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GENERATING AND SUSTAINING MEANINGFUL PROFESSIONAL DEVELOPMENT OPPORTUNITIES FOR GRADUATE TEACHING ASSISTANTS FACILITATING COURSE-BASED UNDERGRADUATE RESEARCH EXPERIENCES IN THE BIOLOGICAL SCIENCES

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Dean of the Graduate School

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Amie M. Kern

2022

Dedication

This work is dedicated to my mother, Selinda Kern. She is forever in my heart and thoughts.

May the pain be low,

The pleasure be high,

And may the ransom be paid.

-Selinda Kern

And may the ransom be paid.

-Amie Kern

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by

AMIE M. KERN, B.S.

DISSERTATION

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

Department of Biological Sciences

THE UNIVERSITY OF TEXAS AT EL PASO

May 2022

Acknowledgments

Graduate school has been an arduous journey, fraught with many personal struggles to finish my formal education and complete my doctoral degree. Despite everything, I can appreciate the fact that nothing worth having comes easy. Though a difficult journey, it is one I am truly grateful to have taken because of the community I found with likeminded individuals and the life knowledge I gained through my experiences. I would like to acknowledge the supportive figures in my life who have helped make this achievement possible.

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Secondly, I would like to acknowledge my committee members for taking on this project without any hesitation and for all of their continued sound advice. Collectively, they have helped me to rebuild much of the confidence I had lost and have shown me that there is nothing to fear from them; they, too, are only there to help me find my way. I am extremely lucky to have found this group of patient mentors.

It is important that I also thank my family and all of my friends who I consider family. Shannon, Matt, Sarah, and Ethan, who are always championing the path of change I have taken. Leigh and Paul, who have always been there for me and believed in me, even when I gave them reason not to. And finally, I want to acknowledge Jose, whose continuous love, patience, and support makes every day a little easier. Thank you.

Abstract

Current national efforts to reform postsecondary laboratory education have emphasized the incorporation of authentic research opportunities into science, technology, engineering, and mathematics (STEM) curricula. Within the last decade, course-based undergraduate research experiences (CUREs) have emerged as a viable mechanism to achieve this goal. Evidence within the biology education literature suggests that student engagement in CUREs has the potential to positively impact their development of scientific inquiry and process skills, content knowledge, and affect in the domain. While the majority of studies have focused on student outcomes, few studies have examined instructor outcomes in CURE learning environments. This is especially true for graduate teaching assistants (GTAs), who are frequently tasked with teaching CUREs, yet who often receive little, if any, professional development (PD) to improve teaching skills that are vital to this type of instruction. This body of research addresses this need by: (i) identifying the core tenets of CURE GTA professional development initiatives; (ii) creating, implementing, and evaluating a novel professional development program for GTAs to improve CURE instructional outcomes at The University of Texas at El Paso (UTEP); and (iii) assessing the scalability and sustainability of said program as a model for GTA PD nationwide.

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List of Abbreviations

STEM - Science, Technology, Engineering, and Mathematics

CURE - Course-Based Undergraduate Research Experience

TAs - Teaching Assistants

GTAs - Graduate Teaching Assistants

PD - Professional Development

PCK - Pedagogical Content Knowledge

BioTAP - Biology Teaching Assistant Project

ABLE - The Association for Biology Laboratory Education

SABER - The Society for the Advancement of Biology Education Research

AAAS - American Association for the Advancement of Science

ABLE - Association for Biology Laboratory Education

CURE - Course-based Undergraduate Research Experience

CV - Curriculum Vitae

IRB - Institutional Review Board

NASEM - National Academies of Sciences, Engineering, and Medicine

NRC - National Research Council

PCAST - President's Council of Advisors on Science and Technology

SEA-PHAGES - Science Education Alliance-Phage Hunters Advancing Genomics and Evolutionary Science

URE - Undergraduate Research Experience

Chapter 1: Introduction

Re-Envisioning the Landscape of STEM Laboratory Education

Recent national reports indicate that undergraduate enrollment has continued to increase exponentially, with more than 70% of high school graduates electing to attend college, and more than 30% of those individuals electing to pursue a STEM degree (McFarland et al., 2018). For those undergraduate STEM majors, subdisciplines within the biological sciences have consistently been the most popular fields, attracting as many as 11% of students at some point within six years of entering postsecondary education (Chen, 2013). Despite the large number of students interested in biology, only a fraction (< 50%) of those students earns a degree in the field (McFarland et al., 2018). Since the early 1970s, this continued and systematic loss of trainees from STEM disciplines has led to the United States ranking 20th among all nations in the proportion of college students who earn degrees in STEM (Kuenzi, 2008). As concerns rise that universities are losing too many students early along their academic journey, resolving the issue of how to retain these undergraduate STEM majors has become a matter of critical importance across the United States (PCAST, 2012).

For many students majoring in STEM, retention drops during the first series of core subject courses (Kendall et al., 2014). Indeed, poor student performance in these early courses can often predict whether a student will continue in a given STEM major throughout their college career (Seymour & Hewitt, 1999; Kendall et al., 2014). Additionally, several other factors have been noted to contribute to high levels of attrition in STEM programs. These factors include student perceptions that the classroom culture is hostile and/or unsupportive, lack of students' "habits of the mind," and misalignment between what students' expectations are and the reality of the situation (Conley, 2003; Ost, 2010; Rask, 2010). Untrained "habits of the mind," for instance, are often seen in less experienced students who have not yet developed appropriate study habits, or metacognitive skills, to support effective learning in STEM (Costa & Kallick, 2008).

Given the influence of the aforementioned factors on student retention in STEM, it is perhaps unsurprising that numerous calls to action have emerged within the last decade (National Research Council, 2003; AAAS, 2010; PCAST, 2012). For instance, reports, such as the *BIO2010* initiative published by the National Research Council, have expressed the urgent need to improve STEM education on a national level (National Research Council, 2003). Recommended curriculum improvements would engage undergraduate students through active learning exercises designed to develop interdisciplinary thinking and foster communication skills. Education reform efforts are necessary, as many research biologists are still being educated in preparation for the biology of the past, not that of the present or future (National Research Council, 2003). Moreover, there is a crucial need to rebuild the capital of American brainpower if we are to meet the demands of tomorrow, with economic forecasts pointing to a need for approximately one million additional STEM graduates by the end of 2022 (Schwab, 1960; PCAST, 2012).

Such "calls to action" are not novel. In the biological sciences, national movements to reform STEM education have been ongoing since the 1983 report, *A Nation at Risk*, brought widespread attention to achievement in mathematics and science, insisting that biology faculty develop coordinated plans to improve instruction (National Commission on Excellence in Education, 1983). Notably, science faculty have been called upon to bridge the gap between theory and praxis in order to attract more undergraduates to STEM fields (Holt et al., 1969; National Commission on Excellence in Education, 1983; Project Kaleidoscope, 2002; National Research Council, 2003). Importantly, the common goal of all of these reform efforts has been to develop and implement science instruction that better reflects what scientists *actually* do (Spell et al., 2014).

Engaging students in authentic scientific practices is one posited mechanism for achieving this instructional goal, thereby increasing student success and persistence in STEM (Spell et al., 2014). An ideal means of engaging students in such practices is through traditional undergraduate research experiences (UREs), where a student works on a research project under the apprenticeship of a faculty member in that faculty's laboratory (Seymour et al., 2004; Lopatto, 2006). Conclusions from a growing body of literature have demonstrated the positive impacts of these types of faculty-mentored research experiences on students' persistence in STEM, understanding of disciplinary-level content knowledge, self-efficacy, and development of critical thinking skills (Seymour et al., 2004; Lopatto, 2006). Nearly all recommendations for reforming laboratory curriculum include incorporation of authentic research practices, as they are significant to students' personal and professional growth (Holt et al., 1969; Sundberg et al., 2005).

Despite strong evidence supporting the need to make authentic research experiences more widely available to students, numerous challenges related to faculty time, funding, and availability of space often present as obstacles to achieving that goal (National Academies of Sciences, Engineering, and Medicine, 2017). For instance, because most UREs operate on an apprenticeship-type structure, where an undergraduate works one-on-one with a more experienced researcher, there are often very limited opportunities for student to participate in a traditional research experience (PCAST, 2012; Rodenbusch et al., 2016). The possibility for recruitment and selection bias can likewise make securing a research internship difficult for many students, allowing only a small group of high-achieving or research-interested students to participate (Bangera & Brownell, 2014). Resolving these and other logistical issues universities face in creating broad-reaching opportunities for undergraduates to immerse themselves in research-driven experiences has become the focus of current reform efforts within the postsecondary biology education community (Auchincloss et al., 2014; Spell et al., 2014).

CURES as a Model for Laboratory Instruction in the Biological Sciences

The majority of STEM reform efforts have been directed toward instructional practices in the lecture environment, although most introductory STEM courses likewise typically include a laboratory component (Velasco et al., 2016). Because laboratory course topics often parallel those of lecture topics, the long-held consensus has been that they serve the practical purpose of reinforcing or demonstrating a theoretical discussion presented in class in a manner that ideally sparks student curiosity in the subject (Holt et al., 1969). Despite this claim, the structure of traditional laboratory curricula has often resulted in students expecting exploration of laboratory topics to occur in the same lock-step progression as they are accustomed to in their lecture courses (Weaver et al., 2008).

More specifically, research indicates that traditional laboratory curricula frequently define and describe a topic in only narrow terms, and laboratory procedures are relayed with immutable, "cookbook" directions that are expected to produce a predetermined outcome (Domin, 1999; Weaver et al., 2008). As alluded to previously, conventional laboratory exercises were intended to engage students and increase scientific interest through experimentation (Schwab, 1960). However, laboratories with such predictable structure have been shown to foster an unrealistic view of science and do not accurately relay how scientific research is performed (Bencze & Hodson, 1999; Rahm et al., 2003; National Research Council, 2006).

In contrast, incorporation of authentic research experiences into the introductory biology laboratory course environment would greatly augment the number of students exposed to the excitement of discovery and the rigor of the scientific process (Spell et al., 2014). One proposed solution to the obstacles surrounding authentic research experience availability is the course-based undergraduate research experience (CURE). A CURE is a type of laboratory course in which students address a research question or problem that is of interest to the broader community with an outcome that is unknown both to the students and to the instructor (Domin, 1999; Buck et al., 2008; Weaver et al., 2008; Auchincloss et al., 2014). One of the primary functions of CUREs is to make research experiences available at scale, rather than to a select a few individuals who seek out research internships or who are handpicked by faculty (Auchincloss et al., 2014; Bangera & Brownell, 2014). It is important to note that, as part of this process, CURE students are viewed as legitimate participants in scientific research because their actions contribute to achievement of research goals (Corwin et al., 2015).

Students who have participated in CUREs have demonstrated academic gains similar to those exhibited by students who partake in independent research experiences (Auchincloss et al., 2014; Spell et al., 2014; Corwin et al., 2015). Indeed, positive student outcomes associated with CURE participation are numerous and include an increased interest in scientific research as well as gains in research skills, self-efficacy, and persistence in the sciences (Lopatto, 2007; Harrison et al., 2011; Brownell et al., 2012; Olimpo et al., 2016). Research conducted by Rodenbusch et al. (2016) on the Freshman Research Initiative at the University of Texas at Austin revealed, for instance, that participation in CUREs increased students' likelihood of graduating with any degree within six years of starting the program by more than 16% relative to a matched comparison group. Work conducted by Bangera and Brownell (2014) showcased similar positive student outcomes, leading the authors to advocate that universities mandate CUREs as introductory laboratory experiences for all students. With their vast potential, CUREs may truly be the answer to the national call for widespread involvement of undergraduate students in authentic research (AAAS, 2010; Bangera & Brownell, 2014; Rodenbusch et al., 2016).

In comparable fashion, CUREs have been cited to have a positive impact on the educators involved in such opportunities, including the promotion of a broadened interest in teaching and possibilities for establishing stronger rapport with students (Shortlidge et al., 2015). While this is the case, it is likely unsurprising that there are also many documented challenges to instructing CUREs. For example, research conducted by Shortlidge et al. (2015) identified seven prevalent obstacles reported by CURE instructors. These obstacles included: (1) time and work investment; (2) the expanded role of the instructor; (3) overcoming student resistance; (4) the uncertain nature of scientific research (teaching patience through iteration); (5) lack of background in scientific research (inexperience with project design) ; (6) the ability of instructors and students to deal with the unknown; and (7) an unwillingness for instructors to invest the necessary time and effort to enhance their teaching practice.

Course observation data further reveal that CURE instructors need to be a mentor, guide, and/or counselor to students and often have more face-to-face time with students than they would typically have in a non-CURE course (Shortlidge et al., 2017). Collectively, these findings suggest that CURE instructors have a wide range of additional teaching responsibilities beyond those required for leading a traditional laboratory course. CURE facilitators are often expected to make instructional decisions, including how information should be presented, which concepts should be emphasized, and how to evaluate student work (Ryker & McConnell, 2014). Many instructors have recounted challenges keeping track of and consulting on numerous simultaneous projects, some of which pushed the bounds of their expertise (Shortlidge et al., 2015).

Because students in CUREs are working on real research problems with unknown answers, the experiments may not always go as planned, and research projects may venture into unknown territory for both the students and the instructor(s) (Shortlidge et al., 2015). As such, student resistance may also become an issue, as some students may not want to be challenged to think on their own without being told what to do or given answers (Shortlidge et al., 2015). Even skilled scientists have reported difficulty in designing an experiment in an area that is not in their specific domain of expertise (Shortlidge et al., 2016).

Considering the Role of the CURE Instructor

Recent studies suggest that attention to the mentor-mentee (i.e., teacher-student) relationship within CURE spaces can potentially address some of the above-mentioned concerns. In their work on developing and evaluating a mentor training program for CURE undergraduate teaching assistants (UTAs), for instance, Moy et al. (2019) sought to examine how UTA engagement in the program impacted their ability to connect with mentees in their classrooms as well as their overall perceptions of program effectiveness. Data indicated that UTAs felt the program enhanced their pedagogical content knowledge and professional skills (e.g., building trust with students). Likewise, UTAs reported increased confidence in their role as instructor. Collectively, these findings suggest that structured mentorship programs can serve as a productive model for CURE TA preparation.

As the importance of engaging students in CUREs continues to become more mainstream in undergraduate STEM education, preparing individuals to effectively facilitate such courses becomes increasingly more relevant. CURE instruction varies between university, and by department, but it is always intended to be facilitated by a "senior researcher" (Auchincloss et al., 2014). Faculty members, postdoctoral employees, and student TAs are all deemed as appropriate individuals to fill the position, as they are all thought of as possessing the expertise needed to execute the role in an efficient and purposeful manner. This leaves a wide range of individuals with varying levels of research proficiency in charge of facilitating CUREs.

Effective CURE instruction may depend on where in this spectrum of research experience an instructor falls. It can be challenging for novice researchers to facilitate CUREs, for instance, due to the dynamic nature of CURE learning environments (Moy et al., 2019). Numerous calls have been made for universities to mandate CUREs as introductory laboratory courses, yet the ability to implement them may be limited by the variation in instructor effectiveness alluded to here and elsewhere in the literature (Bangera & Brownell, 2014).

Variation in the types of instructors charged with CURE facilitation has led to speculations regarding the attributes of a successful CURE instructor. It has been suggested by Shortlidge et al. (2015) that if adequate structural support for CUREs is provided, the challenges to developing and implementing CUREs may be surmountable. I contend that such action is crucial, as it is well-known that quality teaching can enhance student learning and is a key predictor of student success (Darling-Hammond, 1997). Kendall et al.'s (2014) study of biology TAs showed, for instance, that student perceptions of TA teaching effectiveness were directly related to the instructor's teaching techniques and their ability to develop rapport with their students.

CURE instructors are substantial contributors to the educational mission of their universities, yet there is a lack of empirical data on how to best prepare them for their teaching roles in this context (Reeves et al., 2016). The data that do exist, such as the aforementioned studies by Shortlidge and colleagues (e.g., Shortlidge et al., 2015), largely attend to the role faculty have in facilitating CUREs. Yet, research indicates that the development of such pedagogical knowledge and basic teaching skills for TAs in biology — including those facilitating CUREs — has long been undervalued, and often ignored, in favor of research development (Nyquist et al., 1997; Luft et al., 2004; Austin et al., 2009; Schussler et al., 2015). Thus, providing CURE TAs with opportunities to develop the instructional expertise needed to maximize undergraduate student learning outcomes should be a priority for the universities that employ them (Nyquist et al., 1997).

The Need for Instructor Professional Development in CUREs

Teaching assistants are playing an increasingly important role in undergraduate education, especially in STEM disciplines (Moy et al., 2019). Rushin et al. (1997) reported that 97% of surveyed graduate schools used TAs in some form of undergraduate instruction. Biology TAs, more specifically, were found to be responsible for 91% of laboratory courses at research institutions, and TAs in Colleges of Science were often noted to have more personal contact with first-year STEM students than most faculty members within the college (Rushin et al., 1997; Sundberg et al., 2005).

It is therefore clear that there is a direct need for effective and continued pedagogical advancement in undergraduate STEM laboratory education (Sirum & Madigan, 2010). TAs within the STEM disciplines receive minimal pedagogical support, training, and/or continuous mentoring during their graduate tenure (Luft et al., 2004; Tanner & Allen, 2006; Sirum & Madigan, 2010; Kendall et al., 2014); yet these are the same individuals whose first teaching experience is often providing instruction for an undergraduate laboratory course. Research indicates that nearly 85% of TAs report not feeling adequately trained for their teaching assignments (Russell, 2009). In the biological sciences, this is particularly concerning considering that 88% of biology TAs are assigned to teach introductory laboratory courses, which may be the first and last STEM laboratory experience for many students (Reeves et al., 2016). Better teacher training could provide a powerful impact on undergraduate student learning at many colleges and universities, especially within the context of CUREs (Reeves et al., 2016; Zehnder, 2016). Unless TAs are given the proper training and resources to teach effectively, introductory-level biology students may not reap the full benefits of CURE activities (Ryker & McConnell, 2014).

In a broader sense, it is important that one recognizes that instruction (whether in CUREs or elsewhere) is a complex, multifaceted phenomenon that involves interactions between instructors, students, and instructional materials (Cohen & Ball, 1999). Instructor capacity is widely viewed as a critical element of good teaching and is imperative to providing quality education with "the capacity to produce worthwhile and substantial learning" (Cohen & Ball, 1999). Arguments provided by Cohen and Ball (1999) contend that reform efforts are typically focused on instructor outcomes or course descriptions with the aim of enhanced student learning, but not both simultaneously. The authors argue, instead, that instructional reform requires considering all interactions that take place between the instructional materials, the instructor, and the students.

As a case in point, incorporating one's research into a CURE can be especially challenging for instructors who have little teaching experience or who have not engaged in various kinds of active, high-impact teaching practices (Labov et al., 2019). To address the most common barriers to implementing authentic research experiences, instructors need time for professional and pedagogical skills development (Spell et al., 2014). Traditionally, PD initiatives offered to TAs has been focused on logistics and classroom management with little formal discussion of effective pedagogical practices or feedback regarding teaching practices (Luft et al., 2004; DeChenne et al., 2012; Hardré & Burris, 2012). Yet, the pedagogical skills necessary for teaching are not instinctual and can be acquired only through more structured training and educational programs (Foley, 1974; Remesh, 2013). Importantly, research has demonstrated that participation in such initiatives (e.g., a course on pedagogy) can positively influence a graduate student's learning and attitudes toward teaching (Zehnder, 2016).

In a more holistic sense, previous research notes the value of developing instructor capacity through teacher training that includes elements of effective lecture design, assessment design, classroom management, diversity in the classroom, and active-learning strategies (Velasco et al., 2016; Zehnder, 2016). While researchers have offered a few suggestions for successful program characteristics, prior studies have failed to identify the central tenets of effective CURE TA PD (e.g., McDonald et al., 2019; Moy et al., 2019). In keeping with the literature, the structure of such PD should be content-focused, promote active learning, be provided for a sustained time period, and utilize collective participation (Desimone & Garet, 2015).

A review of the K-12 literature suggests that teachers with deep understanding of subject matter content, who are also proficient in pedagogical content knowledge, were more successful in promoting student engagement and improving student learning than their counterparts who did not possess those attributes (Darling-Hammond, 1997; Malcom, 2008). Likewise, effective CURE TA PD should promote a deep understanding of the subject matter content, along with training in the best pedagogical practices to assist TAs in engaging with students around CURE instructional activities in a manner that fosters student learning and success (Shulman, 1986; Avery & Reeve, 2013). To these ends, the most effective CURE TA PD programs will promote the use of CURE-specific instructional strategies as benchmarks for guiding change in teaching practices (Avery & Reeve, 2013).

