edited based on feedback from the committee member and chair of the committee.

Informational Questions

1. Please describe your role at your institution.
2. Please describe the future faculty program you manage (the program components, faculty and staff involvement, participants, and any other important features).

After these informational questions, the researcher asked questions framed by the literature review: pedagogical approaches, and professional development processes, learner-centered pedagogies, critical lenses, and organizational benefits and barriers.

Pedagogical Approaches (Teaching and Learning Area)

The questions asked more specifically about program curriculum, specifically its offerings regarding faculty roles (research, teaching, service), how the program trains in learner-centered pedagogies, and about the opportunities to practice or apply their knowledge. The teaching and learning questions narrowed to address active learning and inclusive teaching curriculum and their role in the overall program approach to effective teaching. Studies concluded that active learning and inclusive teaching are key to student persistence in STEM (Dewsbury et al., 2022; Seymour & Hunter, 2019).

1. What teaching strategies and theories are included or help guide the FFP curriculum?
2. Please describe any active learning and/or inclusive teaching that is included in the curriculum.
   a. How are participants trained in learner-centered pedagogies?
3. Are there DEI elements or components?
   a. How are participants acquainted with issues of power and privilege in pedagogical practices?

Professional Development Processes/Models

Professional development models address the processes for professionalization and socialization of graduate students and postdocs to the various roles of faculty, the ways community is built around this training, and engagement and access dynamics.

1. What is your approach to professional development of graduate students and/or postdocs? Does this differ from professional development of faculty?
2. How is the program (and program elements) assessed? How are impact and "effectiveness" evaluated?

Organizational Benefits and Challenges

Organizational questions addressed institutional contexts, such as fiscal support, staffing, dynamics with graduate student and postdoc home departments, and relevant policy. Questions were asked to understand the placement of the program within the institution, the ease with which the program finds collaborators, and any staffing or recruitment challenges that impact the future faculty program.

1. What organizational and institutional supports and barriers impact the future faculty curriculum for graduate students and postdocs?
2. What is on the horizon for your program? Are there changes coming in curriculum, processes, staffing, or institutional context?
3. What materials should I analyze to get a fuller understanding of your program?

The interviews lasted 75 minutes and were conducted using Zoom, which generated a transcript for each interview and allowed the researcher and interviewee to see each other. Zoom works well for interviews because it has many assistive features, like instant captioning and audio controls for hearing impaired interviewers and interviewees. It also allows for interviews with people geographically distant from the researcher (Archibald et al., 2019). Transcripts were edited by the researcher for accuracy and concision and then uploaded into Dedoose for coding.

Supervisor Interviews

Informational questions asked participants to describe their role at the institution and to briefly describe the future faculty program at their institution. The interviewer then moved into questions about organizational barriers and benefits, as described in Appendix A.

Supervisors were asked how the program has overcome common challenges like funding and institutional location. They were also asked to describe their role in future faculty program success and the possibility of future faculty programs to affect change in STEM education. Interviewees were asked to grant the interviewer access to materials that would help the researcher fill gaps or learn about the areas identified in the research questions.

Demographic/Background

1. Please describe your role at the institution and your relationship to the future faculty program.

Professional Development Processes

2. How does the future faculty program support STEM educational processes?
3. What incentives and support encourage participation?

Pedagogical Components

4. What pedagogical approaches and professional development processes are utilized in the program?

Organizational Contexts

5. What organizational and institutional supports and barriers impact the future faculty program?
6. How is the program (and program elements) assessed? How are impact and "effectiveness" evaluated?
7. What is on the horizon for the program? Are there changes coming in curriculum, processes, staffing, or institutional context?

The interviews were scheduled for 45 minutes and were conducted using Zoom, which generated a transcript for each interview and allowed the researcher and interviewee to see each other. Transcripts were then cleaned and condensed by the researcher for accuracy and uploaded into Dedoose for coding. Names of participants and other identifiable information were removed from transcripts.

Document Procedure

A period of materials gathering followed the interviews. This collection focused on course syllabi, program handbooks, and workshop descriptions in addition to materials gathered online before the interviews (program descriptions, applications, lists of courses, program components). Documents were checked for accuracy and authenticity to ensure that they honestly reflect the program (Merriam & Tisdell, 2016). Interviewees directed the researcher toward useful documents not available on public websites. Document collection was limited to those documents that would help the researcher answer the research questions. Materials had names of instructors, trainers, and participants removed. Documents contributed less to the results than the researcher had expected. They served to reinforce the information shared in interviews but did not add significantly to the data.

Follow-up Interviews

After transcribing and coding initial interviews and collecting and coding documents, the researcher scheduled a follow-up interview with each of the three program directors. The intent of this interview was to clarify any remaining questions about the program and to ask any questions that would help the researcher to address the study's research questions. After coding the other materials, the researcher saw the need to ask questions that would help participants discuss their program's role in transforming faculty roles and STEM teaching.

1. Some people would say that it is wiser for students in STEM to focus on research. How would you respond to them?
2. So much of our work is focused on graduate students and their professional development. How do you see your work impacting undergraduates in STEM?
3. Do you have anything else you want to tell me?

The interviews were scheduled for 45 minutes using Zoom. Transcripts were cleaned and condensed and uploaded to Dedoose for coding.

Data Analysis

Transcripts of interviews and digital copies of program materials were uploaded into Dedoose for coding after being cleaned and condensed. Each case's documents were labeled by its study name (Central, SW, and NW). This assisted in keeping data organized and easily analyzable (Baxter & Jack, 2008). Merriam and Tisdell (2016) encouraged researchers to begin analysis while still collecting data, so the coding process began at the completion of the first interview. The first cycle of coding involved a priori coding based on the interview questions and open coding. The various sections of questions (program functions, pedagogical approaches, conceptual frameworks, professional development processes, and institutional benefits and barriers) provided initial categories for the codes. These codes included “active learning,” “inclusive teaching,” “faculty and staff support,” “faculty and staff as barriers” among others. Open coding also allowed for new codes. Some of these new codes included “flexibility,” “COVID,” “undergraduates,” and “CIRTL.” This coding process was the same for program documents and interviews, with the exception that some documents required memos because their text couldn’t be highlighted), which were coded simultaneously. The larger groups of coded passages were then exported as spreadsheets centered on the central theme, like active learning or organizational barriers. This process helped the researcher to visualize and conceptualize the data.

Data analysis included both within-case analysis (Creswell & Poth, 2018), which is important when analyzing multiple forms of data about one site, followed by cross-case evidence analysis (Yin, 1981), which provided the themes for discussion and assertions. Within case analysis led to findings about individual programs and their unique contexts. For example, the data indicate that the location of a program in a particular office was correlated with certain choices in professional development processes. Also, cross-case analysis is where the researcher looked for similarities across programs that might be recreated in other institutions and differences that indicated the supports and contexts most conducive to these programs. Similarly, cross-case analysis showed commonalities in how programs are approaching learner-centered pedagogies and how they differ in this area. Analysis looked for direct replication, where the cases provided similar results and contrasting results with anticipated reasons (Yin, 2011). In this case, the researcher sought to learn how one area of interest, professionalization, for example, created similar or different results based on the form it took between cases.

In multi-site case studies, conclusions are usually referred to as assertions (Stake, 1995) or building “patterns" or “explanations” by Yin (2009). While this study was not a traditional case study, all three of these words are useful in considering how this study might add to the field and establish a set of better practices that are also attentive to institutional dynamics. Analysis looked for direct replication, where the cases provided similar results and contrasting results with anticipated reasons (Yin, 2011).

Limitations

Limitations are important to recognize in any study design because they are areas where the validity of the research may be questioned. Multi-site studies can demand a lot of time and resources (Herriot & Firestone, 1983). The researcher addressed this issue by conducting interviews over Zoom, which did not require travel time or money, and by collecting documents that were easily accessed and only those which helped to answer the research questions. Despite these steps, the researcher needed to be careful to keep the data collection and data analysis within the scope of the study.

This study was also limited by the small sample and number of interviews. Just three programs were studied, involving three interviews per program. Participants were not interviewed or surveyed. Furthermore, documents reflected the most recent curriculum and did not provide a historical understanding of how topics have been treated in past courses and workshops. This limitation was answered by the experience of leaders who shared historical information in interviews. Furthermore, there was no direct observation of workshops or class instruction, so the researcher relied on information gleaned from interviews and documents to understand curriculum instead of directly witnessing it. Direct observation would have added to the time spent on the study without necessarily adding new understanding.

Merriam and Tisdell (2016) outline a few limitations of using documents in qualitative research: they may be incomplete, it may be difficult to follow a path of logic from one document to another, and they are not developed with research in mind, so they can be difficult to analyze. Indeed, the researcher learned that not all documents yielded useful data, so some documents were easily coded or not used. The researcher sought to address the limitations of documents by 1. Checking their data against information gleaned in interviews; 2. Asking interviewees to confirm the accuracy and authenticity of documents if there was a question of validity.

Role of the Researcher

The researcher is currently a program director for graduate student instructional development at a large, research-intensive university. The researcher was previously a program manager and designer of a STEM future faculty program based at a health sciences university, so there may be bias in favoring one strategy or system over another. The researcher sought to mitigate this bias by choosing programs that have proven successes and publishing records. The researcher has experience teaching college writing and does not have experience teaching STEM, so it was important to focus on learning about the successes and accomplishments of STEM future faculty programs and the ways that these programs find support in their work rather than evaluating them or calling into question their work. Clearly, the poor teaching and unwelcoming environments in STEM are not personal failings on the part of faculty but part of a broader culture of education.

Summary

This chapter began by describing the research questions and how they seek to explore the areas identified in the conceptual framework—teaching and learning, professional development, and organizations with a critical lens. Site selection criteria was explained and sites proposed. Data collection was described as taking two forms: interviews with key leaders (program managers and their supervisors) and document collection to add breadth and depth to data collected in interviews. The methodology was a comparative qualitative study, and a rationale was provided for this methodology. The interview protocols and document procedures were described in this chapter. Data analysis processes were also detailed in this chapter. The chapter ended with a discussion of the study limitations and the positionality statement of the researcher.

CHAPTER 4: FINDINGS

This study sought to learn about the organizational, professional development, and curricular aspects of effective STEM-oriented future faculty programs in order to make recommendations for the field of graduate student and postdoc educational development. As programs funded by the Preparing Future Faculty grant reached into their third decade and more institutions sought to establish programs or grow their current programs, it was important to learn more about how these programs were situated in their institutions and the steps they have taken to thrive. Additionally, STEM fields continue to see HME students leave STEM majors at alarming rates (Seymour & Hunter, 2019), and since future faculty programs have been identified as key players in transforming STEM education, studies needed to begin to build a set of recommendations for the field. In particular, a critical perspective was needed to examine the ways these programs are addressing inequities in STEM and the roles educators play in either reinforcing or disrupting the status quo.

This chapter is organized into three main sections, which correspond with the research questions. First, the teaching and learning curriculum is addressed with sections on learner-centered pedagogies. Second, the professional development processes and models are discussed. Following that, the findings regarding organizational contexts are shared, including supports and barriers experienced by each participating program. Findings regarding power and privilege follow the organizational section. Lastly, the data are shared on transforming STEM education and the program leaders' sense for their program's role in such a transformation.

Teaching and Learning

The three programs approached teaching and learning curriculum in some common ways, much like faculty development often looks similar between institutions. All three programs professed to engage evidence-based teaching as the core curriculum of their programs. This included instruction or resources on active learning, student engagement, learning science, and theory-informed pedagogies. They appeared to diverge in more specific areas like which areas they emphasized (UDL, active learning, etc.) and the processes by which participants gained the knowledge.

Programs were studied using research questions about teaching and learning strategies, inclusive pedagogies, and active learning. They were also asked if there were specifically DEI approaches to teaching in their curriculum and if they include curriculum on power and privilege in the STEM classroom.

Active Learning

Active learning was a core part of the curriculum in all three programs. Leaders from all three programs shared the understanding that active learning is key to great teaching in STEM (Miller et al., 2021). It has been found to benefit marginalized students and female students most significantly (Ballen et al., 2017; Haak et al., 2011), but STEM has been resistant to letting go of the lecture model (Dewsbury et al., 2022). Participants in every program were acquainted with and often practiced in the most common active learning strategies like think/pair/share, one minute paper, gallery walk, and jigsaws. Program managers showed a great breadth and depth of knowledge in this area. Programs taught these concepts and also modeled them so participants could see them at work in the classroom. One program director explained their approach,

> we frame it all in constructivism, say learning isn't learning unless the students are owning it as their own, making it up, or putting it together with their own knowledge making those connections. So as a philosophy, you have to be actively engaged in learning.

All three programs included curricula about cognitive science and motivation, which they studied in conjunction with active learning strategies to better understand the process of learning through active learning. Understanding and utilizing cognitive science, specifically scientific understanding of motivation and growth mindset, is important to student achievement and persistence in STEM (Canning et al., 2019). One leader described their approach to evidence-based teaching as including active learning, cognitive science, and transparent design this way:

> we do a lot about introducing them to active learning. And I think this is important for STEM. What is the research behind including all of these various teaching strategies? … What are the different kinds of strategies for active learning? How do they get students involved and engaged? We do some work with inclusive teaching like, how do we get everybody involved and engaged? And why does that matter? And why should we care? And we look into things like metacognition, understanding: How do you know what you know? Motivation? All of these things are kind of linked together. Building student motivation for classes through transparency in teaching is another big one, so explaining to students, why are you doing this? Share with them…here's the research showing this is why we're teaching this way and outlining clear learning objectives before you start, backwards design. Figure out, what do you actually

> want students to get out of this? And how do we align that with how we're going to teach, and how we're going to assess. Making sure all of those things are established. Those are the main components of what we teach in the pedagogy course. (SW)

One example of active learning curriculum was NW's observation form, used to give feedback to postdocs on their teaching, which included a section on active learning. Rather than checking a box for if an active learning strategy was used, their form asked the observer to note the complexity of the strategy. Participants were encouraged to think about their active learning strategies in terms of Bloom's taxonomy to be sure that they were not just engaging lower-level thinking. As the program director explained,

> It's like hands on, but not necessarily minds on. I think that's how it's phrased. And so there can be activities. But they're easy… A great example of this is jeopardy. Lots of beginning teachers are like, Oh, we'll do a game. We'll do jeopardy, and that's all low level. It's all recall. So then the trick is like, all right. Well, how do we make it meaningful? Meaningful and active?

This position was consistent with Freeman et al., (2014) which found that active learning in STEM classrooms is still evolving. The program director added that in their program they did not see active learning as an add-on or trend but as central to pedagogical training: "we are training future teachers to have this be the norm."

Not all participants were quick to see the benefits of active learning, particularly if they had not seen it done well in their own classes as students and if most of the teaching in their departments was focused on content delivery through lecture. Some participants' initial reactions to active learning were negative:

> challenges that our STEM participants have when they come into our program, is that it's so different than the way they've experienced education, themselves, if they were an undergraduate student in engineering, or science, and then they go to graduate school, and they see this model of content delivery, that we come in to our classes, and we're, they're leading the classes, they're talking about education, what they want it to be, what their vision for their students are, they're talking to each other about how students learn what motivates students, you know, they're watching videos and reading the articles and responding and reflecting as part of their learning. And then in around week four, we do this early course feedback, which we're modeling, as good teaching techniques to get some feedback from your students, and pretty often have students split. Some of them say, Wow, this is great. I actually am interested in class and the time flies by and it's just not what I expect. And then some of them are saying, Would you just lecture more, please, because I don't know how to do this. Like, I never seen a class like this before. I need you to just tell me what I need to know. (Central)

There was an additional challenge in teaching observations, when graduate students and postdocs felt pressure to lecture (both spoken and unspoken) by the instructor or even by the students. This is an example of the content-centeredness often found in STEM teaching, which when paired with poor teaching, works to push students out of STEM fields (Seymour & Hunter, 2019).

Inclusive Teaching

Inclusive teaching principles and strategies were included in much of the curriculum but there was variation in the importance granted to them, the specificity of discussion around diverse students, and the centrality of the content to the overall program. Examples of inclusive teaching included: a program learning outcome that explicitly stated that participants will be trained in diversity, equity, and inclusion approaches to teaching and learning; programming around inclusive teaching but not as a program requirement; and specific workshop lessons in inclusive teaching topics. As one program manager put it, "We don't do any explicit anti-racist teaching within [the certificate]... it's not explicitly part of the practice program. I teach a course on inclusive teaching. That includes things like that, but that's not part of the program." She added that anti-racist teaching and DEI concepts were available but taught by another department and not incorporated into the certificate program. There was also an integrative approach: inclusive teaching through the lens of scientific teaching, which situates the instructor as one constantly engaged in data collection (feedback), reflection, and improvement (Handelsman et al., 2004). Learning outcomes for this course stated that participants will "learn how to teach scientifically with inclusive, demonstrably effective, student-centered pedagogies."

There was a range of strategies and approaches described as "inclusive" in these programs. Dewsbury et al. (2022) stated that inclusive teaching in STEM is "only recently being fully unpacked and operationalized" in higher education classrooms (p. 2). One program stressed the importance of modeling inclusivity and attention to privilege in every part of their program, including reflection on the positionalities held by participant instructors. Some common strategies across programs included asking for and using correct pronouns, assuming a diversity of students in every classroom, studying student data to understand diversity at their institution, and considering a more trauma-informed lens when discussing course topics:

> We talk about certain diseases … since so many of the postdocs are biomedical, that if they want to talk about something like cancer, their students are going to have experience with that. What does it mean to be holding space for the students' own experiences with disease while they're studying the disease?

Another example was treatment of the deficit model, which assumes that students who are not in the white, middle and upper class are coming into science with deficits and "ignores systemic influences that shape disparities" in educational outcomes (Davis & Museus, 2019, p. 122). There were opportunities for participants to learn about and discuss deficit models and find ways to challenge them: "we try to be transparent about the need to resist it and to counteract it." Here is one example:

> [we ask] "what are some of the common challenges that students face as undergraduates primarily?" We have this exercise where we look at student research studies from across the US … the National Student Engagement Survey, national survey student engagement… And it says things like what percentage of students study more than 10 hours a week. And what percentage of students have a disability? What percentage of students have children at home, right? And so we look at all of these various characteristics of students who will be in their classes in the future. And think about what does this mean for them. What are the advantages of this? How do we look at this as an opportunity and a characteristic that's going to help these students? And what are the potential roadblocks or stumbling points for these students? What can we anticipate where some of their

> interests or time might be split? And can we build some empathy around these things so that when we're in the classroom, and we see a diversity of student behavior, we don't interpret it to mean that lazy student, or that student who can't keep up. But we interpreted that the student is balancing three things at once, or that student might need some additional resources. (Central)

While the programs' approach to inclusive teaching varied, there did seem to be a fundamental belief in inclusive teaching. Even when inclusive teaching content was found in an optional course, the program director stressed that they were experiencing higher participation in that course. All of the program leaders moved easily between talking about active learning, inclusive learning, and the science of learning, reflecting the belief that these things were connected and overlapping. They also gave attention to factors outside the classroom, like hidden curriculum and structural inequities, what von Vacano et al. calls "macro level influences" (2020), that influence student learning and persistence.

Critical Perspectives on Teaching and Learning

These programs clearly had active learning, and to some extent, inclusive teaching, as important pillars in their curriculum. But the question remains if their efforts will help slow or stop the flow of HME students out of STEM fields. Perhaps there should be a greater attention paid to the harm caused by cutthroat, lecture-based, high stakes STEM courses. In their survey of 10,000 undergraduates in STEM, Seymour & Hunter (2019) reported that these traditional STEM classrooms are still very common. There is also a question of the value of calling out inclusive teaching specifically. For example, if inclusive practices are considered equally as important as any other practice, they might not be used, just as an instructor may choose gallery walk over the one minute paper and not ascribe much weight to that decision. Programs treatment of and processes around inclusive teaching seemed to be still evolving.

Professional Development

The programs could not identify a clear and specific professional development model or framework they followed in designing their programs. While this may seem surprising, it may be less surprising when considering the significant flexibility and creativity they showed in overcoming organizational barriers. Each program seemed to be specifically suited to its institutional context. This may point to why there is a lack of nationally or internationally recognized teaching professional development models for graduate students and postdocs.

However, there were echoes of professional development models in their programs and a set of shared values, primarily in the areas of mentoring, establishing teaching community, and confronting the research/teaching dichotomy. There was mention of using CIRTL certificates to create pathways and structure in their program. There was also mention of employing some aspects of extended learning communities and scientific teaching in approaches to graduate student and postdoc professional development.

Asynchronous, Individualized Model

Professional development seemed to follow two paths: asynchronous, self-motivated engagement with the material (with occasional interactions with mentors or CTL staff) or small group, cohort-based engagement with the material. Central was able to support hundreds of participants because their programming was available asynchronously. This path was reliant on CIRTL workshops and opportunities and had participants work through a checklist that included observed teaching and feedback, workshops, courses, and teaching portfolio items. SW's new postdoc program followed a similar path (minus the CIRTL workshops) because of the challenges of providing training to postdocs during regular working hours. Despite what may seem like an impersonal approach to professional development, Central's program director said,

> our approach to professional development relies on that student centered and inclusive mentorship approach, so that we hope folks feel like this is a place that all people interested in teaching can come in engage with us. That's across disciplines, across degrees … across gender, across nation of origin, and across age … what we hear from some of our participants is [Central FFP] was the place where I made human connections at [Central University], this program was a place where I felt … inspired to enter a teaching career.

Even while programs utilized the less personal approach to professional development, they did not view it as the optimal approach, often espousing values of community and close mentorship.

One program director recollected the thinking behind their asynchronous offerings:

> we needed an alternative so that people could still get the exposure to this professional development, but not lock it into the classes. And so we took those learning outcomes at the foundation level, we have 10 of them .... And we say, all right, we know that these are accomplished in those two courses that were already on our books. We also had a workshop series, like a teaching workshop series for graduate students that had been so poorly attended over time that they just

> stopped doing them. So when I got here, people were like, we should really start doing that teaching workshop series again. And so we were able to say, if we align the workshop series with these learning outcomes for the certificate program, then we have a mechanism to attract … the audience of students who are participating in [Central FFP], but maybe can't take the courses. Or maybe you can take one course and some workshops instead. So it's a bit of a choose your own adventure through the foundation level of the program. (Central)

Because participants were moving through the curriculum at their own pace and out of sight of program staff, they needed to submit reflective writing or other documents to show their engagement. These were usually given a check mark and no additional feedback. Program directors that used this system said it was largely a result of lack of staff and not the way they would choose to document completion.

Cohort Model

Programs all offered some opportunities to be part of a group or cohort. For example, even if participants were not grouped into cohorts, they often found a cohort in capstone courses or teaching in higher education courses. NW had a cohort model on the extreme end, where mentors worked closely for an entire academic year with just three mentees or two groups of three. These mentees also designed and taught a course together, so they had real inter-reliance. All mentorship groups attended trainings together as a cohort, which helped them build bonds outside of their triad. Mentors also observed their teaching and provided feedback. NW's program director stressed that the post-teaching debrief was the most valuable learning time in the program.

Even while there was variation in the shape and intensity of cohorts, all programs put value on the experience of community, not just while participants are in the program but also their ability to find and form teaching community as junior faculty. This is consistent with the literature, which identified teaching communities as one of several important steps in increasing the use of evidence-based teaching in STEM (Borrego & Henderson, 2014). Indeed, Borrego & Henderson (2014) found that the opportunity to share ideas and discuss teaching strategies helped faculty develop their skills and a reflective practice.

Program Components

As mentioned earlier, none of the three future faculty programs cited a professional development model as the basis for their program design. They employed many of the strategies of experiential learning, including Kolb's learning cycle (which emphasizes learning as a process that is tested and refined through concrete experience) (Kolb, 1984), even if they did not deliberately approach the work with this theory in mind. The three programs were all adaptations to their organizational contexts and there was not an expectation that they adhere to a standard model. But in their programming one might begin to see some set of commonly used approaches:

1. Instruction of some kind in evidence-based teaching (workshop or course or both)
2. Observed teaching and feedback (varied between a session or two of guest teaching and teaching an entire quarter as part of a teaching team)
3. Opportunities to reflect on their learning and/or teaching (reflection seemed to be the most common form of accountability)
4. A checklist of requirements to achieve completion or certificate.

CIRTL

It is nearly impossible to talk about STEM-focused future faculty programs without discussing the Center for Integration of Research, Teaching, and Learning. This national network has 45 member institutions using CIRTL to varying degrees for additional workshops, certificate levels, networking for participants and staff, and as connection to current scholarship in STEM education (Mathieu et al., 2020). While CIRTL provides workshops on evidence-based teaching topics, it does not provide a set curriculum to member institutions. CIRTL does offer courses in teaching in STEM and inclusive teaching, which are taught either as MOOCs or as synchronous online courses. Of the programs in this study, two were member institutions. SW admitted that they did not have the local capacity to support and promote engagement with CIRTL programming, so they were questioning continuing the membership. Central utilized it primarily for postdocs and some graduate students because of their need for asynchronous opportunities. Even when programs were members of CIRTL, nearly all the decisions and content for curriculum were made locally. Still, CIRTL has great potential because it connects programs to the larger picture of transforming STEM education and connects them to the important work of teaching undergraduates for greater persistence (Mathieu et al, 2020).