Overview of the Following Research Chapters

The following chapters are a collection of manuscripts which address the following aims: (i) identify the core tenets of CURE TA professional development initiatives (Chapter 2); (ii) create, implement, and evaluate a novel professional development program for GTAs to improve CURE instructional outcomes at The University of Texas at El Paso (UTEP) (Chapter 3); and (iii) assess the scalability and sustainability of said program as a model for TA PD nationwide

(Chapter 4). All manuscripts include IRB-approved human subjects' data, and each has been submitted and/or is currently being prepared for publication.

Chapter 2: Preparing Teaching Assistants to Facilitate Course-based Undergraduate Research Experiences (CUREs) in the Biological Sciences: A Call to Action

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Introduction

Undergraduate Research

The 1983 report, *A Nation at Risk*, brought widespread attention to low and inequitable rates of achievement in mathematics and science, insisting that biology faculty, in particular, develop coordinated plans to improve instruction (American Association for the Advancement of Science [AAAS], 2010; Chen, 2013). Since the report, national calls for education reform have escalated. Notably, science faculty have been tasked with bridging the gap between research and teaching in order to attract more undergraduates to STEM fields (National Research Council [NRC], 2003). The common goal of reform efforts in this area has been to develop and implement science instruction that better reflects what scientists *actually* do (Spell et al., 2014).

One means to address this aim is to involve students in undergraduate research experiences (UREs). Prior studies indicate that students who participate in UREs advance in their analytical and critical thinking skills (Seymour et al., 2004; Lopatto & Tobias, 2010), display increased academic achievement and retention (Russell et al., 2007; Cole & Espinoza, 2008), and are more likely to engage in graduate studies (Lopatto, 2004; Seymour et al., 2004; Russell et al., 2007). UREs centered on faculty-mentored research projects, specifically, impact a student's ability to "think like a scientist," with reported gains in collaboration and communication, as well as improvements in student affective outcomes such as interest in science and development of a science identity, being observed (Seymour et al., 2004; Hunter et al., 2007; Thiry et al., 2011). For these reasons, participants of UREs are often better prepared to advance in science fields than their peers (Thiry et al., 2011).

Despite strong evidence supporting the need to engage more students in research, there are numerous challenges to achieving that goal, including limits on faculty time, funding, and the resources needed to offer UREs (National Academies of Sciences, Engineering, and Medicine [NASEM], 2017). Because UREs traditionally engage students through one-on-one apprenticeships, opportunities are frequently confined by a finite number of research faculty at a given institution and limited space within each researcher's laboratory (PCAST, 2012; Rodenbusch et al., 2016). Thus, there is inequitable access to opportunities for undergraduates to participate in UREs, as certain groups of students may be more likely to seek out research apprenticeships or to be handpicked by faculty to join their labs (Auchincloss et al., 2014; Bangera & Brownell, 2014). Furthermore, some faculty may be hesitant to take on undergraduate students because training them may result in lower research productivity than the training of a graduate student (Chopin, 2002; Prunuske et al., 2013; Morales et al., 2017). More broadly, recent studies highlight that, in a mentored research experience, students can have negative interactions with their research mentors, be those faculty or other trainees (Cooper et al., 2019; Limeri et al., 2019; Tuma et al., 2021). Although undergraduate research is largely appreciated as a high-impact practice in most STEM disciplines (Lopatto, 2010; Russell et al., 2010; O'Donnell et al., 2015; Lanning & Brown, 2019), there are clearly questions regarding access to and quality of UREs.

Course-based Undergraduate Research Experiences

An emergent solution to some of the drawbacks and limitations of apprenticeship-style undergraduate research opportunities is course-based undergraduate research experiences (CUREs). A CURE is a course that is generally integrated into laboratory curriculum, where students address a research question or problem that is of interest to the broader community with outcomes that are unknown both to the students and to the instructor (Domin, 1999; Weaver et al,. 2008; Auchincloss et al., 2014). Like many inquiry-based courses, CUREs engage students in essential research elements such as using scientific practices, collaboration, and iteration. However, CUREs are distinct from inquiry courses in that they are not only designed to induce the aforementioned outcomes, but they additionally provide the opportunity for broadly relevant and novel discovery—occasionally even resulting in student authorship on scientific publications (Auchincloss et al., 2014). This critical design element of CUREs is not missed by students. Indeed, students have reported perceiving that their CURE experiences are akin to what it would be like to conduct research in faculty-run labs (Rowland et al., 2016; Goodwin et al., 2021). However, in order to truly engage students in scientific research in the course setting, it is important that CURE instructors actively foster the premise of students as legitimate participants in scientific research and ensure their actions are contributing to achieving research goals (Corwin et al., 2015a).

Like students who partake in UREs, students who have participated in CUREs have demonstrated numerous cognitive and affective gains (Corwin et al., 2015a; Shapiro et al., 2015). These include an increased interest in scientific research as well as gains in research skills, scientific literacy, scientific identity, emotional ownership, self-efficacy, and persistence in the sciences (Harrison et al., 2011; Brownell et al., 2015; Olimpo et al., 2016; Indorf et al., 2019; Cooper et al., 2020; Esparza et al., 2020; Ramírez-Lugo et al., 2021). Participating in CUREs in introductory biology courses, in particular, can result in an increased likelihood of students graduating on time and ending up engaging in apprenticeship-based research experiences, compared to matched students enrolled in traditional introductory biology laboratory courses (Rodenbusch et al., 2016; Indorf et al., 2019). CUREs may be particularly impactful for students traditionally underrepresented in STEM fields (Ing et al., 2021) and for students who enter a CURE with lower academic preparedness than their peers (Shapiro et al., 2015; Ing et al., 2021). With their vast potential, CUREs present a viable answer to the national call for widespread involvement of undergraduate students in research (AAAS, 2010; Bangera & Brownell, 2014) and are being broadly promoted as essential to the undergraduate experience (NASEM, 2015).

CURE Instruction

The CURE model can be embedded into classrooms in a countless number of ways. Implementation of CUREs, like any evidence-based pedagogy, is highly context-dependent, and CUREs vary across universities, departments, and instructors (see Science Education Research Center, 2021, for examples; Olimpo & Kern, 2021). There are two major categories of CUREs - the 'network' CURE and the independent CURE (Shortlidge et al., 2016). In a network CURE, faculty often attend a training along with individuals at other institutions to implement a CURE based on an already-established structure (e.g., the Genomics Education Project (Hark et al., 2011); SEA-PHAGES (Jordan et al., 2014); Tiny Earth (Hurley et al., 2021). In contrast, independent CUREs typically emerge from a faculty member's research interests or program (e.g., Fisher et al., 2018; D'Arcy et al., 2019).

The extant literature on CUREs has largely focused on student outcomes and descriptions of CURE curricula (e.g., Olimpo et al., 2016; Rodenbusch et al., 2016; McDonald et al., 2019), with less attention paid to the central characteristics of CURE instruction (e.g., Esparza et al., 2020). Although there is an assumption that the CURE model is facilitated by "senior researchers" (Auchincloss et al., 2014; Rodenbusch et al., 2016), this task has increasingly fallen to graduate teaching assistants and other instructional faculty as the inclusion of CUREs in STEM laboratory curricula has continued to increase. Faculty CURE instructors of both network and independent CUREs have reported that effective CURE instruction necessitates sufficient and relevant research experience on the part of the instructor (Shortlidge et al., 2016; Shortlidge et al., 2017). Consequently, it may be challenging for novice researchers to facilitate CUREs due to the dynamic and unpredictable nature of a CURE learning environment (Shortlidge et al., 2016; Heim & Holt, 2019; Moy et al., 2019). As the goal of engaging students in CUREs continues to become more mainstream in undergraduate STEM education, ensuring the preparedness of individuals to facilitate such courses becomes increasingly more relevant.

While the specific design and context of each CURE will inherently lead to variance in student outcomes, such outcomes will also inevitably be impacted by instructor quality and effectiveness. This could be particularly true at the introductory level, where laboratory classes are frequently taught by multiple instructors, who likely vary widely in their capacity to effectively teach a CURE and/or their buy-in to the CURE model (Esparza et al., 2020; Goodwin et al., 2021).

Graduate Teaching Assistants

The majority of CURE research and advocacy to date neglects the salient and prevalent reality that graduate student teaching assistants (TAs) are often the primary instructors of the introductory laboratory sections where CUREs are or will be embedded. Data collected from 65 institutions demonstrate that TAs are responsible for teaching the bulk of the introductory biology labs at 71% of comprehensive universities and at 91% of research universities (Sundberg et al., 2005). Graduate students are clearly a key factor in undergraduate science education, yet the prominent role of TAs, in particular in undergraduate biology education, is rarely addressed or acknowledged (Gardner & Jones, 2011).

Many practitioners and researchers have advocated for more holistic and robust professional development for TAs than what currently exists (Schussler et al., 2015; Connolly et al., 2016; Reeves et al., 2016; Feldon et al., 2017; Connolly et al., 2018). Brief trainings, such as the common graduate student professional development "boot camp," are not effective (Feldon et al., 2017), and it is well documented that, in many cases, TAs receive minimal pedagogical support, training, and/or continuous mentoring during their graduate tenure (Rushin et al., 1997; Austin, 2002; Luft et al., 2004; Tanner & Allen, 2006; Gardner & Jones, 2011; Kendall & Schussler, 2012; Schussler et al., 2015; Goodwin et al., 2018). Thus, it is not surprising that nearly 85% of TAs feel inadequately prepared for their teaching assignments (Russell, 2009). Compounding the impacts of having underprepared TAs is the fact that the majority of biology TAs (88%) are assigned to teach introductory laboratory courses (Schussler et al., 2015). We know that the majority of STEM students leave STEM majors after introductory courses (PCAST, 2012); therefore, these courses may be the first and last science laboratory experience undergraduates have during their academic careers. Consequently, it is of critical importance that these courses are taught by prepared instructors (Reeves et al., 2016). Unless TAs are given the proper training and resources to teach effectively, introductory-level biology students may not reap the benefits of revised curricula like CUREs (Ryker & McConnell, 2014). Indeed, attention to TA training could have a powerful impact on undergraduate student learning at many colleges and universities, especially within the context of CUREs (Reeves et al., 2016; Zehnder, 2016; Esparza et al., 2020; Goodwin et al., 2021).

In a broad sense, it is important to recognize that instruction (whether in CUREs or elsewhere) is a complex, multifaceted phenomenon (Cohen & Ball, 1999). Instructor capacity is widely viewed as a critical element of good teaching and is imperative to providing quality education with "the capacity to produce worthwhile and substantial learning" (Cohen & Ball, 1999). Cohen and Ball argue that instructional reform requires considering all interactions that take place between the instructional materials, the instructor, and the students. A review of the K-12 literature suggests that instructors with deep understanding of subject matter content, who are also proficient in pedagogical content knowledge, were more successful in promoting student engagement and improving student learning (Darling-Hammond & Bransford, 2007; Malcom, 2008). As stated previously, faculty often teach CUREs based on their personal research and/or pedagogical interests (Shortlidge et al., 2016; Shortlidge et al., 2017). Thus, faculty teaching CUREs may have both a deep understanding of the subject matter (the research topic) and pedagogical content knowledge, resulting in the necessary instructor capacity to teach a CURE. However, if CUREs are taught by TAs, they may not be experts in research, experienced in evidenced-based teaching, or even have an interest in teaching. In some cases, teaching can simply present a financial means for TAs to pursue their graduate research (Golde & Dore, 2001; Austin, 2002). These factors, in turn, could likewise be detrimental to the TA's students' experiences in the CURE.

CURE-specific Challenges

Course-based undergraduate research experiences introduce an added complication to any conversation of effective instruction, in that their focus is not just to convey content, but rather to provide a research experience. Even for Ph.D.-level instructors, incorporating research into a course can be challenging if their research experience is not similar to that in the CURE, they have little formal teaching experience, and/or they have not engaged in evidence-based teaching practices (Shortlidge et al., 2016).

A documented challenge for TAs who have taught discovery-based chemistry and biology labs is empowering students to take control of their own learning—TAs tend to have difficulty allowing students to have autonomy in figuring out answers on their own and tend to intervene and control the situation rather than allow their students to experience failure (Kurdziel et al., 2003; Luft et al., 2004; Gormally et al., 2016). This is potentially problematic for TAs, given that faculty who teach CUREs believe one must "have the ability to deal with uncertainty" and have a "background in research" in order to deal with the unpredictability of science and to troubleshoot unexpected issues (Shortlidge et al., 2016). This idea was directly reflected in a study on one institution's TA-taught CUREs, in that TAs reported that their lack of expertise in the research topic was a challenge (Heim & Holt, 2019). The same study reported that TAs felt that the most prevalent issue with CUREs was the unpreparedness of undergraduates to participate in a research-based curriculum. This preconception, alongside the desire of TAs to demonstrate their knowledge to students and the fear of receiving negative evaluations from frustrated students (e.g., Kurdziel et al., 2003; Gormally et al., 2016), all present salient barriers to TAs teaching CUREs. Further, if a TA is not interested in the research topic and creates a negative or complacent classroom climate as a result, it could impact student outcomes (O'neal et al., 2007). Undergraduates see TAs as less knowledgeable than faculty in traditional (cookbook) lab settings (Kendall & Schussler, 2012), and this perception could be exacerbated if a TA is challenged by the level of research and teaching expertise necessary to teach a CURE.

Finally, undergraduates in CUREs are expected to collaborate with the instructor and their peers (Auchincloss et al., 2014). Thus, the interactions in a CURE should be intentionally facilitated and may require more of a mentor-mentee relationship than a traditional teacher-student relationship. For faculty, this can be a benefit of teaching CUREs (Shortlidge et al., 2016). While graduate students can be effective mentors to undergraduate researchers in individual lab settings (e.g., Aikens et al., 2016), to our knowledge, their capacity to serve as CURE research mentors has not been investigated.

Professional Development

To address the barriers to scaffolding research experiences within the structure of a course, instructors need time to engage in professional development (PD) (Spell et al., 2014). As previously described, most TA PD initiatives have little formal discussion of effective pedagogical practices or feedback regarding these practices (Luft et al., 2004, DeChenne et al., 2015; Goodwin et al., 2018). The skills necessary for teaching are not simply intuitive and need to be acquired through more structured training and educational programs (Foley, 1974). Research has demonstrated that participation in such PD initiatives (e.g., a pedagogy course) can positively influence TAs' learning and attitudes toward teaching (Zehnder, 2016). While researchers have offered a few suggestions for successful program characteristics, prior studies have failed to identify the central tenets of effective CURE TA PD (Spell et al., 2014; Rodenbusch et al., 2016; McDonald et al., 2019; Moy et al., 2019). In keeping with the literature on teacher training, the structure of such PD should be content-focused, promote active learning, be provided for a sustained time period, highlight diversity, and utilize collective participation (Desimone & Garet, 2015; Zehnder, 2016).

Reeves et al. (2016) put forth a framework that outlines desirable TA PD outcomes: cognition (includes knowledge, attitudes, and beliefs about teaching); teaching practices (i.e., instructional practices); and undergraduate student outcomes. Facilitators of CURE TA PD initiatives would do well to attend to these outcomes as a means to assist TAs in engaging with students around CURE instructional activities in a manner that fosters student learning and success (Shulman, 1986; Avery & Reeve, 2013). To these ends, the most effective CURE TA PD programs will promote the use of CURE-specific instructional strategies as benchmarks for guiding change in teaching practices (Avery & Reeve, 2013).

Graduate training is frequently focused on the graduate student journey from novice to expert researcher, although many other aspects of scholarship are paramount to becoming a successful academic (Austin, 2002). CUREs, in particular, may present an unparalleled opportunity for graduate students to gain exposure to multiple aspects of faculty positions. Many graduate students may be relatively novice researchers as well as teachers, but recent research shows that graduate student investment into both activities can be mutually synergistic (Feldon et al., 2011; Shortlidge & Eddy, 2018). Having the chance to teach CUREs can be a valuable and timely opportunity for TAs to develop both research and teaching skills. Reflecting this idea, the chemistry education research community has recently advocated for "CURE leadership as a training platform for future faculty" (Cascella & Jez, 2018).

Perspectives Regarding the Necessary Components of CURE TA PD

As STEM education continues to integrate the CURE model into undergraduate curricula, the critical, systems-level issues discussed above must be considered when heeding calls for developing CUREs, especially when faculty are not the course lead. Given the relative dearth of literature on CURE TA PD, we designed two exploratory mini-investigations to capture the perspectives of CURE TAs and CURE designers/facilitators regarding essential elements of CURE TA PD. We contend that this course of action is critical in providing objective (rather than anecdotal) support for the recommendations made at the end of this article. By collating the outcomes of the few existing studies on CURE TAs and this current exploratory work, we can provide support for recommendations for advancing CURE TA PD efforts across a diversity of institutional environments. Our intent is to increase readers' awareness of the value and importance of CURE TA PD and encourage conversation among CURE TA PD facilitators.

Mini-Investigation #1: CURE TA Perspectives

To date, research on the perceptions of TAs who teach CUREs has been limited to single instructional contexts (Heim & Holt, 2019; Moy et al., 2019; Goodwin et al., 2021). Thus, we sought to expand our collective knowledge of the experiences and perceptions of CURE TAs across the range of contexts in which they teach. Specifically, we explored the following guiding questions:

1. *Do CURE TAs perceive that they are facilitating essential CURE elements in their courses?*
2. *What are the classroom environments and structures in which TAs teach CUREs?*
3. *How do the benefits that graduate TAs describe compare to those reported by faculty CURE instructors?*

4. *How do the challenges that graduate TAs describe compare to those reported by faculty CURE instructors?*

Investigatory Approach:

Through targeted and snowball sampling, we (E.E.S. and E.G.) recruited 22 CURE TAs from 15 institutions for online interviews. Interviews were held via Skype and lasted approximately 50 minutes. Interviews were semi-structured, allowing the interviewer to follow up on responses while progressing through a set of predetermined questions (Cohen & Crabtree, 2006). The interview protocol was iteratively developed by two researchers (E.E.S. and E.G.), and interview questions were piloted with non-participant TAs prior to interviews. Questions were designed to gain an understanding of the context in which each TA teaches their CURE and to understand the attitudes and beliefs of TAs regarding teaching a CURE. Interviews were transcribed verbatim (Rev.com). To analyze interview data, we used open coding to inductively create a codebook (E.E.S. and E.G.), which listed codes that captured specific perceptions and experiences described by the study participants. We then used the codebook to code each interview transcript (E.G.). Results from this coding process are reported as key themes. This study was approved by the Portland State University Institutional Review Board (IRB #174246).

Observations and Findings:

TAs Believe that They Facilitate CURE Elements in their Classrooms

To facilitate a CURE, instructors need to scaffold specific elements of research into their curriculum (Auchincloss et al., 2014). The interview data suggest that TAs generally believe that they robustly facilitate the critical CURE elements of Collaboration, Iteration, and Relevant Discovery in their classrooms, with the most variability observed with respect to facilitating Iteration. For example, while several TAs described students having numerous opportunities to repeat experiments when initial trials did not work out or to confirm initial experimental results (Iteration), some TAs found that iteration was difficult to scaffold in their class:

> *"Iteration, in particular, is one of the hard ones to fit in [the CURE], because the experiments that a lot of the students did involve growth. That's one thing you can't really speed up."*

While a few TAs expressed uncertainty about the Relevant Discovery involved in the CURE, the majority were aware that their students were addressing novel and relevant research questions. One TA explained:

> *"We actually told [the students] in the beginning of the course—and this is one incentive to actually do novel things—we told [students] if they actually address something that's novel and that work actually… leads to a paper, [the students] would be coauthors on a paper."*

Our data indicate that TAs believe they are facilitating these critical CURE elements within their classroom, though in some instances, TAs find these elements to be limited or are unsure of their presence within the curriculum. These results highlight the need for further studies collecting empirical data on how and how frequently these elements are facilitated in TA-led CUREs.