Socialization to Research and Teaching Careers

Program leaders viewed teaching and research as complementary and were well-versed in sharing research that has shown that teaching professional development does not have negative effects on graduation or on research (Shortlidge & Eddy, 2021). They did not seek to replace research as a priority, but rather, saw teaching and research as complementary. Additionally, they viewed teaching professional development from the graduate student or postdoc perspective of following their interests, which reflected their learner-centered approach to teaching and learning. As one program director explained,

> I think it's really important for STEM students, especially, to have that opportunity to engage in teaching among people who support that interest and have resources to help them prepare and to think about what they're going to be doing after grad school… especially at a place like [SW], which is very research-focused, we have a lot of students have blinders on. After you go to grad school, you do a postdoc, you become an R1 professor and one of the things that I think is really important and hopefully comes out when I talk to students who express other interests is that there are other things you can do. (SW)

In addition to supporting the teaching interests of participants, these programs included resources and training to help participants pursue careers that include teaching. All the programs studied asked participants to create a teaching portfolio that included items like a statement of teaching philosophy, syllabi, lesson plans, student and peer evaluations, reflections, and diversity statements in teaching. These portfolios not only helped them to be competitive on the job market, they also reinforced the theoretical, practical, and reflective work done in the programs.

Mentoring Processes

Mentoring in teaching was a component of all three programs, although they ascribed different values to it and had varying abilities to support it in their programs. In the SW program, it was primarily seen in the observation and feedback process. This was similar in NW, although it was noted that mentors were very involved with course planning as well. Capstone courses at SW and Central offered mentoring in teaching by someone in their department (not always the best mentoring) and sometimes by CTL staff who observed and gave feedback. One program director shared their mentoring approach (she called it an “undertapped opportunity”):

> the discipline faculty serve as teaching mentors at the capstone level. We make it the responsibility of the participant to identify that teaching mentor, it is often their primary faculty advisor, but not always, because I tell them, here's a chance for you to get a second person in your list of recommenders. And sometimes your faculty advisor is the most amazing teacher you've ever seen. And sometimes they're not. And sometimes, you might like a different perspective, and to see how someone else teaches. And so one other alternative might be to keep your eyes open about who has a great reputation for teaching in your school and ask if you might be able to assist them with one of their classes. Often great teachers are also very willing to mentor around teaching. They've been very successful with finding arrangements like that. As the teaching mentor, we have a two page handout that describes the expectations which are pretty minimal. We asked them to allow the participant at least two times to teach, you know, about two weeks is even better, but at least two times is the requirement. We asked them to open up their class planning as much as they're comfortable with to share, like as the apprentice model that I was telling you about. And then to be present to observe their teaching and provide them with feedback. We don't follow up on that and we don't get a copy of that. We just ask that they do it and hope that it's being done. (Central)

The leader's primary concern was that participants were not accessing quality mentoring in teaching and that the program was not giving mentors clear guidelines or training. One answer to this problem was to recruit quality teaching mentors (like NW), but due to their stricter requirements, this limited the participants accepted in a year. In effect, higher standards for teaching mentorship equaled fewer participants and possibly a smaller impact.

Critical Perspective on Professional Development and Mentoring

Even while future faculty programs in STEM asserted their charge was not to supplant research but to partner it with teaching, the programs and their participants were suffering under the dichotomy. Programs were crafting their professional development not on a set of best practices but on seemingly unmovable realities: silos of departments, the primacy of research, the division in faculty between those who prioritize teaching and those who prioritize research (the latter being higher in status). Programs were succeeding in their mission despite the challenges, but even while they found success, the system was not serving graduate students, postdocs, or undergrads very well.

Clearly, the potential for future faculty programs has yet to be realized. Meanwhile, macro-level influences (structural racialization, structural marginalization) are shaping the way students experience STEM (von Vacano et al., 2022), and in turn, future faculty programs. According to von Vacano et al. (2022) framework, meso level interventions, such as inclusive teaching, universal design for learning, and student empowerment, are key to addressing the macro level influences. Furthermore, these programs recognized the power of mentoring, the importance of multiple modes of engagement, and the pressures placed upon graduate students and postdocs to follow a traditional route. But in the tension, they also suggested a new path for professional development and mentoring that has the possibility of supporting a greater diversity of students, including HME students. Key to this new path are equity-minded principles, processes, and strategies in rethinking future faculty programs in STEM.

Organizational Contexts

These programs represented a diversity in the world of STEM higher education: one land grant research institution, one small STEM-focused school, and one large STEM-focused school. They enjoyed many institutional supports, like engaged faculty and staff, consistent funding, and strong leadership. They also faced many institutional barriers, from logistical challenges to faculty attitudes.

Funding for these programs followed consistent threads. The programs did not always have their own budgets and at times had to share funds with other initiatives. Grant funding was common for program launch or redesign but less common later. Programs shared that they were funded at a sustaining level but were not able to grow. SW’s program director was paid by grant funds, which affected the sustainability of that position. She shared,

> Technically, my position is grant funded and the grant runs out after next year…We're trying to get the university to take over the funding cause. I'm going to pilot how useful it is to have somebody like me. But if my funding runs out, I have to leave. (SW)

One program manager noted that once a program was launched, it did not make sense to pursue outside funding because you could not build structure on funding that will run out. While all three programs did not report layoffs or other budget cuts, they also recognized that static budgets were negatively affecting their ability to grow and serve more participants, which is consistent with the literature (Connolly et al., 2016). One program manager added that funding influenced their decision not to pursue research projects on the program.

Structural barriers to participation were reported at every institution. Postdocs had their own unique set of challenges. Leaders listed problems like postdocs lacking the ability to register for courses, the flexibility in their schedules to attend courses and workshops, or support from their departments to teach and experience observation and feedback. These barriers are well-documented in the literature (Price et al., 2021; Ebert-May et al., 2017). The program director of NW, which focused on postdocs shared,

> We don't have any data about PI support. So I can just say anecdotally, some PIs are totally excited about it [the future faculty program]. Some postdocs aren't comfortable telling their PIs. And those ones typically are teaching at [specific campus] so they can sneak out of the lab and then come back in…. Sometimes the post docs who don't have PI approval will skip office hours and will only come for office hours in the weeks they're teaching. Sometimes folks have gotten permission from their PI, and then their PI sees how much time they're spending on the course, and like, Wait a second. You're gone a whole day. What's up with that? (NW)

That is not to say that only postdocs struggled to participate. In some departments, graduate students had teaching assistantships just once in their time at the institution and it happened early in their programs. This means participants struggled to find observable teaching opportunities when they needed them. Many departments did not allow graduate students to teach as instructor of record and TAships did not always include observable teaching. Often, postdocs were not allowed to teach at all. The lack of teaching opportunities for graduate students (there were more opportunities for TAs than for instructors of record) limited their interest in the topics like course design, which are important for future faculty. Additionally, graduate students could not expect the same set of rules regarding their teaching from one institution to another or even between departments within the same institution. This lack of consistency and clarity served as another organizational barrier.

Program Flexibility

All three programs existed in institutions that were research-oriented. Central and SW programs were at institutions that only offered STEM majors. The NW program, housed in a college of biological sciences, was very immersed in research as institutional priority (although there are some shifts in this area to hire what are called "teaching faculty"). All three programs struggled with the schedules and priorities of their participants. For example, most postdocs work a regular 40-hour week in the lab, so programming needed to accommodate their schedules. Another example was when a participant in the SW program needed a teaching mentor, it could be hard to find a faculty member willing to fill the role, and there was no guarantee that they were a model of effective teaching. All three programs practiced great flexibility, whether this was found in scheduling, staffing, curriculum, and/or modalities. This flexibility was clearly tied to their organizational barriers.

Staffing Challenges

All three programs had a staff of 2-3 people, and while these leaders were passionate about and dedicated to the work, they felt an acute need for more staffing support. One leader explained,

> The staffing part is kind of a challenge right now, because we're understaffed in the area of TA development and future faculty. That's where I did most of a lot of my work until I became the interim director, and then that work tended to go away. So we had to find faculty to teach the capstone course. (Central)

They temporarily recruited two adjunct instructors to teach their pedagogy courses, but recognized that this was not a long-term solution. The leader echoed this, “So there really are just 3 of us here that are full time staff, and so we're the ones running all the programs. It would be lovely to have another person, but we do what we can with what we have.” All programs seemed effective at recruiting help for parts of their programming that were occasional but were not able to advocate for larger teams to lead their future faculty programs. As one program director explained,

> when there were three of us, and we had 50 people in the program, it was fine. But now we still have three of us and there are 350 people in the program…they can't all take the courses because there's not room for everybody to take the courses…we wanted it to be a deep learning experience and deep learning experiences require time from both the program managers and the participants. (Central)

One leader connected staffing issues with their ability to mentor participants:

> we don't have enough staff to run this program that has grown so big, or time, I guess, it's maybe time and money and staff are all connected to each other. Right? We could really use another one or two people to really dig in and be able to provide the kind of mentorship that we that these students deserve. (SW)

NW's program director echoed this by stating that their program was necessarily small because of the time and energy spent mentoring.

In addition, there was a strain put on the small staff members that ran these programs. SW experienced a literal shutdown of their program when both leaders involved in the program left their positions (and did so during COVID, which lengthened the hiring time). At the time of this study, the success of the program was based on two people who replaced them who had done their best to recreate the program. As one program director noted, "what I'm realizing is … I'm just ridiculous… this is part of what it means by running the program on the cheap is that I've been doing it all."

Leadership and Faculty Involvement

These programs had at least one dynamic leader that was skilled in connecting with others across the institution, advocating with leadership for the program, and attracting faculty and staff support. This is consistent with Hill et al (2019), which established these skills as fundamental to program success. Faculty and staff support mentioned by leaders were sometimes individuals, and other times came from departments or schools. For example, NW shared that postdocs in their program were usually mentored by teaching faculty (faculty hired for a larger teaching load than research) based on individual interest of the faculty. SW mentioned a deliberate campaign to garner faculty support because

> Our associate director teaches the pedagogy class that most people take. Other than that, there's no faculty involved. I mean, they teach the classes that people TA for, but it's a small enough number of students that we basically just run it all in house within the teaching center. (SW)

Central began holding informational and networking events to help faculty learn about their program, meet the teaching observation team, and sign up as teaching mentors:

> it is sort of a kickoff networking event that's going to bring the observers, which are our graduate student fellows that I was telling you about, we've got eight of those plus two graduate TAs, they observe and our faculty observe…the participants might feel a little awkward about this team of strangers, that one or two of them come into your class and observe and it feels like a judgment. And it's not right. It's meant to be developmental, not evaluative. But we want a chance to just have some face time and let them know that we're normal people. And we're very nice. And we just want to talk to him about teaching. But we were going to invite the mentors to come to that as well, so that they can hear the overview of this program. And it's not just one student in their class, but they see that there's this whole network of people who are working on preparing future faculty.

The leader discussed some departments that engage the program in a deeper way to access the training for their graduate students:

> We do have some…partnership arrangements with some schools. Which means that we have a good pipe pipeline of participants from those schools, because of this partnership arrangement. So in civil engineering, they decided that they had a

> little bit extra money to declare civil engineering future faculty fellows, and they offered $500, something like that…I think they pick five a year to go through [Central FFP]. And then they also get a little extra bit of mentorship around teaching from their discipline….they get like a sort of a mentoring package around faculty with each faculty prep... So we always have civil engineers in [Central FFP], because they're always coming through the pipeline… In economics, they require their students to participate in [Central FFP] in order to teach as Instructor of Record starting their third year of their program, because economics relies on graduate students as instructors of record. And so this was an easy way for the school to get their students trained, they don't give them any extra money for participating. But when you're an instructor of record, you get more money than you do as a TA. Right? So it's a good opportunity for that. Industrial and Systems Engineering has the same sort of fellowship idea that they get a little extra money, and they get to teach as instructor of record. So those partnerships do mean that we've got a pretty consistent flow of participants from those specific schools.

In this example, the future faculty program gained departmental support in exchange for training their graduate students in pedagogy and preparing them to be instructors in the department. This is consistent with the literature, which has found greater support for programs like TA training that have short-term benefits to the department or institution (Bowman et al., 2020). Partnerships such as this bring clear benefits to the institution, but also highlight the pressures on future faculty programs to provide clear benefits beyond graduate student or postdoc professional development.

Logistical Challenges

All three programs faced some challenges posed by logistics of course scheduling. For example, the NW program required a very specific level and focus for their postdoc-taught courses. These courses were sometimes canceled at the last minute because of budget concerns. The Central program found scheduling with postdocs nearly impossible because of their work schedules, so many of them completed the program using alternatives to the credit courses and creative alternatives to traditional teaching observation. SW found that their only required course is often in conflict with other important courses required for PhD students.

Despite the logistical challenges to participation, the programs did not need to promote within their institutions. They drew their participants largely from word-of-mouth and department referrals. There was some concern that if they began to promote, they might be overwhelmed with interest. One leader shared,

> there aren't a ton of incentives … But we have not really had any problem getting our grad students and postdocs. Particularly because we are completely a STEM institution. We don't have a school of education. There's no other place for them to learn any of this stuff, and most of them are here, especially grad students and postdocs, to go into academia. So they are more than happy to come and learn. (SW)

Institutional Tension Between Research and Teaching

These programs reported a feeling of tension in prioritizing research versus teaching. This may have come from faculty mentors of graduate students or from administration or from participants themselves. Central's program director shared "They just can't participate because their advisor will tell them that you're not here for that. That's not your reason for being in this lab." While all three programs discussed the challenge of mentors and faculty advisors as barriers to accessing and completing future faculty programs, these individual stances were part of a larger culture within STEM. As one program director put it:

> the nature of the R1 institution, where research is king and teaching is sometimes seen as a distraction, it is a part of the culture, and it seeps down to the faculty, chairs, grad students. And it's just the truth of the way these types of institutions are. So it can be hard to get inroads and to get the respect for the program. If faculty are saying to their grad students, you know, your time is better spent elsewhere, no one's going to care about your teaching when you go on the market. (Central)

Program leaders worked to help faculty at their institution understand that research and teaching are complementary rather than in conflict. As one leader explained,

> they're going to be experts in their discipline and experts in their discipline. They need a variety of skills, not just … their content knowledge and skills that come from their graduate work and STEM. But the ability to communicate that expertise to others, to figure out what new problems need to be solved and how to approach them. And a host of other skills, some of which are interpersonal and some of which are communication oriented. And I think all of which connect back to their teaching development, so that the things that they're learning through teaching is a necessary complement to their development as a STEM researcher … we have researchers and teachers … in the same human form. We've

> connected these functions from the start of our educational model. We have the discovery happening alongside the teaching, and often by the same people. (Central)

Another leader added that there was an often-forgotten dimension to this tension: the goals of graduate students and postdocs. She shared that they received significant support and mentoring in research at their institution, but if they wanted these things in teaching, the future faculty program was where they went:

> within their lab, they have a bunch of people who are supportive of their interest in research. But they don't always have people who emotionally support them in being interested in teaching, and so being a part of the program is being a part of the community. I think it validates their interest in teaching; they need to have people who feel like teaching is a valid career choice, and it's not like you failed out of research. (SW)

Institutional Supports: People and Resources

Programs were asked about institutional support enjoyed by their future faculty programs. These supports were easily categorized into people and resources. People included faculty, staff, graduate students, postdocs, and any others who support the mission of the program. While all programs desired more faculty involvement with their programs, they also mentioned faculty who were already contributing, in this case, by inviting postdocs to teach classes:

> The department really has to be supportive of them [FFP participants]. And the biology department really is. They had to be supportive of the idea of active learning … actually, because we have such a big contingency of education

> research going on in the biology department … we actually have a lot of support that way. (NW)

Similarly, Central mentioned a few departments where faculty volunteered to mentor graduate students in teaching:

> They have an arrangement with the teaching mentor, who is probably the instructor for the course. The student participant is going to get to deliver about two weeks or so of course material. They're operating slightly differently than a TA because we want them to have this apprenticeship in teaching. So they are talking about how the syllabus was created, contributing to that, if possible, talking about how assessments are created and contributing to that as possible. So we don't have real, like prescriptive structure for those mentoring relationships, other than to say, you're mentoring this student in teaching, definitely, we need to see them teach.

There were also departments that worked with the future faculty program to design their own pathway through the program. Program leaders identified staff in the graduate school, DEI office, and educational technology offices as offering support in the form of workshops and partnerships. One leader described a partnership:

> In economics, they require their students to participate in [Central FFP] in order to teach as Instructor of Record starting their third year of their program, because economics relies on graduate students as instructors of record. And so this was an easy way for the school to get their students trained, they don't give them any extra money for participating. But when you're an instructor of record, you get more money than you do as a TA. (Central)

One shared aspect of these three programs was that leadership, at least in the closest supervisory role, not only strongly supported the program but was also involved in its programming to some extent. In fact, all of the supervisors in this study had past or current experience as a mentor or leader in the future faculty program. This strong, involved leadership was identified by Hill et al. (2020) as central to future faculty program success.

Programs also found resources in support of their missions. All three programs were the recipients of grants either for the initial design and launch, for their redesign, or for program evaluation. While these grants were valuable, leaders noted that they did not make sense for sustaining programs and grant writing was a task that took a lot of time, which all program leaders considered a hurdle.

Critical Perspective on Organizational Contexts

These were successful programs in many of the ways we assess programs in higher education: they met their outcomes, participants experienced growth in their skills, staff and faculty felt satisfaction by being involved, and they invited participation from across their institutions. A critical perspective might also ask what else they could do or be if an equity lens was applied to their organization. For example, how might they empower more graduate students and postdocs if programs could build capacity? How might the removal of organizational barriers enable them to create programming and new professional development models that provide greater access to participants from HME backgrounds? What cultural norms need to change for greater faculty and staff participation? A critical perspective, as shared by von Vacano et al. (2022), suggests that simultaneous attention to both meso-level interventions (like the training found in future faculty programs) and also macro-level shifts toward equity accompanied by increased access to opportunities and resource allocation toward programs doing meso-level interventions will lead to an inclusive STEM education.

Power and Privilege

In the interest of getting a more granular understanding of inclusive teaching in each of these programs, it was helpful to apply a critical lens and ask how these programs attend to power and privilege. How were they training the next generation of STEM educators to not only be aware of the diversity of their students but to also counteract some of the historical imbalances and inequities in STEM fields and in classrooms in general? Dewsbury et al. (2022) and von Vacano et al. (2022) stressed the importance of this step because they assert that pedagogical training in inclusion and diversity without a critical lens on power risks creating educators who have only the most general understandings of inclusive teaching, which they are then more likely to cast aside.

Questions about power and privilege were difficult for leaders to answer. One leader understood power and privilege as a global issue affecting not just undergraduates in STEM but also the agency of graduate students. They shared the experience of watching participants from their program give a lecture for their capstone project and feeling shock and dismay that graduate students with so much knowledge of evidence-based teaching would turn to the lecture. They shared how the conversations went after the observation:

> If you learned all this stuff about how to be a student-centered instructor, what are the barriers to being a student-centered instructor? Is this how you want it to be

> and they'll say things like, I'm still a grad student, I don't have the power to change this yet. (Central)

They connected this feeling of powerlessness with the slowness of change in STEM teaching. Still, they asked participants in this situation, “How are you going to use these things that you've learned about pedagogy to help us all move the needle towards more student-centered instruction?” They also invested participants with a sense of responsibility about the power imbalances in STEM:

> recognizing the power that's inherent in the system that is higher education that we built. I will say, over and over again, we built this system, we're part of this system. If we don't like the system, we have to work on changing this system. It's alive and well because of us because we keep doing the same things over and over again. (Central)

SW’s program director shared that their participants seem to be motivated in how they teach by their experiences as undergraduates in STEM. Some experienced the lack of power and privilege that is often part of having a marginalized identity and these experiences motivate them to change teaching and learning in their fields. Others recognized that they benefited from great privilege in their educational journeys, largely due to their identities, and seek to make change:

> They're like, I know I've always had a very privileged path and I know that my experiences aren't universal, and so that's why I want to try to make things better for the people who are not me and who didn't have … an easy glide through the system.

Even despite these motivational factors, the researcher could not find significant curriculum that addressed power and privilege or employed a critical lens to pedagogical practices. This is not to say that power and privilege were not discussed, but these discussions were largely informal and not part of programming.

Programs included in their curriculum some discussion of the power dimensions in the classroom. For example, STEM educators letting go of the power of the expert:

> We talk about it when it comes to active learning, and the need for the instructor to relinquish some power as the guide in the front of the class and how scary that can be for experts to relinquish that control over the class. (Central)

This was a common complaint about using active learning techniques by faculty in content and expertise focused fields (Peterson et al, 2020). Programs also mentioned the different power dynamics that their participants experience because of their marginalized identities, including gender:

> We talk about presence in the classroom, too. What is it? How are our different genders and races perceived as instructors? How did the students perceive us with our different identities? Notions of expertise. Who gets called “doctor”? Who doesn't? We talk about it on the first day of class. I recommend that they use “doctor” and that they introduce themselves as “doctor,” and I explain why. (NW)

Program leaders also stressed that participants were grappling with power and privilege in their labs and that could bleed into their work as instructors. As a result, any work the program could do to address these issues would also help participants in their daily work environments (or at least help them imagine how they might lead a lab differently).

A critical lens is helpful not just to examine these programs and the mentoring that takes place in them; it is also helpful for informing classroom management. One example was a strategy taught in the NW program, which is called equitable call. Formerly referred to as random call, this strategy involved calling on students that were not volunteering. It also included asking specific people to report out for a small group instead of letting each group choose their representative. The program manager shared an example from their own class:

> I just said, Hey, you know somebody from your group report out. And it was the white men who reported out, and we have very few white men in the class, so it was obvious that these were the people who were most comfortable taking the position of representing the group. And that's something that we talk about with our students, with the postdocs, because if there isn't anything that's done ahead of time to choose a group representative. Then it's usually the white dude. (NW)

This strategy is explicitly motivated by the desire to draw participation from diverse students (Eddy et al., 2014).

Grading was a theme that emerged in discussions of power and privilege. Leaders mentioned themes of grading in their programs and institutions. The program director for NW mentioned that they had to do some active dismantling of old ways of understanding grading:

> You know, we have a system that's set up where anyone can get an A. There's no curve. And some of the postdocs ask me … what if they all get A's? Aren't they getting the wrong idea about who can succeed in science?

Similarly, the program director for Central said grading was one area that their institution and their program had not made much progress on and that directly affected access and engagement:

> [Central University] is a very traditional grading culture where we're not so much on the curve, like the traditional curve, but it is definitely a source of angst among our students. If I could wave a magic wand, it's the one thing that I would change the fastest here at [Central], that it's still very competitive, very masculine oriented, you know, like, who's the best student in class... And so [in our future faculty program], it leads to pretty interesting discussions, when we say things like, why do you grade out of 100%? Why do you put a number on that paper at all? Could it be satisfactory, not yet satisfactory?

These programs seemed to be some of the only voices questioning grading systems and asking participants to think critically about them. Clearly, these programs were working to change this aspect of power within STEM, but the change is slow.

Transformation

These programs occupied a crux in STEM education, where learners were also teachers and where learner-centered pedagogical training had its most opportune moment (Dewsbury, 2017). The researcher was interested in learning how these leaders viewed their work when put in the context of affecting change or playing roles in transformation. Connolly et al., (2018) identified three areas where future faculty programs sought reform: 1. to improve undergraduate education through increased pedagogical training; 2. to better train graduate students for traditional faculty roles; 3. to change graduate professionalization so that graduate education will be taken seriously. Of note, these reforms are focused on training faculty better suited to traditional careers, not transformation of STEM.

This section shares leaders' responses to the follow-up interview questions regarding the value of pedagogical training to STEM students and postdocs and the ways they see their work affecting undergraduates. The researcher did not use the term "transformational" in these interviews, to give participants the opportunity to define their roles in their own terms. Follow-up questions were asked about the tension between research and teaching and how program managers viewed their work with regards to it. They also asked about how program managers saw their impact on undergraduates.

Transformation was seen in two primary threads: the importance of evidence-based teaching to one's academic career in the sciences and the effects on undergraduates when future faculty are trained to teach. Evidence-based teaching is still seen as transformational in STEM educational spaces. One part of this transformation was helping participants to ask critical questions; for example,

> How do I think about my own position within this discipline? Am I a researcher only, or am I an educator who researches, and then communicates that information to others? Or am I a practitioner who takes this outside of the walls of academia and discovers new information and still talks about it or writes about it, pitches it to funders and other entities in the future? (Central)

They also learned to question the teaching they have seen:

> Gosh, why is that college faculty member so bad at this part of their job? And then you learn. Oh, wait! They got deep training in their discipline, but no training in teaching. (Central)

Programs trained participants to ask critical questions and be leaders in education spaces:

> You're going to work in a mostly lecture based environment, probably. But then you've got to think about how are you going to do punctuated lecture? How are you going to TILT your assignments? How are you going to use these things that you've learned about pedagogy to move to help us all move the needle towards more student-centered instruction? (Central)

In many ways, leaders of these programs described their participants not just finding successful careers in academia, but transforming both their classrooms and their departments:

> for our students to come out of our program, having achieved the learning goals of understanding how students learn and understanding the differences among students which will appear in every classroom that educators encounter, and that those differences are going to impact the success of their teaching and the success of student learning… We know how to design good courses and good assessments and align those with learning goals and all these various evidence-based teaching practices that they can implement and that doing so puts students at the center of that educational experience. And if they come out of our program only with that kind of reframing of what college teaching means, that it's not solely about transferring knowledge from the instructors' brain to students' brains. But it's centering the students, the whole students, in that learning process. I think that makes changes. What teaching and learning is like in those courses, in those classrooms. They're levers of change. Perhaps at their institutions for the future, as they go into leadership roles and have the opportunity to impact their own

> curriculum and faculty, governance, and all of these ways that change happens. (Central)

This perspective aligns with Dewsbury’s (2017) assertion that future faculty programs in STEM are perfectly suited sites for training inclusive, transformational educators. Participants in these programs were trained to ask critical questions, to use evidence-based methods, and they were expected to show some leadership in these areas.