The Classroom Environments and Structures in which TAs Teach CUREs Vary

Even in our limited sample, CURE TAs are operating across a range of contexts in both lower-division and upper-division courses. We had representation of TAs in our study with experience teaching both network CUREs (e.g., SEA-PHAGES) (n = 6) and independent CUREs developed 'in-house' that aligned with a faculty member's research program and/or that had local relevance to the community (n = 16). Nearly one-third of participants (n = 6) were involved in designing the project or course themselves and, therefore, were already highly invested in the curriculum. We were surprised to learn that half of the TAs (n = 11) were teaching alongside faculty instructors who had a full-time presence in the classroom, and some (n = 6) were supported by additional graduate or undergraduate teaching/learning assistants in the same classroom. The majority (n = 17) of TAs in our sample were non-randomly selected to teach the CURE and had either volunteered or were selected to teach based on merit or past research/instructional experiences. Few (n = 5) reported participating in extended mandatory training for the CURE, such as weekly TA meetings or a TA training course. The breadth of these instructional contexts highlights one of the potential challenges when designing appropriate PD for TAs of CUREs—there is unlikely to be any single uniform solution for the wide range of expectations individual programs have for their TAs.

The following quote illustrates how a TA taught a CURE alongside a faculty member as it was first being implemented at their institution:

> *"I'm not sure how they're [currently] recruiting TAs for that class. But the reason I was selected [to TA] was I had heard what [the CURE faculty instructor's] goal was when they were starting this… Her approach to teaching science in a very hands-on manner, that's something that was not done at the university. But I believe personally [that teaching philosophy] is really important for students. So, when I heard that she was about to implement [the CURE], I talked to her and we completely got along."*

These interviews were conducted in 2017, when CUREs were gaining momentum. Within the past five years, there has been a notable increase in published research studies on CUREs. Thus, it is likely that there has also been an increase in research-based curricula across institutions and courses. TAs being selected to teach CUREs with full-time faculty support is probably not an accurate model for how most TAs will teach CUREs.

TAs Perceive that CUREs Offer Many Benefits for Undergraduates and for Themselves

Participants perceived many benefits from CUREs, both for the undergraduates in the course as well as for themselves as instructors. Over half of the participants (*n* = 14) discussed feeing that CUREs help undergraduates build important scientific skills (e.g., use of scientific tools; experimental design; data analysis; independent problem-solving). Many (*n* = 9) felt it was important for undergraduates to experience research and that, through a CURE, undergraduates could better understand the nature of science (*n* = 11) as well as gain career clarification (*n* = 11).

TAs additionally perceived several direct benefits for themselves while teaching CUREs. Mirroring findings that faculty instructors reported regarding how facilitating CUREs allowed them to connect their research and teaching activities (Shortlidge et al., 2016), many TAs discussed how the CURE helped them hone their own skills related to research (*n* = 10), mentorship (*n* = 5), communication (*n* = 11), and evidence-based teaching (*n* = 15). Like faculty (Shortlidge et al., 2016), TAs also described developing a better relationship with their students compared to teaching other labs (*n* = 15) and felt increased excitement around teaching a CURE (*n* = 14). As one TA explained:

> *"[Teaching the CURE] keeps me on my toes and it makes me better at explaining scientific processes and how experiments work. Doing things this way really keeps me humble and keeps me in check to make sure that I know [the research] and can push that knowledge to someone else… It makes me happy to just sit there with this group [of students], and we're working on this thing as a team, and it makes me happy to see them learning. They light up when it works and they figure things out."*

TAs also experienced some benefits from teaching CUREs that are unique to graduate student status as early-career scientists. A few TAs reported that teaching CUREs offered increased collaboration and mentorship with faculty teaching the CUREs, and they felt that this could positively impact their professional trajectories. Further, roughly a third (n = 7) of our study sample reported that the experience of teaching a CURE was instrumental in solidifying their career goals by confirming whether they were interested in teaching as a major part of their career:

> *"[Teaching the CURE] has changed the way that I view research and writing, but it has also solidified the interest in me to teach, to follow that career path... Education has been in the realm of possibility, and teaching this course really solidified that as: 'Now, that's a career path that I really do want to follow.'"*

While most TAs in our study had generally positive views of CUREs as a whole, a few participants (n = 3) were pessimistic about teaching in general, unenthusiastic about the CURE, and/or expressed attitudes that hinted that the TA may not be fostering an ideal lab environment. For example:

> *"The most important thing [for students in a CURE to learn] is how to work with someone they don't like… I know I was sometimes frustrating as a TA, I'm sure. So having to work with a TA that is not necessarily the best, having a boss or a superior that you don't always get along with or agree with is probably a good life skill."*

As evidenced by even our small sample, there will inevitably be a spectrum of attitudes, perceptions, and buy-in from TAs who teach CUREs.

CURE TAs Struggle with Time Investment and the Unpredictability of Research

Faculty instructors of CUREs recommend that successful CURE instructors need to be able to deal with uncertainty, to have a background in scientific research, and to be willing to invest time and effort into teaching the CURE (Shortlidge et al., 2016). All three of these themes were cited as challenges by TAs in our study population. For example, TAs recognized that they struggled with the unpredictability of research (n = 12) and (less frequently) explained that this was particularly challenging given their own lack of research expertise (n = 4):

> *"Typically, you [face unexpected challenges in research] individually, or with a couple of people in your lab group—not with a bunch of people who are looking to you as an expert. You're trying to make sure that [students] think of you as an expert, but also convey to them that you don't really know what's going on. You're trying to figure it out just as much as they are. There's a fine balance between being able to show them your naivety in an obstacle that may come up while still conveying some semblance of understanding and responsibility… [and show] that you're not just there flailing about."*

Faculty instructors of CUREs also described logistical challenges in teaching the CURE (Shortlidge et al., 2016), which was rarely a theme that directly came up for TAs. However, there was some indication that a TA's lack of research expertise could contribute to logistical issues for faculty instructors and lab coordinators, as TAs occasionally had difficulty in controlling the scope of their students' research questions:

> *"Even though my faculty advisors were not thrilled with me saying this, I told students to shoot for the moon [in designing their research questions] and we'll rein it back from there... I gave them zero constraints to begin with, and I love how that turned out. My*

faculty advisor was not as thrilled, especially when I gave them the supplies list of stuff that we needed. But I didn't know a whole lot about the [experiments students were suggesting], so I didn't want to give them restrictions, when I'm not much more of an expert than [the students] are."

Another major challenge for TAs teaching CUREs was that they felt there was a larger time investment compared to being a TA for other classes (n = 14). One TA described a particularly extreme scenario:

"I would not [recommend teaching this CURE to other TAs]. Run screaming and put in your 20 hours a week that the university asks you to do if you are lucky enough to get a TA position. Don't apply for one [like the CURE], that doesn't pay more but requires a ton of your time, and true dedication, and really knowing what's going on, and you can't call in a substitute. So no, I can't think of even one other grad student that I would ever recommend to teach this."

These challenges align with some of the obstacles explained previously by both faculty and graduate students (e.g., time; unpredictably of research) as well as the recommendations they make for skills needed to teach a CURE, such as research skills (Shortlidge et al., 2016; Shortlidge et al., 2017; Heim & Holt, 2019).

Mini-Investigation #2: CURE Facilitator Perspectives on TA PD

While limited research has been conducted on faculty and TA perspectives of facilitating CUREs (e.g., Shortlidge et al., 2016; Heim & Holt, 2019; Goodwin et al., 2021), no studies, to the best of our knowledge, have examined CURE instructors' beliefs about the potential elements of CURE TA PD. To address this concern, and as a complement to *Mini-Investigation #1*, we (A.M.K. and J.T.O.) conducted a quantitative study to examine the following questions:

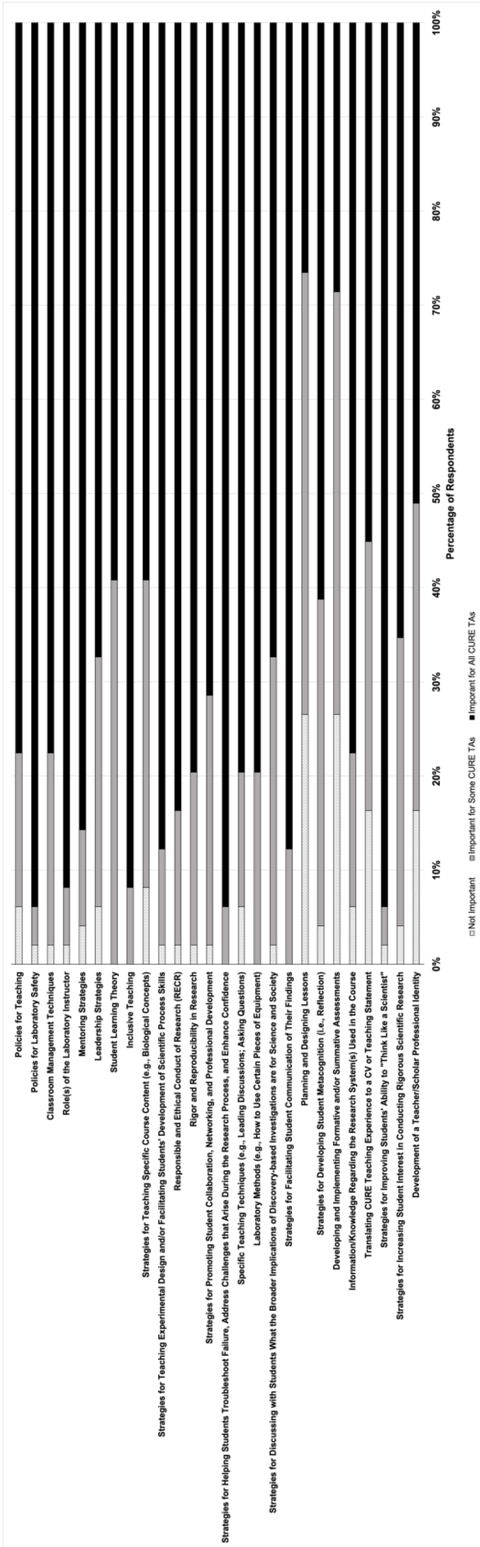
1. *To what extent do CURE facilitators believe potential tenets of TA PD, as cited in the literature, are appropriate for inclusion in PD for all CURE TAs, some CURE TAs, or no CURE TAs?*
2. *Which tenets do CURE facilitators rank as the top three most important elements to include in CURE TA PD?*

Investigatory Approach:

Purposeful sampling was employed to recruit CURE facilitators (i.e., non-TA instructors) (N = 49) in attendance at the 2019 Association for Biology Laboratory Education (ABLE) and Society for the Advancement of Biology Education Research (SABER) annual meetings. Specifically, participants were asked to complete a brief survey in which they indicated whether 26 items related to teaching and learning should be included as part of professional development opportunities for all TAs facilitating CUREs, some TAs facilitating CUREs, or no TAs facilitating CUREs. These items were informed by the literature (including many studies cited in this article), and evidence of face validity was collected through administration of the survey to [under]graduate students and CURE colleagues in the researchers' (A.M.K. and J.T.O.) department.

Observations and Findings:

Frequency analyses were employed to examine patterns in participant responses, which are represented in Figure 2.1.



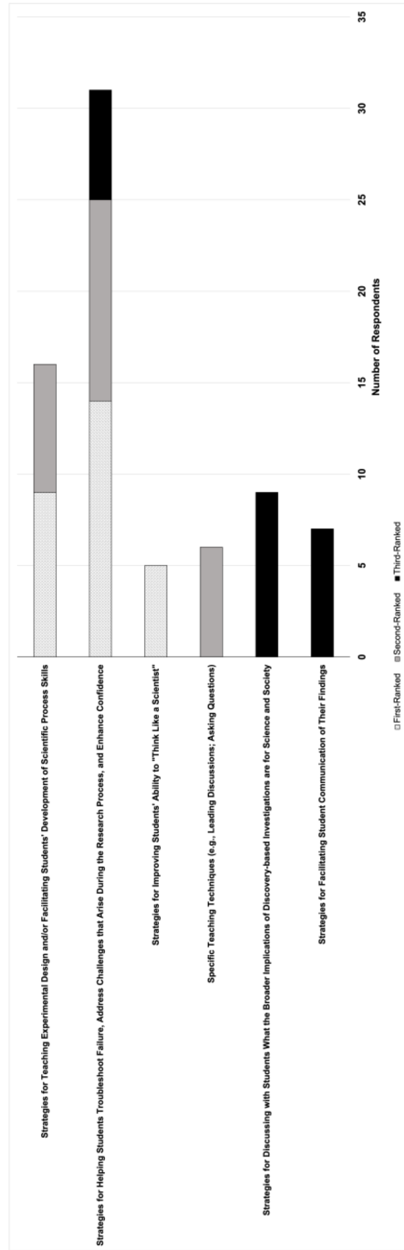


Figure 2.1. Faculty perceptions of the value of various education topics to CURE TA PD (left) and their nominations for the top three most essential topics (right).

These data suggest that a diverse suite of elements ranging from more generalized laboratory and pedagogical practices (e.g., lab safety; inclusive teaching) to more contextualized instructional elements of CUREs (e.g., facilitating collaboration; iteration) were viewed as being necessary for all CURE TAs. Other items — such as developing students' metacognitive abilities and aiding TAs in adopting strategies for discussing with students what the broader implications of discovery-based investigations are for science and society — were believed to be less essential (Figure 2.1). While the reasons for these choices are unclear, we find it interesting that they are contrary to previously reported benefits of student engagement in CUREs (e.g., Auchincloss et al., 2014; Dahlberg et al., 2019; McCabe & Olimpo, 2020). Furthermore, items related to the professional growth of the CURE TAs themselves (rather than their students) (e.g., planning and designing lessons; translating CURE teaching experience to a CV or teaching statement) were frequently ranked as being essential for only some CURE TAs rather than all CURE TAs, suggesting an area for future discussion and investigation.

When asked to select the three most important components that they felt should be included in CURE TA PD, the majority of participants (n = 31) indicated strategies for troubleshooting and addressing challenges that arise during the research process. This was followed by strategies for teaching experimental design and/or facilitating students' development of scientific process skills (n = 16 participants) (Figure 2.1). To a lesser degree, respondents also selected strategies for discussing with students the broader relevancy of their work (n = 9), strategies for facilitating student communication of their findings (n = 7), specific teaching techniques (n = 6), and strategies for improving students' ability to "think like a scientist" (n = 5) as being among their top three choices.

Collectively, these findings corroborate earlier work in the field (e.g., Heim & Holt, 2019) and closely mirror the outcomes described in the first mini-investigation.

Recommendations For Core Elements of CURE TA Professional Development

In consideration of the above findings and the previously reported outcomes summarized herein, we propose that CURE TA PD initiatives should encompass three major elements: (i) enhancement of research and teaching acumen; (ii) development of effective and inclusive mentoring practices; and (iii) identification and understanding of the factors that make CUREs a unique laboratory experience. Each of these elements are described below.

Research and Teaching Acumen

Researchers suggest that CUREs should be facilitated by instructors who have spent time conducting research themselves (Auchincloss et al., 2014; Shortlidge et al., 2016), as this may alleviate expressed challenges with teaching CUREs. Reflective of the central tenets of CUREs (e.g., student engagement in scientific practices, discovery, and iteration), facilitators should also possess an adequate understanding of experimental design principles in order to guide students through the process of creating and/or executing experiments (Heim & Holt, 2019). This might be accomplished by using microteaching approaches in which TAs are tasked with modeling the experimentation process, involving TAs in outlining and discussing central elements of that process (e.g., *sensu* Harwood, 2004), and/or facilitating open conversation about how the TAs themselves engage in research (and how this might translate, practically, into the CURE environment). While arguably less realistic, it might also be possible for CURE facilitators to intentionally recruit TAs who are more advanced in their program of study — for instance, those individuals who have already successfully defended their thesis/dissertation proposal and, therefore, have more intimate familiarity with the research process.

A TA's research training and expertise could be anywhere along the novice to expert spectrum; therefore, it would be wise to engage all CURE instructors in some version of the research itself prior to teaching the CURE. This is likely particularly crucial if a TA is both a novice researcher *and* a novice teacher. One suggestion would be to pair novice TAs with a more senior TA and/or structure TA PD such that novice TAs can shadow more experienced TAs or instructors.

Respondents from both mini-investigations valued the importance of "considering the classroom environment." This finding supports previous studies that have emphasized instructor capacity as a critical element of good teaching (Cohen & Ball, 1999). Professional development that includes giving graduate students a chance to practice relevant evidence-based and inclusive teaching practices could have a powerful impact on TAs' teaching self-efficacy, attitudes toward teaching, and continued use of evidence-based practices (DeChenne et al., 2015; Connolly et al., 2016; Reeves et al., 2016; Goodwin et al., 2018).

Some faculty who develop their own CUREs see those courses as a means to highlight and embody their identity as a teacher-researcher (Shortlidge et al., 2016). Similarly, PD for CURE TAs should offer opportunities for the TAs to reflect on the intersection between research and teaching, so as to normalize and create an integrated framework for facilitating CUREs. Given that graduate students in *Mini-Investigation #1* reported that CUREs offered opportunities for them to improve their teaching, research, and mentorship skills, CUREs may be a unique mechanism for training future faculty to embody a more holistic scholarship (e.g., Boyer, 1990), which has been advocated for over the recent decades (Austin, 2002; Gardner & Jones, 2011).

We further contend that TAs could benefit from CURE PD intentionally designed to curate a mindset that embraces the uncertain nature of research. If CURE TAs are expecting that not everything will inherently go according to plan, and that those experiences can be turned into a teaching opportunity, they will be better equipped to practice this skill in real time. Teaching the need for patience throughout the scientific process and normalizing failure as a part of scientific research are important aspects of CURE instruction that can potentially increase undergraduate student buy-in to the authenticity of the CURE (Corwin et al., 2015a; Gin et al., 2018; Goodwin et al., 2021). Providing TAs with the pedagogical skills necessary to effectively aid students in iteration/troubleshooting and educating TAs about how to troubleshoot themselves is arguably critical in advancing the established research agenda for the course (Corwin et al., 2018; Gin et al., 2018).

Effective and Inclusive Mentoring

Comments pertaining to mentoring and mentorship were replete throughout our dataset and have been cited previously in the literature with respect to teaching CUREs (Shortlidge et al., 2016; Heim & Holt, 2019), highlighting the belief that instructors in CURE contexts have a more substantial role than solely that of a deliverer of information and lab moderator. The need to adopt multiple roles can be intimidating to TAs, as illustrated by TAs in *Mini-Investigation #1*. Informal conversations with respondents in *Mini-Investigation #2* suggested that CURE TA PD should address components of effective mentorship and project management, much like how a principal investigator might lead their own lab group and manage different projects (Dolan, 2016). In addition to identifying and demonstrating effective mentoring strategies (e.g., through role-play), we encourage CURE TA PD facilitators to make use of existing instruments (e.g., Mentoring Competency Assessment (Fleming et al., 2013)) to engage TAs in exploring their own perceived strengths and weaknesses in this area. There are a number of resources within the *Entering Mentoring* curriculum (Center for the Improvement of Mentored Experiences in Research, 2021) that provide realistic case studies that could likewise be used in TA CURE PD. Further, developing in-house case studies for TAs to engage with that are rooted in the institution's context and, perhaps, the CURE content could give TAs practice in handing situations before they arise.

Given that an explicit goal of CUREs is to make research experiences more accessible and equitable for undergraduates (Bangera & Brownell, 2014), intentional TA PD in inclusive pedagogy will be critical for all students to feel like they are 'doing science.' Part of this effort will be making this aspect of why we do CUREs explicit to TAs (more below) and by reinforcing this intentionality by integrating practical inclusive teaching skills into the PD (e.g., Dewsbury & Brame, 2019).

Knowledge of What Makes a CURE Unique

CUREs offer students a unique platform to engage in research that addresses real-world biological problems. Consequently, for those TAs with limited (or no) experience teaching CUREs, we advise PD facilitators to explicitly discuss what distinguishes a CURE from other forms of laboratory instruction (e.g., traditional labs; inquiry-based labs). This might be accomplished by first informing TAs that they are responsible for a research-driven course and asking them to discuss what they feel this opportunity entails relative to the laboratory experiences that they likely engaged in as a student. TAs might also be prompted to consider how CUREs mirror (or not) apprenticeship-style research training. With this framing in mind, PD facilitators could then more formally introduce the dimensions of CUREs (Auchincloss et al., 2014) and lead TAs into a discussion of how they anticipate facilitating such a course. As a training or assessment exercise, TA PD could include TAs completing a modified LCAS for instructors (Corwin et al., 2015b) or, at minimum, reading the survey items as a group to gain an idea of the specific actions that they could be taking in the classroom to facilitate CURE elements. CURE TAs might be expected to read journal articles from the literature regarding why CUREs are being implemented nationally and to learn about some of the potential outcomes from CUREs. Therefore, those facilitating CURE TA PD should also be relatively familiar with the CURE literature base in order to lead a journal club or similar opportunities for CURE TAs. Lastly, PD facilitators may wish to take advantage of published tools (e.g., Olimpo & Kern, 2021) to aid the TAs in articulating the research and pedagogical goals of the CURE as well as documenting the course activities and assessments that align to each of the five dimensions of CUREs (Auchincloss et al., 2014).

Concluding Remarks

Since their advent, CUREs have increasingly been incorporated into STEM curricula nationwide. While there are now countless studies documenting the impact of CUREs on students' academic and professional growth (e.g., Olimpo et al., 2016; Peteroy-Kelly et al., 2017; Connors et al., 2021), substantially less attention has been given to instructors in this same context. This is especially true for TAs, who are largely responsible for facilitating laboratory coursework, including at both the introductory and advanced levels (Sundberg et al., 2005; Schussler et al., 2015). Accordingly, this article reflects our strong advocacy for the development and implementation of intentional CURE TA PD opportunities and likewise offers guiding recommendations for those interested in meeting this need.

We recognize that CURE TA PD efforts will not emerge as "one-size-fits-all" solutions to preparing graduate teaching assistants, nor do we believe that they should be. The data from *Mini-Investigation #1* highlights that, even in a small sample, CUREs are implemented in a variety of contexts and that each context will require nuanced PD. However, we encourage creators, facilitators, and evaluators of CURE TA PD initiatives to consider the following: What level of training and experience do the TAs facilitating the CURE have with respect to research, teaching, and mentoring? What facets of TA PD are essential to include for the particular CURE, and which have a supporting role? What makes those facets essential (i.e., why are they necessary and valuable)? What form will the PD require, and when will it be implemented?

Establishing targeted goals and feasible PD activities will ideally mitigate reported concerns regarding the lack of time and expanded role of the instructor in CUREs. Furthermore, soliciting routine formative feedback from both the TAs and their students can serve to enhance PD quality and provide constructive commentary on TA praxis. There are a number of ways to collect such feedback (e.g., minute papers; metacognitive prompts administered to TAs during prep meetings), and the methods used should reflect the intention. There are likewise mechanisms by which one can intentionally and systematically assess the outcomes of their

CURE (for more, see Corwin et al., 2015a; Shortlidge & Brownell, 2016), which may or may not be a goal for the institution or faculty member leading the initiative.

Although CURE TA PD approaches will inherently reflect the context in which they were created, a concerted and explicit effort among members of the biology education community to attend to this element of CURE implementation will enable said approaches to be adaptable for use across institutions. Establishing partnerships with stakeholders in Centers for Teaching and Learning and Graduate Schools can expedite this process, ostensibly leading to the genesis of new knowledge and techniques for promoting TAs' effectiveness in the CURE classroom. Creating a community of practice and culture around CURE TA PD will likewise foster sustainable advances for all parties involved beyond the immediate environment of the PD itself.

Chapter 3: Empowering Graduate Teaching Assistants to Facilitate CUREs: Outcomes of the SMART CUREs Professional Development Intervention

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Introduction

CUREs as an Instructional Model for Undergraduate Biology Laboratory Education

National efforts to reform science, technology, engineering, and mathematics (STEM) laboratory curricula have historically emphasized the importance of integrating authentic research practices into the learning environment, as these "real-world" experiences have been shown to have a significant impact on students' personal and professional growth (Holt et al., 1969; Sundberg et al., 2005). Within the last decade, course-based undergraduate research experiences (CUREs) have been posited to be an inclusive mechanism to meet this need (Bangera & Brownell, 2014). Numerous studies have highlighted the positive influence of biology CUREs on student attitudes, researcher self-efficacy, science identity development, and experimental design competency (Jordan et al., 2014; Spell et al., 2014; Olimpo et al., 2016; Esparza et al., 2020). Faculty who facilitate CUREs have also reported benefits with respect to more direct interaction with students, connecting research and teaching goals, and recruiting students to their research laboratories (Shortlidge et al., 2015; Shortlidge et al., 2016).

More specifically, CUREs are a type of laboratory course in which students address a research question or problem that is of interest to the broader community with an outcome that is unknown both to the students and to the instructor (Auchincloss et al., 2014). While no singular definition exists, CUREs share five common core features, which distinguish them from traditional laboratory coursework. These features include: (1) utilization of scientific practice; (2) collaboration; (3) examination of broadly relevant topics; (4) scientific discovery; and (5) iteration as part of the scientific process (Auchincloss et al., 2014). One of the primary functions of CUREs is to make research experiences available at scale, rather than to a select few individuals who seek out research internships or who are selected by faculty (Auchincloss et al., 2014; Bangera & Brownell, 2014). It is important to note that, as part of this process, CURE students are viewed as legitimate participants in scientific research because their actions contribute to achievement of research goals (Corwin et al., 2015). As is customary in traditional UREs, CUREs engage students in authentic scientific practices through an apprenticeship-type structure that allows them to work on laboratory research projects under the direction of a faculty member (Seymour et al., 2004; Lopatto, 2006).

As alluded to above, students who have participated in CUREs have demonstrated academic gains similar to those exhibited by students who partake in independent research experiences (Auchincloss et al., 2014; Spell et al., 2014; Corwin et al., 2015).Conclusions from a growing body of literature have shown a number of positive student outcomes to be associated with these types of faculty-mentored research experiences such as an understanding of disciplinary-level content knowledge and development of critical thinking skills (Seymour et al., 2004; Lopatto, 2006). Importantly, engagement in CUREs has also been identified as a positive predictor of retention in the sciences. Research conducted by Rodenbusch et al. (2016) on the Freshman Research Initiative at the University of Texas at Austin revealed, for instance, that participation in CUREs increased students' likelihood of graduating with any degree within six years of starting the program by more than 16% relative to a matched comparison group. A synthesis study conducted by Bangera & Brownell (2014) highlighted similar positive student outcomes, leading the authors to advocate that universities mandate CUREs as introductory laboratory experiences for all students. With their vast potential, CUREs may be a viable solution to the national call for greater involvement of undergraduate students in research (AAAS, 2011; Bangera & Brownell, 2014; Rodenbusch et al., 2016).

The Role of Instructors in CURE Contexts

Due to their success, CUREs have continued to be offered throughout national STEM curricula at both the introductory and advanced levels and are facilitated by numerous constituents across diverse institutional contexts. While CURE instruction varies between university, and by department, it is always intended to be facilitated by a "senior researcher" (Auchincloss et al., 2014). Faculty members, postdoctoral employees, and graduate teaching assistants (GTAs) are all deemed to be appropriate individuals to fill the position, as they are all thought of as possessing the expertise needed to execute the role in an efficient and purposeful manner. This leaves a wide range of individuals with varying levels of research proficiency in charge of facilitating CUREs and ensuring that they are implemented with the highest fidelity.

Effective CURE instruction may, in fact, depend on where in this spectrum of research experience an instructor falls. It can be challenging for novice researchers to facilitate CUREs, for instance, due to the dynamic nature of CURE learning environments (Moy et al., 2019). Numerous calls have been made for universities to mandate CUREs as introductory laboratory courses, yet the ability to implement them may be limited by the variation in instructor effectiveness alluded to here and elsewhere in the literature (e.g., Bangera & Brownell, 2014). More broadly, variation in the types of instructors charged with facilitating CUREs has led to speculation regarding the attributes of a successful CURE instructor. It has been suggested by Shortlidge et al. (2015) that if adequate structural support for CUREs is provided, the challenges to developing and implementing CUREs may be surmountable. We contend that such action is crucial, as it is well-known that quality teaching can enhance student learning and is a key predictor of student success (Darling-Hammond, 1997; Sparks, 2002; Sykes, 1996).

More acutely, Shortlidge et al. (2015) identified seven prevalent obstacles reported by CURE instructors. These obstacles included: (1) time and work investment; (2) the expanded role of the instructor; (3) overcoming student resistance; (4) the uncertain nature of scientific research (teaching patience through iteration); (5) lack of background in scientific research (inexperience with project design); (6) the ability of instructors and students to deal with the unknown; and (7) an unwillingness for instructors to invest the necessary time and effort to enhance their teaching practice. Interestingly, these findings closely align with those reported by Heim and Holt (2019), who also identified seven primary challenges faced by CURE GTAs such as: (1) time commitment; (2) lack of expertise; (3) logistics; (4) academic unreadiness of first-year undergraduates; (5) feelings of inadequacy in serving in a supervisory capacity; (6) motivating students to take ownership of their work; and (7) the fact CURE instruction requires lots of critical thinking on the part of the GTA.

CURE facilitators are often expected to make direct instructional decisions, including how information should be presented, which concepts should be emphasized, and how to evaluate student work (Ryker & McConnell, 2014). Many instructors have recounted challenges keeping track of and consulting on numerous simultaneous projects, some of which pushed the bounds of their expertise (Shortlidge et al., 2015). Because students in CUREs are working on real research problems with unknown answers, the experiments may not always go as planned, and research projects may venture into unknown territory for both the student and the faculty (Shortlidge et al., 2015). As such, student resistance may also be an issue, as some students may not want to be challenged to think on their own without being told what to do or given answers (Shortlidge et al., 2015). Course observation data further reveal that CURE instructors need to be a mentor, guide, and/or counselor to students and often have more face-to-face time with students than they would typically have in a non-CURE course (Shortlidge et al., 2017). Collectively, these findings suggest that CURE instructors have a wide range of additional teaching responsibilities than those of a traditional laboratory course. As the number of biology CUREs continues to increase and, consequently, the role of GTAs in CURE facilitation continues to become more prevalent, the need for CURE GTA PD is critical. Accordingly, it is anticipated that effective GTA PD will need to focus on the core features of CUREs as well as the aforementioned challenges to CURE instruction.

Toward Development of Effective CURE GTA PD

As a wide variety of individuals, with varying levels of research experience, can be charged with instructing CUREs, it stands to reason that they may each have different professional development (PD) needs (Bangera & Brownell, 2014; Shortlidge et al., 2015).

Creating PD programs that lead to more effective instructional practices may depend on fully identifying and addressing the needs of less experienced researchers across STEM disciplines. For example, a UTA in Engineering may have different needs and vastly different PD expectations than a fourth year GTA in Biology. With the larger variety of individuals being assigned to teach CURE curricula, it is essential that all individuals be trained in effective CURE instructional techniques (*sensu* Romm et al., 2010). By improving GTA training and teaching ability, in particular, departments can improve CURE experiences for students and potentially offer a greater variety of majors-level introductory courses (Zehnder, 2016).

Prior work conducted by Duran et al. (2009) indicates that teacher efficacy beliefs are positively and significantly impacted by PD programs directed at pedagogical content knowledge. Professional development initiatives that include teacher training exercises have been shown to give instructors confidence, support, and feedback by allowing them to practice a small part of what they plan to do with their students among friends and peers (Kusmawan, 2017). Studies have likewise shown that both science content preparation and sustained pedagogical preparation were necessary to reduce science teaching anxiety and increase science teaching efficacy (Czerniak, 1989). As national standards for what constitutes high-quality STEM instruction continue to rise, preparing effective teachers capable of engaging all students in science learning likewise continues to be imperative (PCAST, 2012).

Previous data from our own group suggest that faculty (N = 49) who participated in one-day workshops centered around CURE TA PD expressed a direct need for the formation of a community to address CURE TA PD as well as a curated repository of CURE TA PD resources. Furthermore, when asked to identify topics that they believed were critical to incorporate into CURE TA PD, survey respondents indicated a number of salient areas ranging from strategies for improving students' ability to "think like a scientist" and troubleshoot failure to mentoring strategies (see Chapter 2). Recently (in Fall 2020), we leveraged these findings to create a virtual professional learning community intervention for GTAs ($N = 7$; 88% of all eligible participants) facilitating biology and biochemistry CUREs at our institution. We were especially interested in examining the following research questions:

1. *What impact does participation in the STEM Mentoring, Assessment, Research, and Teaching in CUREs (SMART CUREs) initiative have on GTAs' self-reported knowledge of and affect toward effective practices for facilitating CUREs?*
2. *What perceptions did GTAs hold regarding the utility and value of the SMART CUREs experience to their own personal and/or professional development?*

Given the interactive nature of the intervention (see *Overview of the SMART CUREs Program* below), we hypothesized that participants would report, at minimum, moderate gains in their knowledge of teaching practices to address the five dimensions of CUREs (Auchincloss et al., 2014). This prediction is in alignment with previous reports in the literature (e.g., McDonald et al., 2019; Moy et al., 2019). Similarly, we anticipated that affective gains with respect to participants' confidence levels in incorporating said teaching practices would be observed, as SMART CUREs was intentionally designed to focus on "unpacking" the practical applications of those pedagogies. Lastly, we expected that GTAs would hold positive perceptions of the program, as SMART CUREs was the only CURE-focused PD community on campus and, thus, would offer the GTAs a space to connect and share ideas around effective CURE instruction.

Conceptual Framework

The conceptual framework guiding this study is based on an adaptation of the basic model proposed by Desimone (2009) for developing and studying effective teacher PD to include CURE-specific teaching knowledge. This framework is especially relevant due to its ability to represent the interactive relationships between the core elements of effective CURE PD, teacher knowledge and affect, classroom practice, and how to best influence teacher and student outcomes. Although we did not explicitly focus on changes in instruction and student-level outcomes, this theory is germane because it outlines a general understanding of defining effective CURE GTA PD practices and how to best implement learning opportunities for the maximum benefit of both instructors and students.

Methods

Participant Sampling and Recruitment Procedures

A mixed methods approach was used to evaluate CURE GTA ($N = 7$; 88% of all eligible participants) outcomes in the context of a virtual professional development intervention. This intervention involved GTA instructors facilitating biology and biochemistry CUREs at an R1, Hispanic-Serving Institution in the Fall 2020 semester. All participants were masters and doctoral students with varying levels of teaching and research experience (see Table 3.1 for participant demographic information). Participants were recruited solely on the basis of having been assigned to facilitate a CURE within the last academic year. Approval to conduct human subjects research was obtained from The University of Texas at El Paso's Institutional Review Board (IRB) under protocol ID #1121694.

Table 3.1. SMART CUREs participant demographic information.

TA Pseudonym	Discipline	No. of Semesters of CURE Teaching Experience[a]	No. of Semesters of Mentoring Undergraduates
Maria	Biological Sciences	3	3
Delphine	Biological Sciences	3	8
Nia	Biological Sciences	4	8
Penelope	Biological Sciences	3	10
Graciela	Biochemistry	2	6
Jasmine	Biochemistry	5	11
Carmen	Biological Sciences	4	8

[a]Please note that only one participant reported receiving prior training in mentorship, while two participants reported receiving prior pedagogical skills training.

Overview of the SMART CUREs Program

The primary intent in creating SMART CUREs was to contribute to the development of PD opportunities that had the capacity to provide GTAs with the necessary pedagogical skills and knowledge to effectively overcome the many reported challenges of CURE instruction (e.g., facilitating student experimentation and troubleshooting) (Cochran, 1993; Shortlidge, 2015; Moy, 2019). Our work was further informed by that of Heim and Holt (2019), who identified seven primary challenges faced by CURE GTAs (e.g., lack of mentoring training), and by insight gained through our own work regarding the core tenets and effective practices for CURE TA professional development (see Chapter 2). Collectively, these and previous findings can inform best practices for developing, implementing, and evaluating CURE GTA PD opportunities in the STEM fields.

SMART CUREs activities focused on four primary areas of importance highlighted by CURE TA PD facilitators and CURE TAs (see Chapter 2), which were: (a) promotion of instructors' pedagogical content knowledge (PCK), which refers to the manner in which teachers relate their pedagogical knowledge to their subject-matter knowledge (Cochran et al., 1993); (b) strategies for engaging students in troubleshooting failure through iterative experimentation; (c) mentoring approaches and project management; and (d) strategies for promoting students' experimental design competency (i.e., ability to "do" science). More acutely, these four areas of CURE-specific content knowledge were used as the foundation for various teacher training exercises (such active learning, backward lesson plan design, etc.).

Intervention activities included alternating biweekly synchronous discussions, asynchronous practical exercises, reflective journaling, and metacognitive activities for the duration of twelve weeks during the Fall 2020 semester. As alluded to above, alternating synchronous and asynchronous sessions were designed to be both theoretical and practical in nature, offering a complementary approach to "unpacking" each of the four central foci of the PD experience. Synchronous sessions were held virtually through the Zoom software platform and included pre-session reading(s) on the weekly topic and reflective journaling prior to the session, with posts submitted through Blackboard, as well as group activities and discussion during the session. Asynchronous sessions were designed to build upon and reinforce the "face-to-face" synchronous meetings.

More specifically, each synchronous virtual meeting consisted of an hour-long professional development exercise coupled with small- and large-scale group discussions intended to develop pedagogical content knowledge, instill teaching self-efficacy, foster mentoring skills, and convey evidence-based teaching practices. Interactive virtual exercises for small- and large-group dialogue included the use of the interactive whiteboard, Google Sheets brainstorming, and virtual breakout rooms to facilitate individualized and personal discussions. In addition to group discussion and forum exercises, participants were asked to develop a personalized teaching philosophy and a mentor introduction video tailored to the CURE that they facilitate, and were given tools to assess the effectiveness of their own CURE.

The complete schedule of SMART CUREs activities can be found in Figure 3.1 below.

Week	Topic	Reading(s) Due	Deliverable(s)
1 (09/07/20)	-	-	(Orientation to Blackboard Site)
2 (09/14/20)	Conceptions of "Good" Teaching	RS #1	Introduce Harwood's Matrix
3 (09/21/20)	*Developing a Teaching Philosophy*	Asynch. "lecture" w/ websites	Teaching Philosophy (1st Draft)
4 (09/28/20)	Achieving Inclusion through Mentorship	RS #2	Prompt #1
5 (10/05/20)	*Video Introduction*	-	Video
6 (10/12/20)	Experimentation in CUREs	RS #3	Prompt #2
7 (10/19/20)	*Reflection on E.D. Matrix; Assessment*	-	Brief Write-up/Synthesis
8 (10/26/20)	Collaboration and Project Ownership	RS #4	Prompt #3
9 (11/02/20)	*Student Collab. Survey*	-	Reflection on Survey Outcomes
10 (11/09/20)	Troubleshooting/Iteration	RS #5	Prompt #4
11 (11/16/20)	*Ethics/RCR Education in CUREs*	E/RCR Articles	E/RCR "Strategies" Handout
12 (11/23/20)	Broader Relevance – CURE/Community Connect.	RS #6	Prompt #5
13 (11/30/20)	CURE TALC Round-Up and Self-Reflection	-	**Focus Group/Post-Survey**
Finals Week	Submit a revised draft of Teaching Philosophy		

Figure 3.1. Weekly overview of the SMART CUREs curriculum.

Survey and Interview Procedures

To determine program effectiveness, participants were invited to first complete a retrospective, post-intervention survey and, subsequently, to engage in a semi-structured focus group interview. The post-intervention survey was intended to capture GTAs' perceptions regarding their role as CURE instructor, mentor, and researcher as well as their overall views regarding program participation. Survey questions included Likert-item statements designed to explore GTA affect, as described previously, and were adapted from McDonald et al. (2019), who evaluated a CURE faculty development model as part of their institution's curricular reform plan (see Appendix 3.1). Semi-structured focus group interviews were brief (~45 min.) and were conducted using a format suggested by Kreuger et al. (2014) for informative group discussions. Interview topics of interest reflected those themes present in our research questions, as well as the weekly forum themes, and covered the following categories of program effectiveness: (a) the overarching SMART CUREs structure; (b) the utility of each of the weekly lessons; and (c) GTAs' future CURE instructional plans (see Appendix 3.2).

Data Analysis

Quantitative metrics obtained from participant Likert-item responses were entered into SPSS (v.25; IBM) for the purposes of frequency analysis. Descriptive statistics were likewise tabulated for all post-intervention survey responses. Due to our limited sample size — and, consequently, a lack of statistical power — no inferential statistical tests were performed.

A descriptive-interpretive approach (Tesch, 2013) was used to analyze qualitative data from this phenomenological study. Specifically, semi-structured focus group interview data were subjected to content and thematic analysis to identify patterns in participant responses with respect to the three topical foci cited above. To achieve this, the raw focus group interview data were first transcribed verbatim and subsequently blinded (with pseudonyms being assigned to all participants) prior to being coded by two individuals with expertise in biology education

(A.M.K. and J.T.O.). Strong interrater reliability was observed ($\kappa = 0.882$; $p < 0.001$), with all disputes being resolved via discussion between the two raters during the consensus coding phase.