In addition to transforming their own practice, and as evidenced above, participants were seen as having great impacts on undergraduates. Leaders working with graduate students emphasized the impacts made by teaching assistants and graduate instructors on the experiences of undergraduates in their courses:

> TAs are an important intermediary between undergrads and faculty. And we know from evaluations of teaching assistants that undergrad students will talk about the value of having a confidant, a near peer, to explain things in simpler terms. Someone who knows the institution from a student perspective, even if they're grad students … to kind of help them through revealing opportunities within the discipline to advance their own career. There's just so many ways that having sort of a coach or mentor who's close to them, that the graduate students play this important role of coach or mentor to the undergraduates. That's really valuable. (Central)

This leader identified near-peer mentoring and visibility as important to undergraduate success in STEM. They saw participants in the future faculty program having immediate positive effects. Another leader echoed these ideas:

> you have that ability to affect the whole learning environment. And there's that … opportunity to maintain a sense of belonging and inspiration that can keep people from falling out of the pathway towards becoming future faculty themselves. Because especially if you're the TA for a big class with a lot of students, a lot of students can end up feeling lost, and then they drop out of STEM.
>
> They could have been amazing. And that's a loss to the world. So as a TA, you are the one who are having that sort of front-line impact because they're not going to be interacting with the professor so much. If it's a giant intro class, they're interacting with the TA. And so the TA is the one who's going to be working with them, providing them the support and the inspiration, and helping them. They can really play an important role in retention in STEM at that very important point in students' lives. But also having these programs available and just having that sense, that teaching is important. I think that's something that can kind of get passed along to undergraduates, just as a broad sense, that it's not just about content delivery. (SW)

In other words, teaching assistants were not only acting as mentors and near-peer models for undergraduates in STEM, they could also transform undergraduate understanding of good teaching in their field.

While TAs had great power in influencing persistence, future faculty programs were often looking beyond the graduate experience to imagine the teaching of junior faculty. When instructors were allowed to design and manage their own courses, participants of future faculty programs had the opportunity to fully practice evidence-based teaching. Program leaders imagined their graduates as change leaders:

> we want them to understand the value of community around teaching, and that wherever they go, that finding this community of like-minded instructors who are curious and reflective, and want to continue talking about teaching will amplify the impact of the training that they've gotten in teaching. (Central)

This notion of participants as evangelists was echoed by another leader:

> the idea is that we want to have active learning or the idea of evidence-based learning embedded in their philosophy so that they take that with them wherever they go. (NW)

Critical Perspective on Transformation

It is important to note that the transformation imagined by program leaders was largely centered on participants as future change leaders in their classrooms and departments. They did not see themselves as playing important roles in transforming STEM, even though they were the leaders, mentors, and trainers of these new future faculty. Furthermore, their vision of that change was not as ambitious as one might expect. There may be many reasons for this, from learned pragmatism of working within large institutions to burnout from leading programs with few staff. Regardless, the data collected in this study points to larger transformations that need to take place to fully support inclusion in STEM, graduate students and postdoc professional development, and the spread of evidence-based, learner-centered teaching throughout STEM fields. These principles, processes, and strategies are shown in Table 2.

Critical Principles	Transformational Processes	Equity-centered Strategies

• Power and privilege awareness • Dismantling inequities • Advocacy interventions for equity	• Individual empowerment • Organizational capacity building • Assessment and evaluation	• Teaching and learning concepts • Socialization and professionalization • Organizational advocacy

Table 2: Critical Principles, Processes, and Strategies

Summary of Findings: Research Question 1

What pedagogical approaches and professional development processes are utilized by effective STEM future faculty programs?

This question is best discussed separately–pedagogical approaches on one hand and professional development processes on the other. All programs professed to using and advancing evidence-based teaching practices in their programs. All had at least some content on active learning and inclusive teaching practices, although their emphasis varied. These programs showed a consistent move toward learner-centered pedagogies, although their progress was varied and not systematic. The researcher noted that many of their materials were created locally, which suggests that each program created its own materials on the same or similar topics. Programs also varied in how much application participants enjoyed. So while all participants were educated in active learning, for example, not all had opportunities to practice active learning in their classrooms.

Program leaders were unanimous in struggling to identify a professional development model or framework on which their program was based. This is consistent with the review of the literature. Echoes of learning communities, scientific teaching, and mentoring models were heard throughout the interviews, but even when these models were raised, they were not identified as central to program design or processes. Indeed, if these programs could be said to have a model, it would be the very unique model they each formed based on their organizational contexts. It should be noted that even while two of these programs are members of the CIRTL network, CIRTL's certificate model did not have significant influence on the local program. Some themes emerged from these highly localized, specific programs: 1. graduate students and postdocs should be treated differently; 2. programming cannot happen in one modality; an effective program has workshops, courses, synchronous and asynchronous programming, teaching opportunities that look all sorts of ways; 3. mentoring in teaching is important, whether it comes from CTL staff or faculty. These three conclusions may be helpful for leaders seeking to create their own future faculty programs.

Research Question 1 Subquestions

The subquestions for the first research question sought to learn about how participants were trained in learner-centered pedagogies (inclusive teaching and active learning) and how they are acquainted with issues of power and privilege in pedagogical practices.

1a. How are participants trained in learner-centered pedagogies?

1b. How are participants acquainted with issues of power and privilege in pedagogical practices?

Training in learner-centered pedagogies looked very similar between the programs. This training came in the form of courses and/or workshops and were reinforced by teaching observation and feedback. They affirmed Dewsbury et al. (2022) in recognizing that training in learner-centered pedagogies required that they "subvert their current understanding of teaching" (p. 2), which program participants had largely gleaned from their own undergraduate education. Active learning was clearly central to the curriculum of all three programs while inclusive teaching practices were sometimes present and not always called the same thing or taught in a consistent way. Central had a strong UDL emphasis, unlike the other programs, and only the NW program mentioned reading scholarship on inclusive teaching with their participants. Similar to inclusive teaching, discussions of power and privilege were less formal than those on active learning and the science of learning. While participants learned about the diversity of students and considered their own diverse identities in the classroom, there seemed to be a lack of learning in this area. This presents an opportunity to develop a set of best practices around power and privilege in STEM future faculty programs, or at least an effort to add to or more widely employ tools already in existence, like the LSE Inclusive Teaching Guide (Dewsbury & Brame, 2019).

Previous literature on the pedagogical components of STEM future faculty programs provided evidence of significant growth in various teaching domains by participants (Coles et al., 2020; Mutambuki et al., 2020; Rozaitis et al., 2020) and have used tools like the COPUS to measure their effectiveness in turning learning into practice (Bowman et al., 2020; Branchaw et al, 2020; Price et al., 2021). This study sought to learn more about the topics included in curriculum and if those topics aligned with Dewsbury's definition of learner-centered pedagogies. In the sense of teaching and learning theory, the data showed many signs of constructivist notions of learning and scientific teaching, which treats the classroom as a laboratory, testing, gathering data, etc. Overall, the programs professed to model (modeling was a strong component in all programs) and instruct their participants in evidence-based teaching, including active learning, and made some gestures toward inclusive teaching. This last item is murkier because even when leaders used the term, the examples they shared did not always resonate with definitions common in the literature (Dewsbury & Brame, 2019). There was also a less than specific treatment of diversity—how it looks in classrooms, how one teaches to it, and how one affirms its value in the classroom.

Summary of Findings: Research Question 2

What organizational or institutional benefits and barriers exist to providing pedagogical training to graduate students and postdocs?

Programs faced significant organizational challenges and these affected their approach to professional development, mentoring, and even their curriculum. This confirms what researchers have found in previous studies regarding institutional barriers (Dewsbury et al., 2022; Connolly et al., 2018). The researcher categorized the challenges as logistics (scheduling, administrative support), faculty and staff engagement, and cultural issues in STEM fields. Because these programs often functioned outside of regular courses, logistical issues like room scheduling and scheduling conflicts with graduate programs were common. These programs were staffed by very small teams, so they all needed more administrative support. Broad faculty and staff engagement, while high in some departments or with individuals, was lacking. Programs found that they did not need to do any promotion to attract participants but needed to work hard to engage faculty as mentors, course coordinators, and allies of the program.

Lastly, the programs existed in organizations still dominated by a tension between research and teaching, where research was prioritized, confirming findings in the literature (Baiduc et al., 2016; Hill et al., 2019). Even while this may not be true for participants, they experienced it in their mentors, advisors, and instructors. In the same vein, the culture that created this tension also emphasized a lecture and test approach to teaching. This instructor-centered way of teaching has been stubbornly entrenched in STEM education (Miller et al., 2021). Programs found they needed to confront these cultural issues in order to be effective, as Dewsbury et al. (2022) found, and that cultural influences limited their transformative power.

Assessment of Conceptual Framework

Based on the review of literature, the researcher proposed a conceptual framework for this study that identified the three primary areas of focus as creating a Venn diagram with STEM future faculty programs at the center (Figure 1). These three areas were teaching and learning, professionalization/professional development, and organizational contexts. The data indicate that these three areas have significant impacts on future faculty programs and they certainly influence each other. The researcher learned that professional development was often the site of the noteworthy differences between the programs and that while programs were concerned and engaged with professional development, there were few models that worked for these programs. Many of the pedagogical topics were the same (active learning, backward design, engagement and inclusion), and while programs did not follow a common model, they did contain common program components (teaching observation and feedback, reflection, creation of a teaching portfolio, etc). While the image of the framework suggests there was a balanced influence between the three areas, the data indicate that organizational context (supports and barriers) had more significant effects on programming than models of professional development. Similarly, the content of the teaching and learning had significant effects on the overall programming as leaders sought to include what they deemed vital content despite barriers. As Hill et al. (2019) explain, “teaching professional development programs are situated within complex organizational environments and involve numerous organizational members.” (p. 1170).

The conceptual framework shared in chapter 3 clearly needed a more specific, targeted treatment of each area (teaching and learning, professionalization and socialization, and organizational contexts), which would more clearly describe and fundamentally incorporate critical perspectives. Viewing the findings in chapter 4 (Table 2) through a critical perspective highlighted three important categories for future program development and assessment: critical principles, transformational processes, and equity-centered strategies. Critical principles included power and privilege awareness, dismantling inequities, and advocacy interventions for equity. Transformational processes included individual empowerment, organizational capacity building, and assessment and evaluation. Equity-centered strategies included teaching and learning concepts, socialization and professionalization, and organizational advocacy. These are some of the same words used in previous discussions of future faculty programs, but the conceptual shift is in applying critical perspectives to every area of the findings. These three categories were found to be central to the effort of sustaining effective programs, growing the access and effect, and amplifying the inclusivity of programs and their effects on undergraduate STEM education.

Building Toward a Model of Program Development

The twin goals of this study—to explore the curriculum and organizational contexts of STEM-oriented future faculty programs and to learn how these programs might further the very critical goal of HME student persistence in STEM through learner-centered pedagogies—were realized both by describing the successes of these programs and also identifying areas for growth. To be clear, the purpose is not to recommend improvements to these already quite effective programs, but to use their knowledge and experience, paired with a critical perspective, to make recommendations for all such programs. The summaries above showed some distinct observations about these programs. In the area of professional development, it was learned that graduate students and postdocs needed to have programming suited to their situations, the programming needed to be multi-modal, and mentoring was key. Taking a critical perspective of these requirements, it became clear that socializing future faculty needed to be reconsidered. Socializing STEM graduate students almost entirely to careers in research, without formal mentoring systems, and without centering the work in equity, reifies the existing problems in STEM education. Additionally, the ways they have been professionalized needs to be changed–not just by increasing pedagogical training but also redefining professionalism for STEM fields–both to meet the needs of their learners but also to help them lead transformation in STEM education.

In the teaching and learning area, the study found programs that offered consistent engagement with evidence-based teaching through instruction, modeling, practice, observation and feedback, and reflection. The programs were adept at teaching active learning and constructivist approaches but across programs, their instruction was not specific in their treatment of diversity, nor did they consistently share the same definition of inclusive teaching. This points to the need for program development that clearly and consistently uses active learning and constructivist approaches to teach and model a shared set of inclusive teaching practices and philosophies.

Lastly, the data illustrate that even with these highly effective programs and dynamic program leaders, there were consistent barriers to their success and growth: logistics, faculty and staff engagement, and STEM cultural issues. These challenges pointed to the need for program development that enjoyed organizational support not just from some individuals but also from leadership, academic departments, and student services. Only with stronger institutional support could future faculty programs realize their potential as training effective, inclusive educators. Thus, program effectiveness and success were viewed through the lens of “macro influences” and “micro interventions,” and a new way of visualizing the key findings (seen in Table 2 on page 105).