Results

Participation in SMART CUREs Leads to Increases in GTA Knowledge and Confidence

Descriptive analyses of GTAs' Likert-item survey responses indicated that all participants reported moderate-to-great gains in their knowledge of the core topics framing the weekly SMART CUREs sessions. Notably, these gains were most substantial in the areas of developing CURE instructional goals and identifying strategies to facilitate student collaboration, troubleshooting/iteration of experiments, and mentoring of student teams (Figure 3.2).

Similar gains in GTA confidence were further reported, with participants additionally indicating that engagement in SMART CUREs empowered them to be more reflective of their own classroom practice (Figure 3.3). Conversely, GTAs' confidence levels were more variable with respect to reading science education literature and promoting students' development of experimentation skills. It is unclear what factor(s) led to this variability, although we posit that general lack of familiarity with the education research literature is contributing to the former observation whereas limitations imposed by transitioning CUREs to an online learning environment in response to the COVID-19 pandemic is motivating the latter observation.

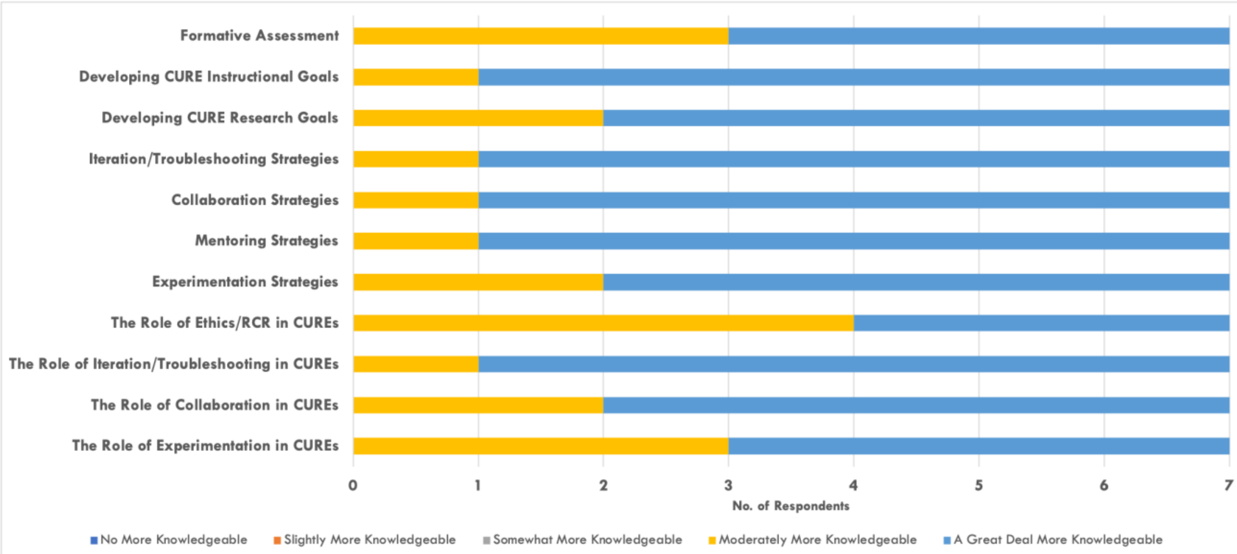

Figure 3.2. Impact of participation in the SMART CUREs program on participants' self-reported knowledge gains with respect to CURE facilitation.

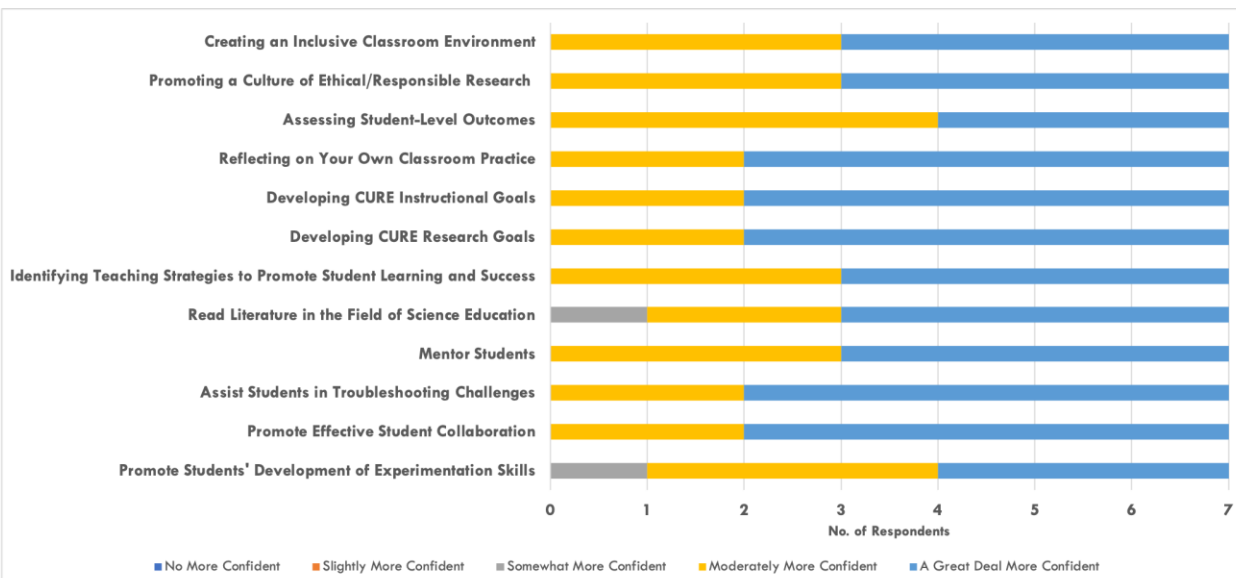

Figure 3.3. Impact of participation in the SMART CUREs program on participants' self-reported confidence gains with respect to CURE facilitation.

GTAs Reported Benefiting from Community Membership, Idea-Sharing, and Career Exploration

Thematic analysis of focus group interview data yielded three predominating themes: (a) the importance of belonging to a community of practice; (b) dedicated time to share ideas and strategies; and (c) opportunities to discuss connections between CURE instruction and career/teaching praxis impacts. In what follows, we describe these themes in greater detail and offer GTA vignettes that exemplify said themes.

Belonging to a Community of Practice

Professional STEM education learning communities have been demonstrated to be a powerful mechanism to create a shared vision and reflective teaching practices among its constituents, thereby ameliorating some of the common challenges (e.g., lack of time; lack of relevancy) associated with PD efforts (Henderson et al., 2011; McDonald et al., 2019). With respect to GTAs more acutely, previous studies reveal that attention to GTA PD is highly variable across institutional contexts, with one study noting that more than half of the universities and colleges surveyed in their research required biology GTAs to spend ten (10) or fewer hours engaged in teaching PD per year (Schussler et al., 2015). Currently, there are limited opportunities for GTAs to engage in pedagogically-oriented PD at the institution at which this research occurred, and there are no other CURE PD experiences available aside from SMART CUREs. It is, therefore, perhaps unsurprising that GTAs in our study capitalized upon the benefit of belonging to a community of practice, as stated by Penelope:

"I hadn't participated in anything like this in the past [where] I felt like I actually got something out of it that I could actually apply to what I was doing. I found myself talking about this program to my parents and my labmates."

Maria and Carmen expanded upon Penelope's comment by describing how participation in the SMART CUREs community allowed them to address unique challenges during the Fall 2020 semester:

"… my other peers that are in the program with me, they don't teach a research-driven course, so we couldn't really collaborate or share ideas so much, because those kinds of courses are structured where the instructors just give you the map, so to speak, and you do what they say, and that's it. There's no questions about it." [Maria]

"I think it was perfect timing to have this type of collaboration – or not collaboration, but being able to talk to others about it, because we all switched to online. And I guess that that was the biggest struggle that I personally was going through, where the students – I was not aware how I was going to be able to interact with them and stuff. So, being able to talk about all of those situations, and problems… I think that was also very helpful. And being able to just talk about it with other people, because I feel like talking about online teaching… is that it's very hard, and people are still trying to figure it out. And being able to figure it out with others, instead of by yourself, it's kind of comforting." [Carmen]

As evidenced by the above statements, community formation was viewed as a conduit for idea-sharing, which, at times, extended beyond the boundaries of the SMART CUREs network itself (as suggested by the quote from Penelope). It is this notion of idea-sharing that we turn our attention to next.

Sharing of Ideas and Strategies

As mentioned by Maria in the above section, sharing ideas and strategies emerged as a common thread among all GTAs. Previous studies have shown that fostering a community of practice that allows for open communication can increase participant ownership of the work achieved as part of the community as well as make transparent that participants' contributions are valuable (McDonald et al., 2019). Open discussion also ensures that all community members can drive the conversation, rather than adhering to a top-down approach involving unidirectional flow of information.

With regard to teaching "tips and tools," Jasmine noted, succinctly, that:

> *"I really liked how it (SMART CUREs) was all set up, honestly. I didn't know you could have different chat groups during Zoom, so I thought that was really neat, and I plan to implement that in my class."*

Others, such as Graciela, acknowledged that interactions within the SMART CUREs community allowed her to recognize and adopt new strategies in her CURE to combat the transition to remote instruction:

“There was one time, and I think it was Delphine (a SMART CUREs participant) who showed the way she was teaching. Okay, so, when I started this fall course (the CURE), and in the pandemic, and all the situation, I was finding it difficult [to figure out] how to keep my students engaged. But what I used to do is I used to take pictures and make PowerPoints, and try to explain them. And then, I did not know whether they are learning, not learning, because if I ask them, they would be like, ‘Yeah, go to the next level. We know what we are doing.’

But then, I didn’t know what to do. I met Delphine. She showed me – She showed all of us how she was making videos and uploading them to Blackboard. And that’s how the students were learning from her. And that really helped me, because I started doing the same thing. And it has really helped me, and I’ll continue doing the same thing in the next semester also.”

More broadly, creating a space to share ideas appeared, for some, to normalize the struggle of pandemic teaching, as highlighted by the following quote from Delphine:

“I think if I had not participated in the program, I would have been a lot more stressed out right now. I would have been a lot more scattered, trying to get in order, just trying to get – I don’t know. It really helped decompress, and talk, and just bounce ideas [around] with people. Even when we just got into our little break-out groups and were discussing teaching strategies or whatever, that we usually started talking about our own personal experience, and that really helped. And [I] realized that everybody’s really going through

this, and it just gave me a space to just feel more, like, 'Okay, this is completely normal. This is just the pandemic, and you can handle it.'"

This latter statement, in particular, reinforces the notion that, while idea-sharing in itself is a valuable practice, the direct benefits to participants with respect to teaching self-efficacy and confidence can be as equally important.

Impacts on Broader Teaching Praxis and Career Goals

Several of the GTAs in our study acknowledged the importance of being provided dedicated time to consider how their current role as facilitators of CUREs might intersect with their future career plans — either short-term, as a GTA in subsequent semesters, or long-term — and/or their teaching praxis. Nia, a biology GTA who expressed interest in teaching at a community college or primarily undergraduate institution following graduation, noted broadly that:

> *"Participating in [SMART CUREs] has empowered me to feel like a better instructor; I feel that I now have a better set of tools to implement in my classroom and that I now have more to offer my students. Even though it was just a couple of weeks, I feel like I truly benefited a lot from this."*

Other GTAs, like Graciela, referenced particular aspects of the SMART CUREs program that aided her in clarifying her overarching approach to teaching and learning:

"This course (SMART CUREs) helped me in letting me know what I actually want. For example, when I was writing [my] teaching philosophy, at that time, I got to understand what I expect or what I want out of my students. So, previously, there were things in my mind, but still, they were not on the floor or something like that. So, when I was writing [my] teaching philosophy, that's when I realized, okay, these are the things that, for example, these four things I really want to teach, and I really want my students to have by the end of the one-year course (the CURE sequence). It (participation in SMART CUREs) was very useful for me.

This sentiment was echoed by Delphine:

"Throughout the Ph.D. process, we've all really focused on how to develop our research skills, and our writing skills, and about how to become better scientists. We teach or try to [teach], and I haven't had any development in my teaching philosophy or any type of what I'm going to be teaching. Because usually it's handed out to me. It's like, 'Here [is the] syllabus. Here's the content. You go and just present it to the students.'

But I've never had to think of myself as the teacher, and a lot of the times when you (the interviewer) were prompting us [with] questions, I was still in the student position. Like, 'Oh, okay, well, what I would do in –.' But it really helped me shift my thought perspective, and I think of myself more as a teacher. I've never even considered making a teaching philosophy, but it really helped me organize myself, and better organize the semester, and how I want to think – It really helped me to feel that. I have a strength, *now, when it comes to teaching, when before it was just – hopefully I can stumble my way through this, and I'll find out, at the end, if I did it or not.*

As Delphine describes, and as Schussler and colleagues (2015) state, "many graduate students are encouraged to develop their skills as researchers but are rarely encouraged to develop their proficiency at teaching" (p. 2). Through engaging GTAs in SMART CUREs, we sought to broadly emphasize the value of this latter practice, particularly given the strong interest in teaching and teaching-oriented careers observed among the GTAs in our study and, similarly, in prior GTA PD work in the field (Tanner & Allen, 2006; Sauermann & Roach, 2012).

Discussion

Over the last decade, the prevalence of CUREs in collegiate biology laboratory curricula has continued to grow, with numerous studies demonstrating their effectiveness at promoting students' science process skills development, positive affect, ability to "think like a scientist," and persistence in STEM (Brownell et al., 2013; Jordan et al., 2014; Olimpo et al., 2016; Rodenbusch et al., 2016; D'Arcy et al., 2019; Olimpo et al., 2019). Comparatively, little research has been conducted on the perceptions of faculty who facilitate CUREs (see, as examples, Shortlidge et al., 2016, and Shortlidge et al., 2017), and even fewer studies have investigated the perceptions of GTAs tasked with leading these courses. Those that have demonstrate that GTAs largely feel that they benefited from teaching CUREs with respect to their development of pedagogical and research-oriented skills. However, these same GTAs frequently reported challenges with respect to mentoring students, directing independent student research projects (which are often topically diverse), and allocating sufficient time to the CURE to ensure that it was implemented with high fidelity (Heim & Holt, 2019; Goodwin et al., 2021). While these challenges signal a need for CURE-specific GTA PD, to the best of our knowledge, our study is the first to describe a concerted effort to meet that need.

The SMART CUREs program was intentionally designed to integrate both theoretically- and practically-oriented exercises centered around the five core dimensions of CUREs (as described by Auchincloss et al., 2014) as well as perceived areas of importance reported by CURE faculty/staff and GTAs (see Chapter 2). Given the ongoing COVID-19 pandemic, all program activities occurred virtually, although a staggered system of alternating synchronous and asynchronous sessions was employed to allow both for "real-time" discussion as well as independent time for GTAs to applying new knowledge to their own praxis. Our data indicate that SMART CUREs was effective at promoting GTAs' knowledge of and affect toward the majority of weekly program topics. Similarly, GTA focus group data revealed that participants appreciate the community aspect of the program, which provided them with a dedicated space to share ideas/strategies as well as reflect on their own approach to teaching. These findings are akin to the work of McDonald et al. (2019), which demonstrated that faculty who participated in a summer CUREs institute found value in the collaborative nature of the PD and believed that the institute prepared them to teach their CURE curricula according to the timeline that they had developed.

We acknowledge that there are several limitations inherent of our work. Most prominently, our sample size is small — a factor derived largely from the lack of GTA rotation in teaching CUREs (i.e., the same GTA is repeatedly assigned to teach the same CURE). While such a sample size is not uncommon among previous studies on biology GTAs (e.g., Goodwin et al., 2021), we nevertheless caution the reader to be mindful not to overgeneralize the findings reported herein. Additionally, the entirety of the SMART CUREs program was conducted online, and while efforts were made to sustain the program into the Spring 2021 semester, this was difficult given the constant transitioning of instructional modalities due to the COVID-19 pandemic. Consequently, we strongly advocate for future research that examines both CURE GTA PD outcomes across diverse institutional contexts as well as the efficacy of various PD delivery modes, as such studies will ideally yield a more holistic representation of how to best structure CURE GTA PD to maximize both GTA and CURE student outcomes. Further, when done correctly, CURE GTA PD can ostensibly serve to mitigate some of the common challenges associated with GTA pedagogical training (e.g., failing to prepare GTAs to support student inquiry; see Schussler et al., 2015), thereby empowering GTAs to be effective future educators, scholars, and leaders in the 21st-century STEM workforce (Cascella & Jez, 2018).

Chapter 4: Scaling and Sustaining Professional Development Opportunities for CURE Teaching Assistants (TAs): A Case Study of TA, Faculty, and Administrator Perspectives

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Introduction

Course-based Undergraduate Research Experiences: A Brief Overview

Course-based undergraduate research experiences (CUREs) are widely recognized for their ability to engage large numbers of students in real-world scientific discovery, circumventing the challenges associated with the limited opportunities commonly available to students who seek to participate in apprenticeship-style laboratory training (Auchincloss et al., 2014; Bangera & Brownell, 2014; Spell et al., 2014). In contrast to traditional laboratory curricula, which are often described as being prescriptive in nature, student involvement in CUREs enables them to address novel research questions or problems that are of interest to the broader community with an outcome that is unknown both to the students and to the instructor (Domin 1999; Bruck et al., 2008; Weaver et al., 2008; Auchincloss et al., 2014). Additionally, CURE students are reported to gain many of the same academic benefits as those exhibited by students who participate in traditional research settings (Auchincloss et al., 2014; Spell et al., 2014; Corwin et al., 2015). Indeed, positive student outcomes associated with CURE participation are numerous and include an increased interest in scientific research as well as gains in research skills, self-efficacy, and persistence in the sciences (Harrison et al., 2011; Brownell et al., 2012; Olimpo et al., 2016).

Facilitation of CUREs and the Expanded Role of the CURE Instructor

Since their advent, CUREs have been offered across diverse institutional contexts as part of science, technology, engineering, and mathematics (STEM) curricula at both the lower- and upper-division levels and have been facilitated by a number of constituents (Goodwin et al., 2021). While CURE instruction varies between universities and individual STEM departments, it is intended to be facilitated by "senior researchers" (Auchincloss et al., 2014). Among those deemed "senior researchers" are faculty members, postdoctoral employees, and student teaching assistants — all presumed to be capable of executing the role of instructor in an efficient manner. This assumption leaves a wide range of individuals with varying levels of research and teaching proficiency in charge of facilitating CUREs and ensuring that they are implemented properly.

Effective CURE instruction, and the positive student outcomes associated with it, may depend on where in this spectrum of research and teaching experience an instructor lies. Course observation data has indicated that CURE instructors have a heavier workload than those teaching traditional "cookbook" laboratories (Ryker & McConnell, 2014; Shortlidge et al., 2015; Shortlidge & Brownell, 2016; Shortlidge et al., 2017). CURE facilitators, like most standard laboratory instructors, make instructional decisions, including how information should be presented, which concepts should be emphasized, and how to evaluate student work (Ryker & McConnell, 2014). In addition to these teaching requirements, individuals tasked with facilitating

CUREs need to be a mentor, guide, and/or counselor to students and often have more face-to-face time with students than they would typically have in a parallel non-CURE course (Shortlidge et al., 2017).

With respect to the dynamic nature of CURE learning environments, and the fact that students are working on research with outcomes that are unknown both to the students and to the instructor (Domin 1999; Bruck et al., 2008; Weaver et al., 2008; Auchincloss et al., 2014), it is not surprising that numerous difficulties have been reported by CURE instructors (e.g., student resistance; lack of student familiarity with the research process) (Shortlidge et al., 2015; Heim & Holt, 2019; Moy et al., 2019). It has been suggested by Shortlidge et al. (2015) that if adequate structural support for CUREs is provided, the challenges to implementing CUREs may be surmountable. We contend that such action is crucial, as it is well-known that quality teaching can enhance student learning and is a key predictor of student success (Sykes, 1996; Darling-Hammond, 1997; Sparks, 2002).

Graduate Teaching Assistants (TAs) as CURE Instructors

As the number of biology CUREs has continued to increase nationwide, the involvement of TAs in leading CUREs has likewise increased proportionally. Indeed, it is common practice that, at most research institutions, introductory biology labs are taught by TAs rather than faculty (Sundberg et al., 2005). It has also been observed that specialization in the discipline of study is often the only consideration for most TA appointments and that pedagogical knowledge or prior teaching experiences are not required to qualify for job assignment (Mutambuki, & Schwartz, 2018). Consequently, it stands to reason that these individuals would have different professional development (PD) needs than postdoctoral or faculty instructors (Bangera & Brownell, 2014; Goodwin et al., 2021).

Facilitators of CUREs are often expected to emphasize certain laboratory concepts, make a number of instructional decisions on their own, be prepared to evaluate student work, and keep track of and consult on numerous simultaneous projects (Ryker & McConnell, 2014; Shortlidge et al., 2015). Because students in CUREs are working on novel research projects with unknown outcomes, these experiments may not go as planned, and may simultaneously push the boundaries of a student's knowledge and the instructor's expertise (Shortlidge et al., 2015). As such, it is expected that many CURE instructors will be met with student resistance when some students seek immediate answers to questions that are challenging to think about and discover for themselves (Shortlidge et al., 2015). In response to this and other anticipated obstacles, we developed the SMART CUREs initiative (see Chapter 3), which is described in brief below.

SMART CUREs as a Model for CURE TA Professional Development

As stated above, prior work conducted by our group involved the development and implementation of a CURE-focused professional development program that was implemented at an R1, Hispanic-Serving Institution in the Fall 2020 semester (see Chapter 3). Our intent in creating the STEM Mentoring, Assessment, Research, and Teaching in CUREs (SMART CUREs) program was to generate PD opportunities that had the capacity to provide adequate structural support to TAs by focusing on the pedagogical skills development necessary for those TAs to overcome the many reported challenges of CURE instruction (Cochran, 1993; Shortlidge et al., 2015; Moy et al., 2019). Development of the SMART CUREs program was further informed by insight gained through literature review and previous studies regarding core tenets of and effective practices for CURE TA professional development (see Chapter 2). This semester-long intervention involved structured activities and group discussions intended to promote growth in participant knowledge and skills as they pertain to CURE instruction. An expanded description of this program and its associated outcomes is described in Chapter 3 of this dissertation.

Sustainability and Scalability of the SMART CUREs Program

The ultimate challenge to designing an intervention like SMART CUREs is planning for the inevitable time when the implementation phase of the pilot program has been completed. Therefore, sustainability and scalability of the SMART CUREs program has, perhaps unsurprisingly, become the primary focus of the current research. Studies concerning sustainability and scalability are often divided into separate dimensions, though these dimensions reflect closely aligned elements of successful program development drawing on many of the same features necessary for change (e.g., analyzing different levels of scalability or determining a specific order of change necessary for sustainability) (Coburn, 2003; Kampylis et al., 2013). In other words, for an innovation to be scalable, it must first be sustainable (Coburn, 2003). As such, it has been argued by Kampylis et al. (2013) that sustainability and scalability were so closely aligned in their objectives that they should be treated as one construct. Howard et al. (2021) simplified these aligned objectives by proposing that *sustainability* was simply a state of "ongoing change" for an innovation while *scalability* was the "dissemination of change across different contexts." Building on this idea of change, sustainability for the purposes of this study can be viewed as "the continued ability of the SMART CUREs program to meet the needs of its stakeholders” and scalability, by extension, “the ability of the SMART CUREs program to meet the needs of existing and new stakeholders across other STEM disciples and beyond.”

Given this definition of sustainability and scalability as they pertain to SMART CUREs, our research is guided by the following central question:

> *What perceptions do CURE faculty, CURE TAs, and campus administrators hold regarding the scalability and sustainability of the SMART CUREs program as a model for TA PD at a research-intensive, Hispanic-Serving Institution?*

Sustaining any successful pilot program depends on overcoming a specific set of barriers, even if evidence suggests that it meets the needs of a targeted population. Research conducted by Johnson et al. (2004) identified, for instance, several capacity-building factors and program attributes that need to be addressed to sustain education innovations. These capacity-building factors included the presence of champions for an innovation, effective leadership, resources, administrative policies and procedures, and subject matter expertise. Effective program attributes included alignment with needs, positive relationships among key implementers, and ownership by stakeholders. Collectively, these elements heighten an innovation’s ability to be sustained (Johnson et al., 2004).

Building upon the above points, sustainability and scalability of initiatives require critical leadership support across all levels and necessitate establishing measures that promote connectivity among stakeholders (Kampylis et al., 2013). Leadership and discourse among stakeholders are critically important because they have the capacity to both foster a culture of change as communication channels open as well as contribute to participants' collaboration in sustaining the innovation (Howard et al., 2018). We consider SMART CUREs stakeholders to be those individuals with a vested interest in the initiative and/or those who possess leadership roles in maintaining CURE programming and the fidelity of their instruction. Among this group are the CURE instructors (including TAs), the undergraduate participants, the faculty members who developed or established the CURE, and university administrators who have a key role in shaping undergraduate STEM education and instructor professional development on campus.

Conceptual Framework

An intervention map is a framework approach that uses theory and evidence to conceptualize a systematic process and detailed protocol for effective, step-by-step decision-making for intervention development, implementation, and evaluation (Fernandez et al., 2019). The steps delineated in an intervention map can provide a model for asking "why" or "how" questions about determinants of change methods and strategies as well as their relevance to stakeholders (Bartholomew et al., 1998). Work conducted by Bell et al. (2017) established such a roadmap for institutionalizing CURE initiatives, which we have elected to adapt and adopt as a conceptual framework as we seek to sustain and scale SMART CUREs programming. The sustainability and scalability themes presented by Bell et al. (2017) are as follows: (1) enumerate outcomes; (2) identify pilot; (3) engage stakeholders; (4) funding and scale-up; (5) community of expertise; (6) develop cohorts of faculty; and (7) iterative assessment and modification of goals.

Methods

Following the successful execution of our pilot program, we sought to build consensus more broadly among SMART CUREs stakeholders at our university. Strategically discussing the SMART CUREs initiative and seeking the perspectives of essential college-level stakeholders (administrators, department chairs, faculty, and GTAs) allows us to anticipate potential obstacles to adopting and implementing the envisioned change (Bell et al., 2017). Brokering such partnerships also gives us insight into existing states of affairs and has the potential to shift mindsets by building buy-in among stakeholders (Hooker, 2019).

As alluded to earlier, we identified our stakeholders as those individuals who have a role in selecting or preparing GTAs for their assignments as CURE instructors as well as those who may directly or indirectly benefit from properly executed CURE instruction and, by extension, the positive student outcomes it provides. As we navigated the selection process, we identified four key subgroups that warranted consideration: (a) Institutional Administrators (Graduate School, Center for Faculty Leadership and Development [CFLD]); (b) Department and Program Administrators (Department Chairs, TA Committee Assignment Coordinators, First Year Research Intensive Sequence [FYRIS] Directors); (c) CURE PIs (faculty in charge of CURE development or facilitation in various STEM departments); and (d) CURE TAs from the Biological Sciences and Chemistry/Biochemistry departments who participated in the SMART CUREs pilot program.

Participant Sampling and Recruitment Procedures

Participants (N = 21) constituted a sample of convenience consisting of institutional administrators (n = 5), department and program administrators (n = 5), CURE PIs (n = 6), and CURE TAs (n = 5) — collectively representing 91% of all eligible participants. Involvement with CURE facilitation and/or CURE TA PD was the sole criterion for study inclusion. This project was approved by The University of Texas at El Paso's Institutional Review Board (IRB) under protocol ID #1717314.

Survey and Interview Procedures

Participants were initially invited to complete an online survey, administered through UTEP's QuestionPro platform, which was designed to collect details regarding their position, as indicated above. Following completion of this survey, participants were prompted to schedule a one-hour semi-structured interview with the authors (A.M.K. and J.T.O.). Interview questions were adapted from the intervention scale-up framework presented by Zamboni et al. (2019), which focuses on: (a) attributes of the innovation/intervention; (b) credibility of model (evidence base for innovation); (c) relevance to concern of potential adopters; (d) relative advantage over existing practice; (e) simplicity or ease of adoption; (f) model is testable and adaptable; (g) aligned and harmonized with existing graduate PD programs; (h) networking, collaboration and partnership (to foster buy-in); (i) capacity to support scale-up (skills, size, resources and experience); (j) capacity for data collection and reporting systems; and (k) timing or window of opportunity. Please see Appendix 4.1 for detailed interview questions based on this framework. The intent of these interviews was to ascertain participant perspectives regarding SMART CUREs program sustainability and scalability.

Data Analysis

Descriptive statistics were tabulated for all demographic items (see Table 4.1), with data on participants' self-reported position(s) at the university being used to cluster individuals based on role. Transcribed interview data were first blinded to reduce researcher bias and subsequently subjected to thematic analysis (Tesch, 2013), wherein iterative rounds of inductive coding were employed to find patterns in the dataset. Each interview was coded by two researchers with expertise in biology education (A.M.K. and J.T.O.), achieving strong interrater reliability ($\kappa = 0.907$; $p < 0.001$). All disputes were resolved via discussion between the two coders during the consensus phase of the coding process.

Results

Major themes cited by respondents included comments regarding: (a) the need for change; (b) existing PD structure and function; (c) developing program champions; (d) expansion; and (e) sustaining efforts. These themes, and associated subthemes, are exemplified by the following vignettes.

Theme 1: Acknowledge Need for Change

Participants were asked about their perceptions of existing TA PD opportunities at the university, and all interview subjects ($N = 21$) acknowledged the need for change regarding TA pedagogical training. Participants were also asked how SMART CUREs TA preparation might intersect with existing TA PD opportunities, and most respondents ($n = 19$) thought that this type of targeted TA PD would be complementary to and/or an improvement on what currently exists within their departments or divisions. All responses reflected the importance of CURE TA PD as an extension of future faculty development (*sensu* Cascella & Jez, 2018).

Reflections On What Exists

As acknowledged by Zamboni et al. (2019), purposeful reflection on current practices can provide a critical first step in determining how to best sustain and scale an intervention. Among the participants in our study, administrators most frequently detailed how variable TA PD opportunities are both within departments as well as at the whole-campus level. For instance, Cornelius noted the following with respect to his interactions with different program chairs at the institution:

"I went program-by-program asking them what their biggest priorities were, especially regarding professional development. And teaching came in second to writing… that's how I learned also [that] not every department has the type of programming that mine has. And so, on the other end of the spectrum, some programs do very little because they're focused on other things. And I don't blame them. I mean, time is finite for all of us, and we have to decide how to prioritize. And sometimes, teaching falls lower on the priority list for other programs. So, that's a challenge for the graduate school because there's not a one-size-fits-all approach that can be delivered."

Similar concern was expressed by Bob, who serves as the coordinator for TA assignments in one of the STEM departments on campus:

"'I didn't know what I was doing.' I hear that kind of thing a lot from the [graduate] students, and I do think that it's (teaching) one of those things in academia that you're kind of expected to just jump in with no training whatsoever. And you can't train everybody on everything they're ever expected to do but you know, a certain amount of training for something like teaching the class, where you have responsibility for grading and evaluating maybe 20 students is warranted in my opinion, and there should be a little bit more formal training."

Whereas administrators recognized that greater attention needed to be placed on TA PD moving forward, the current lack of available training/education was seen as a dire issue by CURE PIs and TA instructors. Rubeus described, for example, that he:

> *"… think[s] the traditional model of graduate education is seriously flawed. And we tend to only teach students in the discipline. In my case, they're taught, you know, as scientists at the bench… All the things we have to do well as a faculty member to be successful, most of them are not taught to us. We learn, right, on the job training, if you will, when we get the job... teaching is very important. And we don't do enough to make sure our students come out as good teachers. We make sure they come out as good scientists, and that's it. That's what we focus on."*

Hermione, a CURE TA, echoed this sentiment, stating that:

> *"We go clueless as of what we have to teach the students and how we have to – how we have to handle not ourselves necessarily, but how can we provide the best teaching or ways for the students. So, if we would know how to or take a program before this, like what we had with Dr. X and yourself (the interviewers), where we share our experiences and then somebody who had been in the education setting for a while would help us understand how we can do those things better. So, I think that if us being TAs, not knowing what we're going to do, and then somebody comes in and they're seeing us, then I think that would be enough evidence for someone to develop a program where we can*

learn from before actually getting to those TAships where we go and teach other students."

Collectively, the above viewpoints suggest that while there is some PD being offered to GTAs, it varies between departments in what and when it is offered. Further, in many cases, while it may be helpful for graduate studies preparation, it is not a robust preparation for leading a classroom. These data also strongly suggest a shared opinion regarding a need for change.

Considering How New Complements the Old

In order for an intervention to be institutionalized and scaled, it should ideally provide for a novel expansion of programming currently absent or limited within the organization (Zamboni et al., 2019). In establishing a foundation for considering this in the context of our own study, Cornelius noted the differences in CURE and non-CURE instructional models:

"From the information that I have, if [a] CURE is an apprenticeship model, it would be taught differently than any other – I mean, how many other apprenticeship-type courses do we have? You have to take an independent study, or you get to the dissertation stage or to a very specific type of course. So, yes, I do think [CURE TA PD is needed] because when you are teaching somebody as your apprentice, there's a chance that more lines can be blurred. There's more observation. There's much more – yeah. I mean, students are always observing you, but when they're spending that apprentice time with you, it's a more in-depth observation. And so, I think what we model, some of us are very aware of ourselves and how we model things, the questions that we ask, how we engage our

students. But what does that look like on a one-to-one? And the inference that I'm drawing is based on mentoring and how we know how to mentor based on how we've been mentored. Very few of us have gone through any formal kind of mentor training as faculty."

Other respondents felt that all TAs, even those not teaching a CURE, could benefit from the mentoring and pedagogical training that SMART CUREs could offer. As pointed out by Amelia, an administrator:

"I think it would be very useful to integrate it [the SMART CUREs curriculum] into TA training in general. If a department has TA training, let's say chemistry and biochemistry, has TA training that lasts two, three days a week prior to the start of classes, for example. Integrate this, a module or two or a whole day specifically talking about CUREs, because everyone will benefit from this, even if it's a student that is not going to be TAing a CURE. They would benefit from the idea of how to mentor a student in research period."

Aurora, a CURE PI, shared the same sentiment:

"I think it [participation in the SMART CUREs curriculum] should be highly encouraged. I think it is something that I think all of our GTAs should go through. I think it should be part of the training regimen that they go through. If they're going to be brought in as TAs, if we're going to be handing off educational responsibilities to them, if we're gonna be charging students' tuition fees for this, we have the responsibility to give our students as customers of the university, a well-trained cadre of professionals giving

them information that's valid and giving them an experience that is more in league with what they signed on for."

Angelina, a CURE TA, also pointed out the importance of this type of training for TAs who plan to go into commercial industry as opposed to wanting to be future faculty:

"I think it's very important for me being I don't know, like, because in the future, I don't want to be a professor, but I want to know how to deal with people, how to mentor people."

Taken together, these responses highlight the differences between CURE and non-CURE instructional contexts and reinforce the critical need for a targeted PD program like SMART CUREs. Additionally, these data demonstrate a need for something different in PD programming than what currently exists.

Theme 2: Built for the Masses

All participants were asked about the content and structure of existing PD opportunities for TAs within their departments. While all participants replied, only fourteen (14) were able to describe the content and foci of TA PD in their division, and thirteen (13) discussed the format and structure of PD that was available to graduate students in their department. The points made by participants in this section only differed from those in Theme 1 if they had some type of PD available in their department to discuss and describe; otherwise, participant responses were a reiteration of the previous theme and the need for change.

Content of Existing PD/Foci

Participants were asked to describe particulars relating to the content and foci of existing PD, and the following quotes highlight the topics that emerged as well as some of the ways that departments are dealing with the lack of targeted PD. For example, Ludo, an administrator, described the ways that his division is overhauling their existing PD curriculum:

> *"In the graduate school, we're working on implementing a core curriculum, of course out of competencies, that we wanna have all of our PD program driven off of. I actually have a copy I was looking at earlier today of cataloguing some of our older, professional programming, but we work on communication, programming, well-being, ethics, integrity, leadership, and collaboration as our main topic areas*."

Bob, another administrator, described how experienced TAs in his department had taken the lack of guidance into their own hands and put together information-sharing sessions to help each other:

> *"This semester, some of our TAs have put together an introductory informational seminar that's gonna occur this Friday, where it's gonna be for all the new TAs, they're gonna basically share their thoughts and wisdom on – these are some of our TAs who've been there for five years, including one of my students… And they were including things that were not just like how to be good in the classrooms, but they were like, here's how to get your health insurance hooked up correctly."*

Some CURE PIs lamented the lack of formal TA PD but described an apprenticeship model of PD where TAs learn what is expected of them from the PI they are working for:

"The way the TA normally works; our TAs are not only the TAs from the master's program, most of them teach lab under guidance of a professor. And it goes all along with that professor whom they're working with. That type of thing, but if you ask me; is there a professional development course or they all go through something; unfortunately, they do not. I would love to see that happening."

Pansy, a TA, described existing PD opportunities that she had participated in and how they helped her as a CURE instructor:

"I took a professional development course when I started UTEP my very, very first semester. So, it helped me develop my CV. It gave me kind of like a walkthrough to apply for grants. But it didn't help me as a professional teacher. It helped me as a professional student, as a professional grad student."

Collectively, these responses tell us that while some PD is offered, it is generally limited to graduate student-centered content as opposed to any type of teacher training. Based on administrator responses, it would also seem that there is an awareness for the need to replace or revamp existing TA PD offerings.

Format and Structure of Existing PD

The above descriptions regarding the format and structure of existing PD programs within our study context portray hastily-scheduled PD workshops that either are not advertised and recruited well or that simply lack the structure necessary to instill pedagogical skills development. The classroom management focus of existing PD was described more by Cornelius:

> *"The graduate school offers this half day or several hours in the afternoon or morning TA/RA/GA training that covers basic stuff about being a TA including some elements of the Americans for Disability Act, Title IX, some of the legal things... So, we hit on some of the more general elements of being a teacher."*

Some administrators, while they knew PD programs existed, were not aware of what that looked like when they were rolled out, as expressed by Filius:

> *"As far as I know, we don't really have any. I know there is some training, right, by the graduate school, and I know that we meet with TAs – we used to anyway, at the beginning of the year, and then that kind of got taken over by the graduate school. And I would say, based upon the fact that since I've been here, on the effectiveness of the TAs and the number of issues and problems that we have not diminished, that would be my indicator that they are not effective. I don't know the details of what they are, but there doesn't seem to be any change."*

PIs like Aurora, who were aware of existing PD programs, discussed their thoughts on participation and gave a potential explanation for the lack of greater access to PD opportunities:

> *"I am not aware of anything besides this current group that's going through [your SMART CUREs program]. I'm not aware of anything that mimics that. And again, if I'm not aware of it, it's probably because it's falling under the radar. It's not being advertised, and people are not being encouraged to engage in those sorts of experiences. And that's another failing that I see broadly with a lot of the opportunities that UTEP does offer. They're not really structured and advertised and recruited well. And I think that's one of the things that I see successful in this particular program that you guys have been involved with is that you've been bringing in people, you've been [spreading the] word, you've been making personal contact as opposed to just, 'Hey, there's this opportunity, sign up if you want.'"*

Luna, a TA, had some of the same points regarding lack of participation:

> *"They [TA appointments] were scheduled pretty last minute. It was like, 'Oh, it's the first week of school. Here's your assignment. And now you have to give us your whole day as well for that (TA PD).' So, yes, sometimes they (TA PD sessions) simply took too much time, or like, we'd go to a whole day-and-a-half workshop, and some of the stuff didn't apply at all to me, and then some of it was really useful to me but maybe didn't apply to the other GTAs or RAs that were there too."*

Taken as a whole, these responses indicated to us that existing TA PD opportunities are often only sporadically available and lack the structure needed to foster the skills required to adequately support TAs, many of whom are often novice instructors. It is our opinion that TA training workshops should not simply focus on classroom management basics but be part of an ongoing program that is designed to target multiple areas of need and skills development (e.g., pedagogical skill development; leadership; mentorship).

Theme 3: Identify Champions

When asked about ways to establish stakeholder support and encourage new buy-in for the SMART CUREs institutionalization effort, several solutions were offered that centered around the need to identify champions. Responses (*n* = 6) suggested the need for fiscal support initiatives or departmental mandates to foster broad buy-in for the SMART CUREs program. An even larger number of respondents *(n* = 14) thought that it was important to recruit a core group of driven faculty leaders and to motivative mentors in order to establish strong program support.