The table describes the principles, processes, and strategies found to be key to program effectiveness as important players in creating more diverse fields, where HME students feel welcome and engaged. Notably, there were teaching and learning, professional development, and organizational elements in each area, which pointed to the importance of attending to all these areas in imagining a model for STEM future faculty program development. For example, all the program leaders professed a personal commitment to critical principles, but these principles were not often articulated in their programming or were expressed informally. Similarly, programs excelled in some of the transformational processes, like helping to empower individual participants, program evaluation, and building relationships for greater program capacity. But if the critical principles of dismantling inequities and advocacy interventions are applied to the processes, they will need to adjust. For example, program evaluation that has dismantling inequities as a program goal will necessarily look different than previous evaluations. Finally, equity-centered strategies were in some ways already seen in programs, as were some efforts to reimagine socialization to faculty roles, and some amount of organizational advocacy. The difference here was that all these efforts should have equity at the center. This approach was more fully developed in the teaching and learning areas of programs, but not always communicated as such. Taken together, Table 2 represented the growth areas for future faculty programs that will inform a new program development model.

This chapter shared the findings from the data collection and analysis of three STEM-focused future faculty programs. Based on the research questions, themes of teaching and learning, professional development and socialization, organizational contexts, and roles in transforming STEM education were the focus of the chapter. Critical perspectives of each area were included. Themes were then organized into summaries organized around the research questions. The conceptual framework used to inform study design was assessed using data from the study. Using a critical lens, key findings were then organized into a table of principles, processes, and strategies identified through the analysis process that will lead to a program development model informed by critical perspectives.

CHAPTER 5: IMPLICATIONS AND RECOMMENDATIONS

The purpose of this study was to learn the curricular, professional development, and organizational factors that support effective future faculty programs in STEM and what roles these programs might play in diversifying STEM education. Three programs were studied through interviews and document analysis. Coding brought forth themes of organizational barriers like scheduling and budgets as limitations, curricular consistency in evidence-based instruction but variation in learner-centered pedagogies, significant differences in professional development models, and common struggles with faculty engagement and institutional commitment. All programs mentioned the need for flexibility in their programming and staffing. There was significant variability in knowledge and use of critical lenses in creating future faculty programming. Lastly, while leaders did not always say they thought they were working as change agents, their work spoke to this.

This chapter is organized into three main sections: first, the elements of effective future faculty programs as outlined in Table 2 are discussed; the second section of this chapter shares implications of this study for the field of STEM-focused future faculty programs and STEM undergraduate education; third, there are recommendations for future research, and lastly, the conclusion.

Elements of Effective Programs

The findings in chapter 4 can be described in terms of the elements needed to support effective future faculty programs in STEM in ways that will lead toward greater persistence of HME students in STEM fields. As shown in Table 2, these elements fell into three categories: critical principles, transformational processes, and equity-centered strategies.

Critical Principles

Critical principles were identified as playing important roles at the level of participant training, program curriculum and evaluation, and organizational levels of support, barriers, and leadership. Program leaders were able to articulate the ways in which their programs taught and modeled awareness of power and privilege in the classroom in areas like random call, student instructor positionality, and in their attention to active learning as an equity tool. Areas that were emerging were in more direct dismantling of inequities and greater advocacy within organizations by future faculty programs and their participants. Applying critical principles to the work of providing pedagogical training for STEM graduate students and postdocs was identified in this study as an important step toward the overall goal of transforming undergraduate experiences in STEM.

Transformational Processes

Transformational processes were important to the overall effectiveness of programs as well as the experiences of future faculty program participants. They included personal empowerment in the form of greater knowledge of pedagogy, specifically constructivist and inclusive teaching; rethinking training toward academic roles, which have not changed to suit a diverse student population; and equity-minded expressions of learner-centeredness as a transformation from content- and instructor-centeredness. They also included program evaluation and assessment, which all programs undertook to some degree, but which should include critical perspectives. Lastly, organizational capacity building was a transformational process found to be key to program sustainability and growth. This capacity building was dependent on factors like effective and dynamic leadership, strong support networks, and growth-minded funding. All three programs felt pressure to build capacity in their programs, almost as a way of justifying the time and expense of staffing them, but without promises of additional resources.

Equity-Centered Strategies

Programs needed to practice equity at every level of operation. They employed multiple strategies, many of them in the teaching and learning curriculum. These included their training in and modeling of inclusive strategies like active learning, dialogue, building classroom community, using student data to understand student strengths and needs, etc. They also identified areas in professionalization and socialization where they had opportunities to apply equity frames: discussions of career paths, the roles of junior faculty in transforming STEM education toward equity, and in developing mentoring relationships. Programs also identified equity-centered organizational advocacy as a growth area. Based on these three areas of program growth, as well as their previous effectiveness in providing quality teaching professional development to graduate students and postdocs, a new program development model emerged from this study.

Implications/Recommendations

Future faculty programs in STEM are doing important work not only to provide quality mentoring and professional development to participants but also to embed evidence-based teaching in the fundamental teaching practices of their graduates. But these programs can more effectively achieve their goals by using critical perspectives to change the teaching and learning, professionalization and socialization, program assessment, and organizational contexts. This section describes the implications of this study and makes recommendations for the field informed by the principles, process, and strategies described in the previous chapter.

Organizational Advocacy

This study has shown the pervasive power of organizational contexts in deciding the shape and content of future faculty programs in STEM. In making recommendations for institutions, it is useful to consider networked leadership as a model for supporting these programs and the goal of supporting HME participation in STEM. According to Eddy and Kirby (2020) in networked leadership, people in various offices decide on a shared goal and work toward that goal, listening to voices that might not always have a place at the table. For example, a working group on this topic may invite graduate students and postdocs to participate in their work. Second, networked leadership invites partnerships, where various departments and offices, and sometimes folks from other institutions, work together to meet a common goal. Lastly, networked leadership celebrates boundary spanners, who are people able to reach across silos to listen and communicate with diverse groups. Graduate students and postdocs in STEM occupy various roles as researchers, students, mentees and mentors, and teaching assistants and teachers. As a result, they require the strategic thinking and support of many offices and departments to support both the short-term success and their long-term professional and career development. Eddy and Kirby (2020) emphasized that the most successful boundary spanners are people working from the middle and not at the top of the institutional hierarchy. Most importantly, these programs need the bandwidth to connect with faculty allies and departments. What would these three programs need to make networked leadership work for them? Do they need strategic visions that include networking? Do they need more models of how networked leadership looks at other institutions? Surely, they need more people in the form of FTE to do this work.

As explained in Chapter 4, there are significant barriers to the success of STEM-oriented future faculty programs. Networked leadership efforts can go a long way toward creating the relationships and working groups needed, but some other organizational barriers should be attended to through focused organizational advocacy. For example, offices like the Registrar's office and graduate studies can support the scheduling needs of these programs. This may look different at each institution, but some ideas are to create a master calendar with graduate programs to find slots for future faculty programs, to ensure that future faculty programs are well-integrated into institutional systems and record-keeping, and to provide administrative support. Some programs have answered the question of integration by creating future faculty programs that are official certificates, which also offers incentive for participation (Crowder & Monfared, 2020). Crowder and Monafred's program and the NW program studied here are based in biology departments rather than in CTLs. It should be considered, then, if future faculty programs should live within an academic department rather than in CTLs for these reasons (although this move could present a barrier to participation by graduate students and postdocs outside that home department).

Lastly, there is a need to professionalize the leaders of future faculty programs. Central identified the CIRTL network as a source of professional community for the leaders in their program. Both Central and SW are involved with the POD Network, which provides opportunities for networking and sharing knowledge beyond STEM.

Neither of these organizations provide training to program managers and education specialists who create and sustain future faculty programs. And then there are programs like NW and FUSE, which are used in biology departments and are more connected to networks within biology education than with CIRTL or POD. This divide seems particularly significant and efforts should be made to integrate the two camps. One promising effort is an NSF-funded grant led by Dr. Erin Shortlidge titled "Evolving the Culture of Biology," which seeks to train leaders in future faculty programs in inclusive, evidence-based pedagogy (Rojas, 2022). This program shows promise in professionalizing the leaders of STEM-oriented future faculty programs and offering possibly the most consistent approach to evidence-based, inclusive teaching yet.

Iterative Assessment

One criterion for selection in this study was engaging in program evaluation or assessment, so all three programs were practiced in this area. This evaluation came in the form of annual reports, scholarly papers, and internal reviews. These evaluations were largely focused on the teaching self-efficacy of program participants, as is also common in the literature on STEM future faculty programs. This study pointed to the need for equity-centered evaluation that looks beyond the individual experiences of participants to also look at program outcomes, learning activities, leadership, and mentoring. As Dewsbury (2017) explained, inclusivity in the classroom requires more than a set of strategies but also a comprehensive attention to student belonging, communication in the classroom, identity, and power sharing. These findings called for program assessment that regularly measures progress in these areas.

Deconstructed Socialization and Reconstructed Professionalism

There is a need for a platform for sharing professional development models that are effective. Even while these models are highly localized, as found in this study, there are consistent program components and philosophies that might be unified into a few standard models. For example, a model for graduate students at research-intensive, land grant universities, a model for postdocs, a model for graduate students at health sciences universities, etc. These different models would attend to some of the specificities of scheduling, lab requirements, and teaching assistantships while also framing faculty roles in new ways: as confronting the research/teaching tension and dismantling it, in showing leadership in teaching and learning, and in centering equity in their teaching, research, and committee work.

Mentoring arose in this study, and in the literature, as a crucial piece of the professional development puzzle. Graduate students in STEM are accustomed to being mentored by PIs and other faculty mentors in research (Walker et al., 2008), but rarely in teaching. Future faculty programs provide mentoring in teaching through teaching observation and feedback, small group mentoring, and instruction in teaching. There should be greater recognition of the mentoring taking place in these programs, either in the form of course release, funding, and/or increased attention in the literature. Furthermore, mentoring in teaching would benefit from a more formal approach to the work (Kezar & Posselt, 2020), just as mentoring in research is increasingly formalized through programs like CIMER, which provides mentorship training to STEM faculty (Mondisa et al., 2021). Rybarczyk et al. (2017) found that SPIRES trainees (HME postdocs who were trained in pedagogy) later went on to participate in many important activities related to HME student retention, including mentoring HME students, serving on diversity-related committees, engaging in science outreach, and submitting grant proposals with diversity focus. Clearly, mentoring and training in mentoring makes a difference for HME students.

Even while there needs to be a more structured, networked approach to providing teaching professional development to graduate students and postdocs, there need to be more programs and programs expanding their capacity. Central provided an example of a program that was able to support and sustain hundreds of participants at any given time. While it should be noted that both the program manager and supervisor stressed a need for more staff, the ratio of staff to participants in their program was significant. Many institutions lack the resources to create and sustain a future faculty program (Connolly et al., 2018), but one could also argue that the resources have not been allocated because the institutions do not prioritize this form of professional development. They have not grasped participants short and long term impacts have on undergraduates in STEM and have not conceived the equity impacts of their training. Additionally, one might argue, as many have in the literature, that institutions and departments need to better prepare future faculty for their roles, which include teaching. With enough culture change, change makers, and easily accessed professional development models, transformation of STEM education and socialization will happen more rapidly.

Teaching and Learning Curricular Methods

Future faculty programs are rightly focused on their teaching and learning curriculum as the center of their mission. Yet, programs would benefit from a shared database of curricular materials. Too much time and too many resources are devoted to creating local versions of the same materials on active learning, backward design, group work, inclusive teaching, UDL, etc. These materials could still be adapted but would not need to be constantly recreated. A common store for materials could also address the variation in definitions shown in this study. Programs did not always share a consistent understanding of and approach to inclusive teaching. Additionally, programs would benefit from professional development of leaders in the area of inclusive teaching. Too often the audience for inclusive pedagogical training is future faculty and not the faculty and staff training them and leading future faculty programs. Training focused on program leaders might look like a course offered by CIRTL or an event hosted by the POD network, or the biology-focused program offered mentioned above. By providing training for leaders in inclusive teaching, we should see greater clarity and consistency of these teaching approaches in STEM-oriented future faculty programs. We might also see a more direct treatment of theories and practices that support HME student persistence.

Teaching and Learning Critical Perspectives

The findings of this study called for leaders to have a stronger understanding of critical theories and the ways power and privilege function in STEM. They should be able to articulate how active learning and other constructivist approaches can be used for equity work. They should also train participants in inclusive strategies like dialogue, including student voice, and teaching practices that express growth mindset. Dewsbury and Brame (2019) wrote:

> When instructors engage with their students' voices and acknowledge their students' agency in learning, it transforms the ways in which we construct STEM classrooms. Students' voices guide curricular choices, the support structures that

> help students succeed, and the tools that will promote a positive classroom climate (p. 2)

As the authors suggest, future faculty programs that are truly student-centered can radically transform student experiences in STEM classrooms.

It should be noted that these recommendations require the time and attention of leaders who are already tasked with many responsibilities, so program developers and those seeking to redesign their programs should have a plan for staffing this equity work. It needs to be foundational to program curriculum and identifiable in multiple areas of programming, which may require including DEI specialists in program creation and redesign.