Acquiring Support

There were many participant responses that focused on the need to create effective CURE TA PD initiatives within individual departments and acquire outside financial support as a means of bolstering SMART CUREs community buy-in. Responses from administrators like Cornelius express how this could be achieved through data-driven, top-down support:

> *"There's value in people who are part of the program to be invested in it, to sustain it. But I think also, the way that things are going, everything is so data driven, that if there*

is data that this is working and that it's having an impact and then that it has potential impacts post-graduation or whatever, then proving that to the administration, I think, will also help sustainability because things are a lot easier to sustain when there's top-down support. I believe fully in bottom-up initiatives and lateral initiatives, and I think those things can do very well and can work organically. But there's a moment where something has to be institutionalized because it's gonna need an outpouring of resources or structure that will help."

Administrators like Bob described the heavy workload of CURE instructors and advocated for a need to find additional funding to support them as a means to both lighten the workload that is expected of CURE TAs as well as encourage greater departmental buy-in for SMART CUREs:

"And with these CUREs, I mean, we've had quite a few of them, but I would say they don't have 100% institutional support, where it's really worthwhile for everybody to try to do one. So, the way it's done this semester is they only have money to support half of the TA for the CURE. And then that student has to get supported by the department for the other half. So, now, I have to assign that student to an extra TA assignment on top of this already pretty demanding CURE that they're doing. Okay. Well, this is disincentivizing. And I've had at least one faculty member tell me, well, I'm not doing the CURE again if I have to do it this way. I was like, well, that's not my decision on how to do this. I just know that in order to get the students paid, which they need, then I have to assign them these things. So, anyway, the CURE has to be incentivized, No. 1, and then once you have

it kind of rolling with the CUREs, now the faculty are gonna be psyched about doing that specialized professional development for their students teaching those courses, particularly if it helps their students perform better in their own CURE sections."

CURE PIs like Horace expressed similar views regarding money and top-down buy-in:

"[What is needed is] money and buy-in from the upper administration. For this to be successful, there must be buy-in from the dean and the president and from – basically not at the department level, but above the department level. If there are no incentives, there will not be any major inroads."

Relatedly, CURE TAs like Luna felt that there needed to be some kind of financial incentive to foster program sustainability:

"I think it has to be incentivized to be popular and for there actually to be benefit that's measurable, [be]cause if it's not incentivized, only those new and returning CURE GTAs that had the time and really cared about teaching practices and stuff would take it."

Overall, our findings suggest that there was strong consensus that the sustainability and scalability of the SMART CUREs program may well depend on our (the SMART CUREs facilitators') ability to acquire top-down program support. It was also strongly suggested that we need to secure external funding, which would serve the dual purpose of generating more departmental and administrative buy-in while financially supporting SMART CUREs program needs.

Advocacy by Leaders and Motivated Mentors

Other participants felt that the best way to build program support and create overall program sustainability was to recruit driven faculty leaders and motivated TA mentors to champion the SMART CUREs initiative. This can be seen in responses like the one from Kingsley, an administrator, who suggested that:

> *"Maybe we could come up with CURE ambassadors for each department? There are, of course, undergraduate directors, so it could be a good collaboration between the undergraduate and graduate directors… Yeah, you have to go to them one by one, like a salesperson. Because it's not something that can be – the curriculum can't be done and emailed if you're interested. I think it's a matter of reaching out to each and every unit that they're interested in recruiting. And offering them a solution. You can ask them how their undergraduate research is going, and I'm sure some of them would be so interested in invigorating their curriculum, might be what you already offer. Especially if you are promoting a product that is already tested, already piloted, so it's not something experimental so much."*

Other administrators shared this same sentiment, as captured by the following quote from Amelia:

“So, I think you need to nitpick certain individuals in the different departments that you're gonna be doing this [in] because they are the ones that are gonna be your ambassadors with those that are more old-fashioned or have never heard of a CURE or will never have the intention of teaching a CURE and may not buy into this. It's difficult for me to believe that an individual would not buy into this when you have data that shows that students do better and that there's better retention and blah, blah, blah, the academic outcomes that we are seeing. But I think that just getting those chairs and those faculty members that you know will buy in, they will be the ones that will take care of this.”

PIs like Quirinus agreed that there was a need to find upper-level program champions within each department:

“I don’t think it would be difficult to have the buy in. But you need the upper-level people to be involved at least at the Chair or Dean level if it’s not the Provost Office level. Because the challenges are to swim against the current, and if you put that burden on the faculty, I do not think there would be any buy in. If you put that back on a structural level, I think there would be a lot of buy in.”

Similarly, TAs like Hermione expressed how supportive mentors like her own could encourage SMART CUREs participation and help sustain the program:

"So, I feel like I, if there's a program focused [on] professional development and something that's going to help us for the people who are going into academia or just overall, I think he (the PI) would very much encourage it. Last year, when I got the opportunity to be part of CURES, Dr. X mentioned it to Dr. Z, and Dr. Z was very happy for me to be able to join your program or your class. So, I think if the PIs are in a setting where they want their students to grow, then they would definitely encourage the students to attend and be part of it."

Collectively, the aforementioned findings show that there is a shared perception regarding the need for developing SMART CUREs program champions in order to achieve program longevity. Driven faculty leaders and motivative mentors have the ability to encourage TA participation and may pave the road to overall SMART CUREs program sustainability through greater departmental acceptance.

Theme 4: Expansion of Effort

Participant perceptions regarding the expansion of SMART CUREs included comments regarding optimal program timing and various program needs. All interviewees offered opinions on when the ideal time would be to offer SMART CUREs and nearly all of them (n = 20) offered detailed insight as to what they thought that rollout should look like. Exact timing of projected program implementation varied among respondents, but the general consensus was that there needed to be some type of structured and sustained effort that began prior to CURE instruction and continued for the duration of the CURE TA assignment. Comments regarding SMART

CUREs program needs included a focus on CURE fidelity, mentorship, leadership, troubleshooting, and pedagogical skill development.

Optimal Program Timing

Discussions revolving around ideal SMART CUREs program timing included participant thoughts on why a chosen program length and duration might have the most impact. For example, Dolores, an administrator, thought that exact program timing was less important than SMART CUREs being an ongoing instructor support program:

> *"I think that for most types of professional development programs, it's good to have activity throughout the year, maybe to initiate a cohort with some activity in the late fall semester into the spring. I like summer intensives, but they are not always possible, given what else is going on in the specific program."*

Amelia, another administrator, echoed this viewpoint by stating:

> *"There should be something before the graduate student starts. And I feel that, like with faculty members, there should always be an expert at some point during the semester going in and observing and giving feedback, giving recommendations. And then, if there is additional professional development that would fit that particular student – I would envision this happening at a professional society because it would be extremely useful for the student in the future. So, sometime in the beginning, sometime during the semester, and hopefully, at the end, after the semester is over, that the student has gathered some*

experience, has reached highs and lows during the experience, then go to something much more formal that is being offered by a professional society."

Aurora, a PI, also had the same opinion regarding the need for ongoing TA support:

"I say bootcamp them in August and give them support throughout the year. Because if you can get them a starter set and sit down and plan out what's your first couple of weeks gonna look like, that's really when you capture and kind of solidify the attitudes. And the perspectives of students are that that first experience they have is so vital, it's like imprinting for baby ducklings."

Supporting these previous statements, Hermione, a CURE TA, felt that ongoing support would be the most beneficial for developing instructor capacity:

"One class before the actual semester starts where you guys can focus on some of the tips and tricks all TAs or all people should know before teaching or before going into the graduate setting, and then [continue] along the semester. Maybe not meet every day, but like once a week or once every two weeks or just like how you guys did it sometimes. That would be great so that they can share their experience, they can share the activities that they did, and they can grow while applying the learning in the classes you guys will be providing to the students."

Based on the similarity in responses, there is a clear shared opinion that CURE TAs need the ongoing support that comes with participation in a teaching and learning community. It was also clear from the similarities in response that there is a shared perception that CURE TAs would most benefit from some kind of structured preparation prior to entering the CURE classroom.

SMART CUREs Program Needs

Participants were asked what they thought SMART CUREs should look like when rolled out and what type of curriculum should be targeted for CURE TAs vs. non-CURE TAs. Ludo, an administrator, thought SMART CUREs should focus on communication, as is expressed by the following:

> *"I would think you would wanna focus on the ability to communicate effectively, delegating responsibility, empowering autonomy for those students (undergraduates in CUREs). I think a fair amount of exploration leadership would be helpful in that as well as kind of overseeing a CURE environment, wanting to empower those students to feel like they are getting that real-world experience and really feeling excited about what they do."*

Amelia. an administrator, thought SMART CUREs should focus on the specific elements that define CUREs:

"They need to be trained specifically for certain aspects of that type of course (a CURE), just like there is some training for TAs for regular cookbook labs. This is a little bit more involved. Th[is] type of training involves anticipating what the students might struggle with, explaining to the students the idea that failure is a good thing, it's not a bad thing, in a research-based lab. Failure in a cookbook lab means you didn't follow the instructions to the 'T' as opposed to failure in a research lab, it's doesn't mean that. You need to troubleshoot in different ways. And the TA needs to be a little bit more involved along the lines of what is happening here. And so, the protocols when you're doing a research lab are very different."

PIs like Cuthbert similarly voiced the importance that CURE facilitators need to mentor and motivate undergraduate students in STEM, whereas Luna, a TA, was just concerned with being a better instructor in an inquiry-based learning environment:

"So, I think the GTA in a CURE setting has much more social responsibility towards STEM, towards research in the real world. And it's not just another job… So, I think training the GTA and letting them know what are the – what is the CURE program about. Helping the GTA buy into a sense of responsibility beyond 'Hey, this is my TA job.' That would be a win-win." [Cuthbert]

"CURE GTAs would especially benefit because of the different way in which we're expected to teach, like scientific inquiry-based stuff vs. just 'Here's material. Present it to

your students.' So, yeah, in other ways as well, definitely, but I think that that would be the big one, the how to actually teach in that inquiry-based environment." [Luna]

The comments regarding SMART CUREs curricular needs were interesting and valuable as we iteratively seek to improve our pilot program through SMART CUREs stakeholder feedback. Collectively, all respondent suggestions are already part of the SMART CUREs curriculum, which will continue to be iteratively reviewed to best fit CURE facilitator needs.

Theme 5: Sustaining Efforts

All participants were asked about their perception regarding the benefits and barriers associated with SMART CUREs sustainability, and all respondents offered opinions on both subthemes. Many commenters shared the opinion that a targeted PD effort would ultimately improve CURE instruction and, by extension, its effects on the undergraduate population. Benefits to the individual STEM departments and overall benefit to the university were also mentioned. Perceived barriers included fiscal, temporal, and cultural challenges.

Benefits

Administrators like Dolores could see a clear benefit to sustaining and expanding the SMART CUREs program through effective assessment that could be reproduced to successfully evaluate other PD initiatives at the university, as exemplified by the following comment:

"I see a lot of benefit in developing targeted pilot projects within departments or programs that have really good assessment built into it so that when you get to the end,

we can partner with some events in the graduate school to think about scalability and sustainability… so the kind of pilot model where something is tested in a targeted setting for one semester or two semesters."

Bob, also an administrator, could see the benefit SMART CUREs could have for faculty who are involved with CUREs by improving the way that they function to prepare increasing numbers of students to "do" science:

"The No. 1 thing would be that it would make the CUREs function better. That benefits everybody at all levels in a big way because I think CUREs have tremendous potential, [which] we have not even come close to maximizing in our department. We've run quite a number. We run, I don't know, five, six, seven, eight per semester. It's a lot. But they have really big potential because they can be that first research experience for the students. And if done correctly, then the student is interested in research. This builds our bench of students who could enter our grad programs. This benefits the faculty who need good students to do research and publish awesome papers and ultimately, hopefully, produce good science that's relevant to society and that kind of thing."

CURE PIs like Minerva could see the direct benefits SMART CUREs could have for TAs, their undergraduate students, and the university as a whole:

"We'll produce academic professionals that are better prepared to teach students, and so the reputation of the university would be enhanced that way. Right? So, we could be

known for having people who have teaching skills when they come out of graduate school. And if the TAs can engage in development of the CURE, I mean, that's also good for their CV. Right. That they've shown that they've been involved in developing the course. So, they can put that on their CV."

Likewise, Luna envisioned benefits to other TAs like herself as well as the departments they work in:

"It would help CURE GTAs in a bunch of different ways, like just really being familiar with what a CURE is and some of the best teaching practices that many of us aren't familiar with or weren't familiar with and now are more familiar [with] but could, of course, use more instruction or guidance as well. And I think that would benefit the biology department in making those students who stayed on to do science. I'm not saying it's gonna make more students stay on, but those who did stay on would have a feel for what science really is, like, really what they're getting into, more or less."

Considered together, these findings demonstrate to us that CURE contributors see clear benefits for more people than just the TAs taking part in the SMART CURE PD trainings.

Barriers

Factors dealing with funding and time constraints faced by TAs were very common among barriers cited for SMART CUREs sustainability and scalability. Kingsley, an administrator, reminded us of the time constraints TAs are likely to face that may prevent greater participation and program buy-in:

> *"One thing is we offer all these opportunities in terms of teaching and learning, scholarships, teaching and learning, and diversity, equity, and inclusion programs (e.g., CIRTL) that should be attractive to all our graduate students, not just our faculty. But the issue is how do you get them [to take advantage of] those opportunities. One thing with graduate students, of course, is that they are quite busy. They are trying to write their theses; they're trying to write their dissertations."*

Filius, another administrator, echoed an earlier finding that suggested the need for procurement of external funding to promote long-term program success:

> *"Given the fact that the TA load is higher for these kinds of courses (CUREs), right now the biggest – I don't know how you're gonna get it because there isn't the money… I think graduate students support the training; I think all that's fine. I just think that you're up against the budget wall that I don't know how you break that down. In the ideal world, I don't think there's a problem. At UTEP, I think there's a major problem. I think the best thing to do, my solution to the problem, which really sucks, is you need to find a foundation, or you need to find donors who want to put money in for this that pay for the TAs."*

Minerva, a CURE PI, reiterated the aforementioned concerns regarding TA time constraints and the intense research culture that exists at this university:

> *"I think the biggest obstacle is getting buy-in from the PIs and the grad students because the PIs want the students to be focused on research more than teaching. I'm just speaking from the R1 perspective here that UTEP is trying to maintain. And so, the PIs are pressing more on students engaging in their research and getting their experiments done and their papers written up than they are on developing teaching. That's my impression. Overall, I think that is a big obstacle."*

CURE TA Luna also voiced barriers related to time constraints and other competing interests:

> *"Mainly time, getting graduate students to be able to give up an hour every couple weeks when we have so many other groups and TA meetings and everything that are already requiring those chunks of time. So, I think time, yeah, is the big, big one. And then also, potentially, recruitment, and this would have to do with the ongoing one, not the frontloading one. If the frontloading one were to replace the other TA orientation, perfect. You already have the time kinda carved out there, and the people are already vested in it, both the people teaching it and the GTAs. But for the ongoing one, you'd be competing with other organizations that are very much trying to make their bi-weekly, hour-long meeting something you want to go to. And whether that be campus*

organizations or TA meetings, our various grad groups, you're competing for the time and interest."

Collectively, these responses highlight the research-intensive culture that exists here and at other R1 research institutions. Overcoming the competing interests and tight time constraints already faced by TAs are likely to be our most immediate barriers to broader implementation of SMART CUREs.

Discussion

The purpose of this study was two-fold in that we sought to more broadly build consensus among SMART CUREs stakeholders at our university and to seek their perspectives on SMART CURE sustainability and scalability efforts as we seek to anticipate potential obstacles to program implementation.

All participants agreed that a change in the way we prepare TAs for their roles as future faculty members is needed. This is unsurprising given that researchers have long noted that graduate school PD programs are rarely updated to coincide with the prescient challenges faced by graduate students preparing to enter the academic workforce (Haworth, 1996; Aristigueta, 1997; Schussler et al., 2015). Several administrators and PIs (n = 5) expressed concern that little had changed since they were TAs in graduate school. A few participants even recollected the "trial by fire" type of introduction that they had to teaching, and while some thought of this as a rite of passage, all participants agreed that this was antithetical to the way a CURE should operate. Discussions involving how SMART CUREs would complement existing TA PD frequently concluded that "anything is better than nothing." While it is hard to disagree with this statement, it is imperative that targeted PD activities are developed and administered to meet the needs of TAs who are actively leading undergraduate research in CURE settings and mentoring our next generation of scientists (Schussler et al., 2015).

While our interviews uncovered several PD opportunities currently available to graduate students at the institution (CIRTL, writing workshops, 3-minute thesis, etc.), few focused on teacher preparation and those available were not always accessible due to timing, departmental access, and/or the mechanisms used to disseminate program information announcements. We also discovered that the level and frequency that TA PD is offered varies by department and organization based on their needs. While arguably logical, this limits access to cross-departmental programming and interdepartmental collaboration. Different dissemination processes with a focus on engaging *all* relevant users is more likely to lead to buy-in for an innovation and may also be necessary to develop effective linkages with faculty and TAs that promote program awareness (McKenzie et al., 2005). Broader dissemination of TA PD programming announcements to include the mentors (PIs) and department chairs may also help promote TA participation.

Most participants provided suggestions regarding how the SMART CUREs curriculum could be adapted in the transition from pilot program to institutional model. While these suggestions varied widely with respect to program content, format, and optimal timing, contributors agreed that CURE-targeted PD needed to be both structured and ongoing. Previous work by our group (see Chapter 2) found that CURE TA PD should include: (a) promotion of instructors' PCK, which refers to the manner in which teachers relate their pedagogical knowledge to their subject-matter knowledge (Cochran et al., 1993); (b) strategies for engaging students in troubleshooting failure through iterative experimentation; (c) mentoring approaches and project management; and (d) strategies for promoting students' experimental design competency (i.e., ability to "do" science). All SMART CUREs interviewees agreed that CURE TAs would best be served by engaging in some type of teacher preparation immediately in the months before the CURE began. Participant suggestions for enhancing the SMART CUREs curriculum focused on improving instructor capacity as a research leader and a mentor through pedagogical development. It was also noted that the format of existing PD opportunities was restricted during the pandemic to online forums or hybrid gatherings which also limit TA involvement and interest.

Beyond the structure of the SMART CUREs initiative, participants largely agreed that to garner support and greater buy-in for SMART CUREs programming, we would need to first identify champions within the departments that offer CUREs. It was broadly suggested among participants that SMART CUREs program success would depend on these SMART CUREs champions providing both leadership and program support. This included promoting program buy-in through the leadership provided by driven faculty members or motivative mentors who already support SMART CUREs and who may be able to institute a cultural shift in the way that other faculty members value preparing CURE TAs for their roles as undergraduate teachers and mentors. It was also suggested that program champions would be needed to provide a support role through SMART CUREs program funding and departmental mandates that could require participation in TA PD courses to be awarded a CURE TA position. This was an expected outcome, as it has been established that the ongoing involvement of champions is a key factor to overcoming barriers to successful organizational change and that change was more successful when the need for innovation was defined at a high level within the organization. (Leonard-Barton & Kraus, 1985; Gustafson et al., 2003).

Regardless, there were a number of obstacles that participants suggested needed to be overcome as we seek to institutionalize and expand SMART CUREs program efforts including securing basic funding, addressing time/availability restrictions (for TAs and PIs), and overcoming a strong research-centered cultural mindset. This aligns with the suggested barriers to faculty implementing CUREs themselves, as presented by Bell et al. (2017), which include four major classes of obstacles (student, institutional, fiscal, and temporal) that would need to be overcome to achieve successful program institutionalization. As anticipated, the need for funding seemed to be of chief concern to both institutional and departmental administrative subgroups. There was also a great deal of discussion among CURE TAs and CURE PIs about the lack of time for outside interests beyond the TAs/PIs primary research focus. As this study was conducted at an R1 institution, there was also a consensus that a culture of research intensity existed, where there was a strongly-held opinion that a graduate student's primary focus should be on their research and, consequently, competing PD programming may be met with resistance. This phenomenon is not uncommon, with several prior publications noting that there are disadvantages for academic staff who commit too much time to education, as the markers of academic esteem and departmental promotion opportunities typically come through achieving particular research metrics (Cashmore et al., 2013; Gunn & Fisk, 2013; Fung & Gordon, 2016; Graham, 2015).