Teaching and Learning Constructivist Approaches

Constructivism asserts that students come into any learning environment with previous knowledge and are constantly engaged in the act of creating meaning from what they learn. Social constructivists say that these dynamics are particularly effective when experienced in a group, that students learn from each other in zones of proximal development (Vygotsky, 1978). This study found that constructivist approaches to teaching and learning, like active learning, were central to program curriculum. They invited participants to become students of learner-centered pedagogy, to consider the prior knowledge and experiences brought by diverse students to the classroom, and ask educators to consider the teaching and learning value of those experiences. They also opened the door for STEM participants accustomed to instructor-centered, content centered teaching to consider learner-centered strategies and philosophies. Programs rarely start by considering Freire or Yosso. They more often introduce Vygotsky or

Piaget as doorways into learner-centeredness. Even if they never teach Freire or Yosso, they want to consider how to move from the learning science orientation of constructivism to an equity-centered perspective on active learning and group learning.

Addressing the Persistence Problem

The problem identified at the beginning of this study was not simply the lack of teaching professional development for graduate students and postdocs in STEM. It was also concerned with the high rates of switching undergraduate majors from STEM to non-STEM fields, largely based on teaching. The switching rate has dire consequences for STEM fields, which need innovative, creative scientists to solve the problems of contemporary life. It seems almost silly that the career trajectories of so many undergraduates would be steered by poor teaching (at least when compared to all the work the learner has to complete to earn the degree).

The researcher sought to learn what future faculty programs were teaching that might address these teaching problems and if they viewed themselves as change agents in transforming STEM education for undergraduates in general and HME students in particular. The answer at first seemed largely about replication: how do institutions replicate effective future faculty programs in STEM? The idea that the model already existed seemed obvious. But as the data show, there does not seem to be one program that answers all of the questions raised in the study. Each program studied had pieces of the puzzle and their common successes and challenges suggested that the model had not yet been created.

The program development model featured in this study suggests a path toward this change. It is multi-stepped and multi-faceted, but it is informed by a close examination of the field and of these three programs.

STEM Professional Development Model

Brownell and Tanner (2012) called for widespread, formal programs to provide pedagogical training and mentoring to graduate students and postdocs, citing occasional and unstructured activities as all too common in STEM. Even while this study found highly effective programs in 2023, it also found that STEM-focused future faculty programs could find greater success through the application of critical perspectives, which include equity-based practices throughout programs and their institutional networks. Based on findings in this study, and unlike the conceptual framework described in chapter 3, teaching and learning was core to these programs and all other things grew out from there. Professional development processes mediated access to content (teaching and learning) within the context of each organizational environment. Traditional professionalization and socialization processes were found to undercut the aims of future faculty programs and their efforts toward an inclusive STEM faculty. Thus, these areas needed deconstruction and reconstruction guided by equity. Lastly, organizations were spurred to greater advocacy and stronger assessment practices by applying an equity lens to institutional and departmental culture, which applied not just to future faculty programs but to all the various processes involving learners. See Figure 2.

Based on these observations and in agreement with the literature, there is clearly space for a new program development model, which is the researcher's best attempt at addressing both the successes and the opportunities for growth observed in these programs. It is also an answer to the question of, what professional development model do you follow? To which they responded, we do not. This model maintains the centrality of teaching and learning to the work of future faculty programs, but also recognizes the changes that need to take place in the professionalization and socialization realms, as well as organizational changes that need to take place to support program success and transformative power.

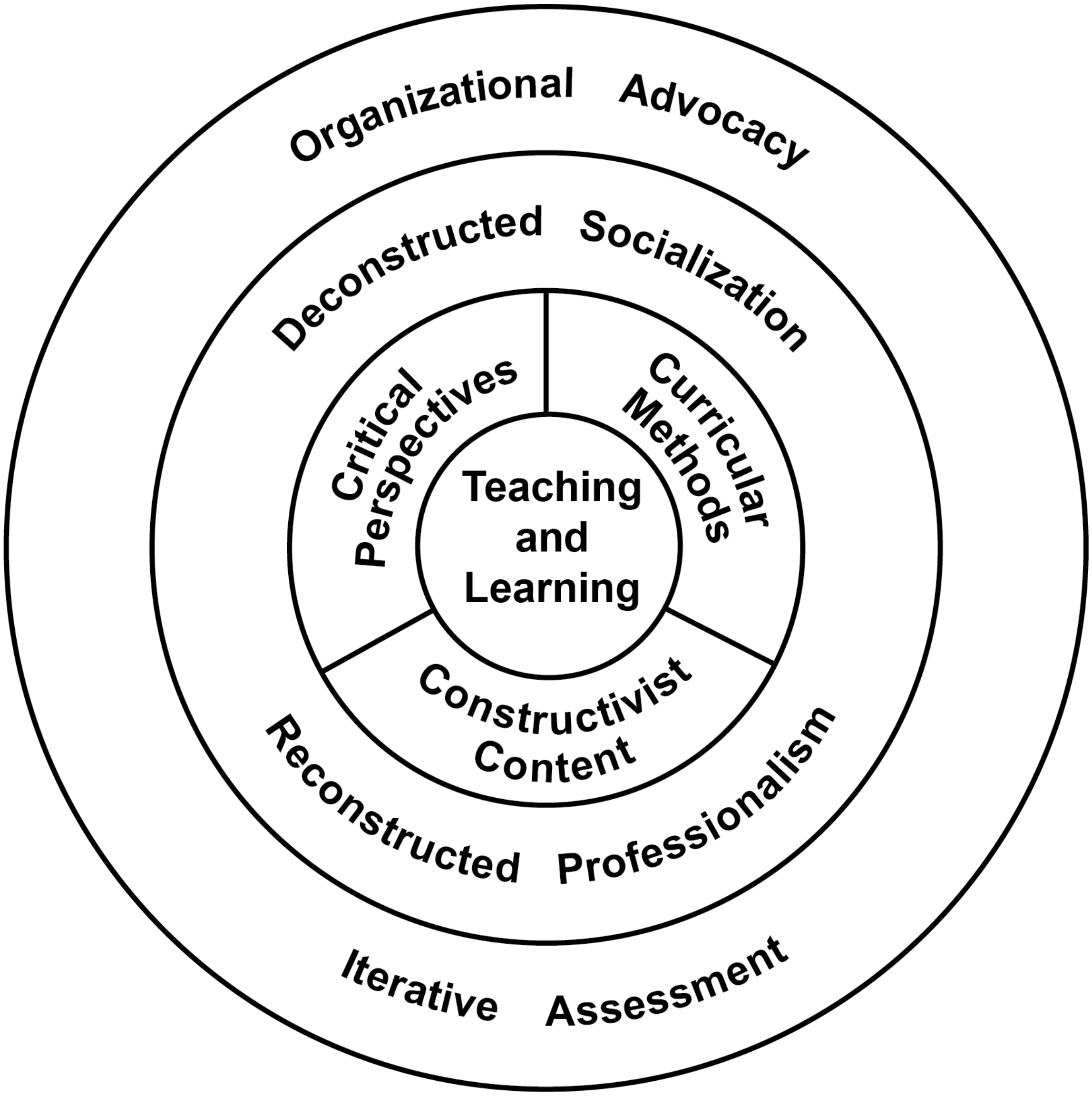

Figure 2: STEM Future Faculty Program Development Model

Constructivist Content	Actively challenge content and instructor-centeredness through active learning and inclusive teaching curriculum	Establish the social and historical dimensions of learning by considering group learning and prior

		knowledge in program curriculum
Critical Perspectives	Call attention to inequities in STEM classrooms through case studies, review of literature, learner reflection	Include curriculum on student voice, dialogue, considering student data, and other inclusive strategies
Curricular Methods	Model learner-centeredness in program courses and workshops	Establish and participate in a shared archive of learner-centered teaching resources
Socialization–Mentoring	Formalize mentoring processes through mentorship agreements	Train faculty to be teaching mentors and recognize mentorship as labor
Socialization–Access	Recruit diverse participants to future faculty programs and help create financial/career/mentoring support networks for participants	Increase program capacity and play a larger role in career and mentoring discussions on campus
Professionalization–Roles	Educate across campus on the diverse career paths open to STEM students and the value of teaching to all paths	Work within professional organizations to provide counter-narrative to research/teaching tension
Organizational Advocacy–logistics	Coordinate with registrar, PIs, and departments for scheduling	Collaborate with campus partners to provide observable teaching opportunities
Organizational Advocacy–leadership	Create a network of collaborators and stakeholders to support future faculty programming on campus	Connect student persistence to future faculty and graduate student/TA teaching professional development through newsletters, scholarship, workshops
Iterative Assessment	Establish equity outcomes for the program and assess for them regularly	Establish a process for learning about participant trajectories post-program to gather information for assessment

Table 3: Table of Recommended Actions (Based on the Model)

List of Questions for Programs (Based on the Model)

Curriculum

1. Does the curriculum actively challenge content and instructor-centeredness through active learning and inclusive teaching? Is this found consistently throughout the program?
2. Does the curriculum establish the social and historical dimensions of learning by considering group learning and prior knowledge? How are diverse voices invited to discussion and decision making in the program curriculum? How does the program curriculum invite the contributions of HME students?
3. How does the curriculum call attention to inequities in STEM classrooms through case studies, review of literature, and learner reflection? How are faculty invited to participate in this aspect of the curriculum?
4. Does the program include a curriculum on student voice, dialogue, considering student data, and other inclusive strategies? How is inclusive teaching defined and enacted in the program curriculum?
5. How does the program model learner-centeredness in program courses and workshops?
6. How does the program participate in a shared archive of learner-centered teaching resources?
7. How does the program recruit diverse participants and help create financial, career, and mentoring support networks for them?

8. Are there efforts to increase program capacity through sustained budget campaigns to fund staff, faculty, stipends for participants (if applicable), and administrative support?

Socialization and Professionalization

1. What steps have been taken to formalize mentoring processes through mentorship agreements and other processes?
2. How are faculty trained to be teaching mentors? Is their mentorship recognized as labor?
3. How does the program recruit diverse participants and help create financial, career, and mentoring support networks for them?
4. What efforts are geared toward educating across campus on the diverse career paths open to STEM students and the value of teaching to all paths?
5. Are program leaders and supporters working within professional organizations to provide counter-narrative to research/teaching tension?
6. Are program leaders part of career and mentoring discussions across campus and within departments?

Organizational Work

1. Are there efforts to increase program capacity through sustained budget campaigns to fund staff, faculty, stipends for participants (if applicable), and administrative support?
2. What steps have been taken to coordinate with registrar, principal investigators, and departments for scheduling to minimize conflicts between the future faculty program and courses important to completion?

3. How are program leaders collaborating with campus partners to provide observable teaching opportunities?
4. Do program leaders create a network of collaborators and stakeholders to support future faculty programming on campus? Have all of the possible collaborators been identified and invited to these efforts?
5. Are leaders connecting student persistence to future faculty and graduate student/TA teaching professional development through newsletters, scholarship, workshops?

Iterative Assessment

1. Are program leaders establishing equity outcomes for the program and assessing them regularly?
2. Are leaders creating a process for learning about participant trajectories post-program to gather information for assessment?

The program development model and these two additional resources, the table of actions and the list of questions, are intended to guide program designers and those redesigning programs. The model may be used to identify areas of focus, while the table and questions are intended to guide leaders in more concrete ways toward achieving the goals of the model.

This model seeks to address the multi-layered nature of the problem through a multi-layered approach to solutions, which are based in the study's findings and in the literature. The hope is that this model will help programs and institutions understand what it means to provide equity-centered, quality teaching professional development and how this quality is realized in curriculum, socialization and professionalization processes, and in organizational processes.

Using the Model to Develop Programs

This model asks program designers to consider the entire ecosystem of graduate education in STEM when imagining, planning, or redesigning their programs. The focus on teaching and learning will seem obvious to designers, as its centrality has been reinforced in the literature for a few decades. But this model also adds some dimension to teaching and learning as it has been previously conceived: a greater attention to and emphasis on the tools that work: active learning and inclusive teaching as teaching approaches, and overlaid by a critical, equity-centered frame. In the teaching and learning area, the model has designers and leaders put focus on those strategies that invite and affirm diversity. Concretely, this might look like teaching active learning as disrupting traditional power dynamics in STEM classrooms, and how future faculty might see the tools of active learning not simply as "engagement" or breaking up lecture, but as moves toward transformation through equity.

In addition to the teaching and learning area, the model has designers and leaders consider ways to recreate professionalization and socialization to academic roles within their programs and departments. As the data show, teaching and learning is strongly impacted by these other areas of training and mentorship. The old model of research as priority, mentoring as informal support of those who look and sound similar, and lack resources for diverse graduate students and postdocs undercuts the effort to train learner-centered instructors who will teach to diverse students. Leaders of future faculty programs will need to work with the various offices and department leaders to tear down these traditional notions of professionalization and build new structures that hold equity central to their efforts. It might mean that mentoring is transformed. It might also ask PIs to reimagine the role of the lab in student and postdoc training. We have already seen some of this transformation of research, as evidenced in IRACDA programs like SPIRES. The key to this model's success is the wider dissemination of these ideas and strategies.

The model also has designers look to and change the institutional cultures that create barriers to future faculty programs and participant access to them. First, institutions will need to work both to remove barriers like scheduling and crediting. Program designers and leaders will need to meet with administrators from the registrar's office, curriculum committees, department leadership, and career and student support offices to increase access to future faculty programs and help programs build capacity. They will need to create processes and possibly offices to recruit and support diverse graduate students and postdocs to participate in these programs. Funding might play a key role in this: studies have found that graduate students of color struggle with financial stability, particularly in the later years of their doctorate. Offering stipends to participate in future faculty programs in the fourth or fifth year could not only help these students to finish their degrees but will also give them pedagogical skills for the job market.

Assessing the Model

Programs have a role in assessing the model based on their experiences with it. After using the model to design or redesign their programs, they should ask if the model is helping them meet their equity goals. Dewsbury (2017) and von Vacano et al. (2022) identified some key features of inclusive teaching (dialogue, student voice, interventions that affect student experience directly) that can be used in the assessment process.

Leaders of assessment projects might also look at institutional changes, if they took place, how they were enacted, and if the model needs to consider institutional barriers differently. The model proposes that institutions consider capacity building as a central effort to invite more and diverse participation. Institutions that develop programs using this model will want to assess the model in this area. Programs should also examine professionalization functions of the model and if changes made based on reimagining academic roles and the training needed to secure careers are feasible. For example, programs may find that unless there is significant buy-in from researchers at an institution, transforming the ways graduate students and postdocs are socialized might be too challenging. But this may add another dimension to the model because researchers may have new insights to add to the discussion that will enhance its transformative power.

Future Research

Future research should continue to examine future faculty programs in STEM to consider their transformative potential, both in the experiences of undergraduates and in the training and development of graduate students and postdocs. Such studies should include critical perspectives, which are key to diverse student persistence and success. In terms of the proposed program development model, three areas of future research seem promising: studies focused on the model as informing new program design or existing program redesign, those interested in the model's effectiveness and efficacy, and studies concerned with the model's application in non-STEM programs.

Program Development

Priorities for future research include studies that will test this model of program development against other future faculty programs and even use it to develop new programs. Many institutions still do not have a future faculty program so it may be useful for organizational advocacy and program design. Using a model of program development may be effective in garnering early support for new programs because leadership will be able to both recognize the layers involved in program success but also advocate internally using a tested model. Furthermore, future studies should explore the ways such a model might be disseminated through national networks like POD or CIRTL, and how professionals in the field might be professionalized through these networks using this model.

Model Effectiveness and Efficacy

One of the limitations of this study was the sample size, so future research should seek to test the program development model for its effectiveness in program development or redesign. Research should explore whether the layers of the model adequately describe the teaching and learning, professionalization and socialization, and organizational levels of future faculty programs. It would also study the principles, processes, and strategies as a set of dynamics (Table 2) and examine their application in different contexts. Research should also explore the model's efficacy in training future faculty in STEM in learner-centered pedagogies. For example, do junior faculty who have completed a program that follows this model teach more inclusively? Do they retain a larger percentage of their

HME students? And do these programs attract and retain more HME graduate students to complete their training?

Applications to non-STEM fields

Future researchers might also explore the applicability of the model to non-STEM fields. One leader in this study noted that STEM was late to embrace evidence-based teaching, which meant that graduates in the humanities, for example, were expected to enter as junior faculty members as "fully formed educators." Conversely, junior faculty members in STEM fields have been at best "emerging." Research should apply the model to other non-STEM programs and examine the fit: for example, do non-STEM graduate students need a reimagining of their graduate training? Is mentorship as important in non-STEM fields? We know the teaching is very similar, but it is possible that non-STEM fields might have a more nuanced or experienced approach to learner-centered pedagogies. Additionally, there might be interest in understanding if this model is simply a possible solution to STEM's problems in HME retention, or if the model might be used just as effectively in English or anthropology.

Conclusion

This study sought to learn more about the curriculum, professional development, and organizational contexts of STEM-oriented future faculty programs. Three programs were chosen for a comparative qualitative study that gathered data through semi-structured interviews with leaders and analysis of program documents. Programs were already known to be effective, as they were practicing program evaluation, were known in national networks as successful, and were engaging in scholarly work on their programs. Still, programs were relatively small and were not available at every doctoral-granting institution. Clearly, there were some barriers to their creation and growth.

Simultaneously, undergraduate education in STEM fields has consistently lost students to other majors because of poor teaching and cutthroat classroom culture. Historically marginalized and excluded students have felt the brunt of these dynamics and have left STEM fields at alarming rates. Not surprisingly, efforts to transform classroom experiences of undergraduates have focused on faculty, who are not always receptive to learner-centered pedagogies like active learning and inclusive teaching (strategies known to have positive effects for these learners). As Borrego and Henderson (2014) asserted,

> It has become painfully clear that higher education change processes are at least as complex as the pedagogies and learning processes they week to promote. STEM education change agents, leaders, and researchers are just beginning to view change as a scholarly endeavor that can and should be informed by the research literature. (p. 221)

Some scholars, most notably Bryan Dewsbury (2017), suggested that professional development of faculty should not be the focus of organizational and departmental efforts; rather, future faculty programs are the most effective sites of training in learner-centered teaching. This assertion was based on two pieces of information: 1. future faculty are still learners themselves and more likely to approach professional development with learners' minds; 2. they are early in developing their teaching practice, so more likely to hold learner-centered pedagogies as fundamental to their practice. These are powerful reasons to locate efforts in future faculty programs, but there are also powerful forces that constrain them: a culture of tension between research and teaching, which holds that research is king; the shape and texture of socialization and professionalization in STEM graduate programs, which often lacks training and mentoring in teaching, and organizational barriers that prevent access and completion.

In order to address these challenges, this study proposes a new program development model for STEM-focused future faculty programs that seeks to address both the constraints on programs, their participants, and their leaders and also imagine a future of programs that not only train the next generation of STEM educators in learner-centered teaching but also as change agents in trained to pull HME students back into active, inclusive, welcoming STEM classrooms.

To be clear, this effort is of the highest importance. STEM fields are the source of cures for disease, solutions to climate change, innovations that improve peoples' lives, and sources of knowledge about our planet and beyond. Students of color in STEM were found to be extremely creative and innovative in their research, so we as a planet need these students (and the faculty they will grow to be) to stay in STEM. Furthermore, this effort is not just geared toward the current generation, but the students of the students of the students. As one program leader shared, "if you train one researcher, you've affected one person and maybe a handful of people they train in their lab; but if you train a scientist to teach, you affect thousands of future researchers and teachers." Most importantly, the findings revealed a new STEM faculty professional development model that critically re-imagines constructivist teaching and learning, deconstructed socialization, organizational advocacy, and iterative assessment in supporting diverse graduate and postdoctoral scholar success.

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APPENDIX A: INTERVIEW QUESTIONS

Program Manager Demographic/Background

1. Please describe your role at your institution. How long have you been in your role?
2. Please describe the future faculty program you manage (the program components, faculty and staff involvement, participants, and any other important features).

   Pedagogical Components

3. What teaching strategies and theories are included or help guide the FFP curriculum?
4. Please describe any active learning and/or inclusive teaching that is included in the curriculum.
   a. How are participants trained in learner-centered pedagogies?
5. Are there DEI elements or components?
   a. How are participants acquainted with issues of power and privilege in pedagogical practices?

Professional Development Processes

6. What is your approach to professional development of graduate students and/or postdocs? Does this differ from professional development of faculty?
7. How is the program (and program elements) assessed? How are impact and "effectiveness" evaluated?

Organizational Contexts

8. What organizational and institutional supports and barriers impact the future faculty curriculum for graduate students and postdocs?
9. What is on the horizon for your program? Are there changes coming in curriculum, processes, staffing, or institutional context?
10. What materials should I analyze to get a fuller understanding of your program?

Supervisor Demographic/Background

1. Please describe your role at the institution and your relationship to the future faculty program.

Professional Development Processes

2. How does the future faculty program support STEM educational processes?
3. What incentives and support encourage participation?

Pedagogical Components

4. What pedagogical approaches and professional development processes are utilized in the program?

Organizational Contexts

5. What organizational and institutional supports and barriers impact the future faculty program?
6. How is the program (and program elements) assessed? How are impact and "effectiveness" evaluated?
7. What is on the horizon for the program? Are there changes coming in curriculum, processes, staffing, or institutional context?

APPENDIX B: REQUEST FOR PARTICIPATION EMAIL

Hello, my name is Amy Forester. I work at Oregon Health & Science University and I am a doctoral student at Portland State University. I am doing a study of STEM-focused future faculty programs, specifically their curriculum and their institutional contexts. I would like to invite you to take part in a research study. Before you decide, we would like you to understand why the research is being done and what it would involve for you. I am therefore providing you with the following information. Please take time to read it carefully and discuss it with others if you wish. When you have read the information provided, please reach out to me if you have questions. Take time to decide whether or not you wish to take part. Thank you for taking the time to read this.

Purpose of the study

This study seeks to explore ways in which STEM future faculty programs train their participants in learner-centered pedagogies and other forms of evidence-based teaching. STEM fields have traditionally shown resistance to teaching professional development efforts aimed at student centeredness (Miller et al., 2021), so it is important to have a STEM focus in this study. This study also seeks to learn more about the organizational and institutional dynamics that shape future faculty program curriculum and participation.

What we would like you to do

After you have read this email and have had a few days to think about it, I will reach back out to you by email to see if you wish to take part. If you consent, I will ask about scheduling two interviews with you, one for 75 minutes and another for 30 minutes.

These interviews will take place over Zoom on a day and time that are convenient for you. They will be recorded.

Why have I been chosen?

You are a program manager of a STEM-focused future faculty program that requires 30+ hours of engagement, practices program evaluation, and participates in scholarly activity. We hope to learn more about these kinds of successful programs in order to consider how they might be replicated at other institutions.

Do I have to take part?

It is up to you to decide whether or not to take part. We will explain the study verbally and in the study information sheet. If you do decide to take part you will be asked to give consent. To do this you will be asked to reply to an email from us to confirm that you are willing to take part. Participation in this study is entirely voluntary and you are free to refuse to take part or to withdraw from the study at any time without having to give a reason.

What are the possible benefits of taking part?

The findings of the study will be shared with participating programs and might benefit them.

Confidentiality

Any information collected during the course of the study will be maintained on a confidential basis and access will be restricted to people conducting the study. Your name will not be disclosed, nor will details of your answers be given to anyone. With your permission, the Zoom interviews with the researcher will be recorded and transcribed. The transcripts will then be examined to ensure that all of the important information has been captured. The transcripts will not contain your name or any information about you that would allow you to be identified. The only people who will have access to the transcripts are the researchers. Some of your comments may be included in a report on the study, but these will be completely anonymous.

What will happen to the results of the research study?

The overall findings of the study may be published in an education or science education journal, but these will not mention you in any way. If you would like to receive information about the results of the study, please let us know, and we will forward a summary of the findings to you at the end of the study.

Who has designed and reviewed the study?

I have designed this study for my dissertation, so it has been approved by my dissertation committee. It has also been approved by Portland State University's Institutional Review Board.

Concerns or complaints about the research

If you have a concern about any aspect of this study, you should ask to speak to Amy Forester who will do her best to answer your questions. If you remain unhappy and wish to complain formally, you can do this by contacting Dr. Christine Cress who is the project leader.

Thank you for taking the time to read this information sheet and considering taking part.

To obtain further information

If you have any questions about this research, please contact Amy Forester (afore2@pdx.edu) who will be happy to discuss the study or answer any questions you may have.

Consent Statement

I have had the chance to read and think about the information in this form. I have asked any questions I have, and I can make a decision about my participation. I understand that I can ask additional questions anytime while I take part in the research.

- ☐ I agree to take part in this study

- ☐ I do not agree to take part in this study

APPENDIX C: STUDY INFORMATION SHEET

Thank you for considering participation in this study. The following is information provided to help you in your decision to participate and to know the extent of participation.

Purpose of the study

This study seeks to explore ways in which STEM future faculty programs train their participants in learner-centered pedagogies and other forms of evidence-based teaching. STEM fields have traditionally shown resistance to teaching professional development efforts aimed at student centeredness (Miller et al., 2021), so it is important to have a STEM focus in this study. This study also seeks to learn more about the organizational and institutional dynamics that shape future faculty program curriculum and participation.

Participation

Data collection at each site will involve these items:

1. Collection of materials (course syllabi, workshop descriptions, handouts) from your public-facing website and those you choose to make available to the researcher. The researcher does not seek to collect every piece of documentary material, only those which help answer the research questions.
2. Interviews: program managers/leaders will be interviewed twice: one 60-75-minute interview and one 30-minute interview. Their supervisors or managers will be interviewed once for 30-40 minutes. All interviews will take place on Zoom and will be recorded.