Despite the barriers that SMART CUREs is likely to face, several benefits were also highlighted during our interviews. Many interviewees felt, for example, that improved CURE TA instructor capacity would directly lead to enhanced undergraduate education in CUREs. It was also proposed that greater preparation of CURE TAs might ease the added workload faced by said TAs and improve instructor affect (e.g., TA teaching self-efficacy). These findings support previous conclusions presented by Goodwin et al. (2021), which emphasize that TAs may need increased support in developing their role as a mentor and researcher should they wish to maximize their effectiveness as CURE instructors. Advances in instructor capacity for TAs would ultimately provide individual STEM departments with better-run laboratory classroom environments and the university, as a whole, with greater research capacity. The most important benefit of SMART CUREs participation would, we contend, be enhancement to fidelity of implementation that would allow CURE curricula to produce the student outcomes they were designed and intended to produce.

Conclusions, Limitations, And Future Directions

As we consider our original aim of exploring to what extent SMART CUREs is a sustainable and scalable model for CURE TA PD, we feel optimistic given the feedback we received during our interviews. SMART CUREs has the continued ability to meet the needs of its stakeholders provided that we continue to iteratively review outcomes and actively use partner feedback to update program needs. The SMART CUREs program also appears to have the ability to meet the needs of new stakeholders across STEM disciples and beyond provided that we use the same standards of iteration and stakeholder engagement.

Proceeding with the roadmap for institutionalizing CURE initiatives presented by Bell et al. (2017), we aim to continue to engage SMART CUREs stakeholders as we build a community of expertise in practice and seek broader buy-in for program funding. We hope that the SMART CUREs program can continue to expand, as it has the potential of creating more impactful CURE environments that have the ability to open research doors to more undergraduates who are central stakeholders of the college system and who already face a wide array of academic and professional challenges (De & Arguello, 2020).

We acknowledge that there are limitations to this study's ability to fully capture the perceptions of *all* participants involved in SMART CUREs sustainability and scalability, as this study was conducted entirely at a single institution with a finite number of individuals. We also acknowledge that our interview groups did not include undergraduate student stakeholders whose opinions on instructors' teaching capacity may also provide additional insight into the need for CURE-centered TA PD. Finally, this study did not capture co-generative thinking among our participant subgroups, as we did conduct focus group interviews to generate discussion about their various overlapping and non-overlapping roles with respect to CURE TA PD.

Chapter 5: Overarching Conclusions

Recapitulation of Individual Study Findings

Student success and retention in STEM majors remain a priority for institutions across the United States, as less than half of enrolled undergraduates in these fields will persist in their program of study and ultimately attain a degree (ACT, 2018; McFarland et al., 2018). Notably, the importance of undergraduate STEM retention has become even more imperative with the renewed interest in biological sciences topics incited by the ongoing global COVID-19 pandemic, which has resulted in scientific findings being freely discussed in the public press and diverse scientists adopting a more prominent position as part of that conversation (Freedman et al., 2020). Students interested in various biological sciences subdisciplines have historically accounted for as many as 11% of all degree seekers (over six years of enrollment) — a statistic that is likely to grow in the upcoming years (Freedman et al., 2020). Despite this expanding interest in STEM fields, however, high attrition rates prevail, and there remains a national need for institutions of higher education to create effective and innovative programs that increase STEM retention and graduation rates (Schneider et al., 2021).

The systematic loss of undergraduates in STEM fields has been actively reported since the 1970s and usually occurs early for undergraduate degree-seekers as students struggle with introductory core curricula (Kuenzi, 2008). Poor student performance in these introductory courses can often be a result of students' expectations, perceptions, and lack of preparedness for the rigors involved in scientific study (Conley, 2003; Rask, 2010). Factors contributing to high attrition rates likewise often stem from less experienced students not having developed appropriate study habits, or metacognitive skills, to support effective learning in STEM (Costa & Kallick, 2008). In response, science faculty have been called upon to help mitigate these factors through education reform efforts that include authentic scientific practices that better reflect what scientists *actually* do (National Commission on Excellence in Education, 1983; Project Kaleidoscope, 2002; Spell et al., 2014). Student participation in traditional (i.e., apprenticeship-style) undergraduate research experiences (UREs) has long been seen as a way for faculty to achieve this goal, as these types of experiences are paramount to students' personal and professional growth (Holt, 1969; Sundberg, 2005).

Positive student outcomes associated with faculty-mentored research experiences are numerous and have been shown to improve students' persistence in STEM, understanding of disciplinary-level content knowledge, self-efficacy, and development of critical thinking skills (Seymour, 2004; Lopatto, 2006). Despite the growing evidence regarding the benefits that these research experiences provide, the apprenticeship-based structure that is inherent of traditional UREs precludes large numbers of students from participating in such experiences given the often disproportionate student-to-faculty ratio at most institutions. Course-based undergraduate research experiences (CUREs) evolved as a means of addressing some of the challenges related to faculty time, funding, and availability of space associated with traditional UREs by enabling a greater number of undergraduates to accrue some of the same benefits seen in faculty laboratories at scale. Due to their overwhelming success in promoting positive student outcomes (Jordan et al., 2014; Olimpo et al., 2016; Rodenbusch et al., 2016; Esparza et al., 2020; Smith, Olimpo, et al., 2022), many universities have catalyzed their efforts to adopt CURE curricula throughout STEM departments and beyond.

As alluded to above, increasing evidence supporting the positive impacts of CUREs on participant outcomes has led to widescale implementation of CURE curricula in introductory-level biology laboratory classrooms across diverse institutional contexts (Goodwin et al., 2021).

Positive impacts of CUREs mirror those seen with faculty laboratories, where undergraduate participation can lead to an increased interest in scientific research as well as gains in research skills, self-efficacy, and persistence in the sciences (Lopatto, 2007; Harrison et al., 2011; Brownell et al., 2012). In contrast to prescriptive laboratory curricula, CUREs adopt a discovery-based model wherein students address a research question or problem that is of interest to the broader community with an outcome that is unknown both to the students and to the instructor (Domin, 1999; Buck et al., 2008; Weaver et al., 2008; Auchincloss et al., 2014).

Consequently, the types of independent student projects conducted as part of a CURE can be as equally complex in design as those projects executed in traditional URE contexts. Given their extensive focus on student-student and student-faculty collaboration as well as their unique course design, it is unsurprising that CUREs present their own set of instructional challenges. Like their URE counterparts, CURE facilitators need to be a mentor, guide, and/or counselor to students and often have more face-to-face time with students than they would typically have in a non-CURE course (Shortlidge et al., 2017). There are also a number of other additional demands noted by faculty charged with teaching CUREs, such as: (1) increased time and work investment; (2) the expanded role of the instructor; (3) overcoming student resistance; (4) the uncertain nature of scientific research (teaching patience through iteration); (5) lack of background in scientific research (inexperience with project design) ; (6) the ability of instructors and students to deal with the unknown; and (7) an unwillingness for instructors to invest the necessary time and effort to enhance their teaching practice.

Despite these challenges, the beneficial student outcomes resultant from CURE participation have continued to augment CURE adoption within STEM laboratory curricula at universities throughout the United States. As the importance of engaging students in CUREs continues to become more mainstream in undergraduate STEM education, preparing individuals to effectively facilitate such courses becomes increasingly more relevant. Because of their widespread popularity and the number of CUREs being offered nationwide, the responsibility for teaching CUREs has fallen on a wide variety of individuals. CURE instruction varies between university, and by department, but it is always intended to be facilitated by a "senior researcher" (Auchincloss et al., 2014). Those deemed appropriate include faculty, postdoctoral fellows, and GTAs.

Variation in the types of instructors charged with CURE facilitation has led to speculation regarding the attributes of a successful CURE instructor. It is well known that GTAs are predominantly charged with facilitating introductory laboratory courses, including CUREs, within most STEM departments (Schussler et al., 2015). It is also important to note that most GTAs may be novice researchers, teachers, or both (Goodwin et al., 2021). Given that CURE instructors are expected to perform all the same classroom duties as their non-CURE counterparts who teach traditional labs, this added teaching load may be intimidating and disincentivizing. To alleviate some of the potential additional burden placed on CURE GTAs and to ensure that CUREs are implemented with high fidelity, leading to positive impacts for undergraduates and instructors alike, several calls have been made to create targeted PD programs that will better prepare the CURE instructor for the dynamic nature of their CURE classrooms (e.g., Heim & Holt, 2019; McDonald et al., 2019).

To address the immediate need for CURE GTA PD, the research described in this dissertation first aimed to define what core elements CURE faculty and GTA instructors believed should be included in CURE GTA PD. This was accomplished through a collaborative effort with Drs. Erin Shortlidge (Portland State University) and Emma Goodwin (Arizona State

University). Specifically, research procedures involved administering surveys to participants as well as engaging in small- and large-scale group discussion with biology educators from various institutions across Canada and the United States. After reviewing the literature for specific challenges related to CURE facilitation, we used participant survey data, and semi-structured interview data with CURE GTAs, to determine best practices for developing, implementing, and evaluating CURE GTA PD initiatives.

As anticipated, there was a shared consensus among respondents that effective GTA PD in the biological sciences should focus, in part, on the core features of CUREs, which include: (a) the use of scientific practices; (b) discovery; (c) broader relevance; (d) collaboration; and (e) iteration (Auchincloss et al., 2014). Additional findings indicated four primary areas of importance for CURE GTA PD program development. Specifically, these encompass: (a) promotion of instructors' PCK, which refers to the manner in which teachers relate their pedagogical knowledge to their subject-matter knowledge (Cochran et al, 1993); (b) strategies for engaging students in troubleshooting failure through iterative experimentation; (c) mentoring approaches and project management; and (d) strategies for promoting students' experimental design competency (see Chapter 2).

Our findings can be connected back to the reported challenges of developing and implementing CUREs (Shortlidge et al., 2015, Moy et al., 2019). In other words, participant responses reflect the same concerns brought up by Moy et al. (2019) and Shortlidge et al. (2015) in reference to effective CURE PD programs elements. Identification of these, and other, central CURE GTA PD themes allowed us to have a better understanding of how various CURE tenets might be effectively transformed into flexible teacher knowledge (Gudmundsdottir, 1987). Through findings revealed within this study, we were able to execute the second aim of this research: the formation of a CURE GTA PD learning community at UTEP that can ideally be used as a model for CURE TA PD programming nationwide.

We created the STEM Mentoring, Assessment, Research, and Teaching in CUREs (SMART CUREs) program with the goal of providing TAs with the necessary support to address many of the reported challenges of CURE instruction and to acquire the pedagogical skills needed for such high-impact activities to be executed properly (Cochran, 1993; Shortlidge et al., 2015; Moy et al., 2019). Our work was further informed by that of Heim and Holt (2019), who identified seven primary challenges faced by CURE GTAs (e.g., increased time investment in course implementation and planning, the unpredictable nature of scientific research), and by insight gained through our own work regarding the core tenets and effective practices for CURE GTA professional development. Collectively, we used these findings to inform best practices and to create a foundation for SMART CUREs activities and various teacher training exercises (such as active learning, backward lesson plan design, etc.).

As described in Chapter 3, the SMART CUREs program was a twelve-week intervention implemented during the Fall 2020 semester. Intervention activities included alternating bi-weekly synchronous discussions, asynchronous practical exercises, reflective journaling, and metacognitive activities. Alternating synchronous and asynchronous sessions were designed to be both theoretical and practical in nature.

SMART CUREs program effectiveness was ascertained by inviting participants to first complete a retrospective, post-intervention survey and, subsequently, to engage in a semi-structured focus group interview. The post-intervention survey captured GTAs' perceptions regarding their role as instructor, mentor, and researcher as well as their overall views regarding SMART CUREs program participation. These topics were followed up on during the focus group interview. GTA feedback confirmed that the type of targeted PD offered by the SMART CUREs program was beneficial, as it both improved instructor self-efficacy and helped them to establish their identities as both CURE instructors and future faculty researchers. GTAs also found that the community support offered by collaborating with other CURE instructors improved their confidence and allowed them to attain feedback from peers for future CURE planning and teaching strategy development. These findings align with those suggestions offered by Shortlidge et al. (2015), namely, that if adequate structural support for CUREs is provided, the challenges to implementing CUREs may be surmountable.

The success of our pilot SMART CUREs initiative drove us to consider how we might expand these same instructor benefits to more CURE GTAs in the many other departments offering them at UTEP as well as at other institutions. Therefore, our efforts for Aim 3 of this research were centered on expanding and institutionalizing the SMART CUREs program. As we made room for change in the trajectory of our audience, we sought to determine what perceptions CURE faculty, CURE TAs, and campus administrators held regarding the scalability and sustainability of the SMART CUREs program as a model for TA PD at a research-intensive, Hispanic-Serving Institution. We identified our stakeholders as those individuals who have a role in selecting or preparing GTAs for their assignments as CURE instructors as well as those individuals who may directly or indirectly benefit from properly-executed CURE instruction and, by extension, the positive student outcomes it provides.

Participants were invited to complete an online survey regarding their position, mentoring/teaching experience, and other identity-related demography. Following completion of this survey, participants were prompted to schedule a one-hour semi-structured interview. Interview questions were adapted from the intervention scale-up framework presented by

Zamboni et al. (2019), which focuses on: (a) attributes of the innovation/intervention; (b) credibility of model (evidence base for innovation); (c) relevance to concern of potential adopters; (d) relative advantage over existing practice; (e) simplicity or ease of adoption; (f) model is testable and adaptable; (g) aligned and harmonized with existing graduate PD programs; (h) networking, collaboration and partnership (to foster buy-in); (i) capacity to support scale-up (skills, size, resources and experience); (j) capacity for data collection and reporting systems; and (k) timing or window of opportunity.

Descriptive statistics were tabulated for all demographic items, with data on participants' self-reported position(s) at the university being used to cluster individuals based on role. Major interview themes cited by respondents included comments regarding: (a) the need for change; (b) existing PD structure and function; (c) developing program champions; (d) expansion; and (e) sustaining efforts. Previous studies pertaining to capacity-building factors and successful program attributes of sustained innovations were utilized to build consensus for SMART CUREs more broadly among SMART CUREs stakeholders at our university (Bell et al., 2017; Zamboni et al., 2019). Following the council of prior research on institutionalization of CUREs, we strategically discussed the SMART CUREs initiative and sought the perspectives of essential college-level stakeholders (administrators, department chairs, faculty, and GTAs), which allowed us to anticipate potential obstacles to adopting and implementing the envisioned change (Bell et al., 2017). These discussions also allowed us unique insight into existing states of affairs within the different departments at our university with the hope of generating SMART CUREs buy-in among stakeholders (Hooker, 2019).

Building upon the above points, our most important findings, as well as those of others, verify that sustainability and scalability of initiatives require critical leadership support across all levels and necessitate establishing measures that promote connectivity among stakeholders (Kampylis et al., 2013). Leadership and discourse among stakeholders are critically important because they have the capacity to foster a culture of change as communication channels open. Likewise, they contribute to participants' collaboration in sustaining the innovation (Howard et al., 2018). Discussion of CURE GTA PD revealed a clear perception that advances in instructor capacity for TAs would ultimately provide individual STEM departments with better-operating laboratory classroom environments and higher research capacity, both of which would benefit the university. We will continue to promote these benefits as we iteratively work to build a community of expertise in practice and seek broader buy-in for program funding.

Discussion of Overall Project Outcomes and Study Limitations

First and foremost, the findings of this body of research reveal a narrative regarding the need for change (Chapter 1), specific elements that needed to be addressed to affect change (Chapter 2), an example of how to address the given need (Chapter 3), and a means of sustaining and scaling a successful change initiative (Chapter 4). The need to create change in academia is not a novel concept, as ongoing change is a ubiquitous element of the educational system. However, creating effective change on the scale needed to make SMART CUREs a success will ultimately require transformational paradigmatic changes on a sufficient scale to shift prevailing values and norms (Tsoukas & Papoulias, 2005; Lewis & Sahay, 2017). Previous research acknowledges that change is never easy, and, sometimes, the cost of change may not be worth the benefits (Hattie, 2008). Critically, the body of research presented herein shows that the benefits of change exemplified by SMART CUREs participation are valuable for *all* who have invested in the CURE model of laboratory education. Further, and perhaps most importantly, this body of research shows that the challenges posited to be associated with CURE GTA PD implementation are conquerable.

Major limitations in this research have been discussed within the individual manuscripts that make up the preceding chapters of this dissertation. The overarching limitations that remain to be discussed have to do with the fact that this research was primarily conducted only at a single university. While we acknowledge that this is a major limitation impacting the robustness and generalizability of our findings, the fact that we conducted this type of research at an R1, Minority-Serving Institution has additional value that we have not yet highlighted.

This institution, like other R1 research-intensive schools, places a greater emphasis on conducting research than on teaching excellence (as determined based on faculty workload policies). This fact, we contend, makes a research-focused form of GTA PD that much more valuable for GTAs who hope to have their own labs and who are the next generation of research faculty — claims supported by our own interview data. UTEP is also heavily invested in improving the persistence rates of underrepresented minority students that constitute more than 85% of our university's population (UTEP, 2022). Consequently, promoting the preparedness of CURE GTAs to lead multifocal research projects in diverse classroom/laboratory settings is arguably a major asset to those GTAs and to the institution, for instance by simultaneously setting the undergraduates in the GTAs' classrooms up for greater success as aspiring scientists. Put in another way, if SMART CUREs found success at UTEP, it is likely to find the same success elsewhere.

Future Directions for CURE GTA PD Initiatives

This body of research was focused on our initial pilot program and did not extend to additional SMART CUREs cohorts. For this research and the type of targeted CURE GTA PD program we developed to benefit others, it will need to expand to additional cohorts of GTAs; first, more broadly within STEM departments at UTEP, then to other departments at UTEP who offer CURE curricula. We discovered during our interview process that several new CUREs had been recently designed and implemented in liberal arts departments at UTEP. We feel that SMART CUREs would be as equally beneficial to these CURE instructors as those in STEM departments, though certain modifications may need to be made to complement the varied disciplinary foci of and research approaches employed by individuals in these departments. As more CUREs are offered across different departments at UTEP, identifying additional ways to ensure that more undergraduates are exposed to these opportunities will be essential.

Because CUREs are discovery-based courses (Auchincloss et al., 2014), CURE facilitators are provided with an opportunity to practice their role as a future faculty member in an academic research setting. It is our opinion that all GTAs would benefit from preparation for this type of environment, as many graduate students, both within our own university and elsewhere (Winter et al, 2018), aspire to continue their careers in academia and one day run their own research lab. This idea of future faculty development would likely be useful to all GTAs, not just those leading a CURE. By using the SMART CUREs curriculum as a standard for other GTA PD at UTEP, in particular, greater numbers of GTAs at this campus would be better prepared for their future rolls as PIs.

On a national level, there is currently no benchmark set for how to best prepare GTAs for their roles as CURE instructors. As more universities are inspired to adopt CURE curricula, and more GTAs are called upon to facilitate CUREs, we hope that other institutions can use the findings from this research to consider whether this type of targeted PD would be beneficial to their own GTAs. If so, we hope that others are drawn to add to this work and create a standard for targeted CURE GTA PD.

An interesting set of comments arose from our interviews regarding the benefits that SMART CUREs participation could have for *all* CURE facilitators, not just GTAs. While most universities employ GTAs to teach introductory undergraduate courses like CUREs, postdoctoral fellows and faculty are still leading CURE classrooms at many institutions and may also be charged with choosing GTAs for their individual CURE assignments (Sundberg et al., 2005). With the wide variety of individuals across different departments charged with CURE instruction, it stands to reason that they would have different professional development (PD) needs and expertise to share (Bangera & Brownell, 2014; Shortlidge et al., 2017). Including these additional target audiences in upcoming SMART CUREs cohorts will be the focus of the next stage of SMART CUREs development. In adopting this approach, our hope is to create a holistic infrastructure that supports the personal and professional growth of *all* individuals within the CURE learning space.

References

ABLE. (2019). Association for Biology Laboratory Education. [ONLINE] Available at: https://www.ableweb.org/about-able/. [Accessed 20 August 2019].

ACT. (2018). National collegiate retention and persistence to degree rates. ACT Institutional Data File.

Aikens, M. L., Sadselia, S., Watkins, K., Evans, M., Eby, L. T., & Dolan, E. L. (2016). A social capital perspective on the mentoring of undergraduate life science researchers: An empirical study of undergraduate–postgraduate–faculty triads. *CBE-Life Sciences Education*, *15*(2), ar16.

American Association for the Advancement of Science [AAAS]. (2010). *Vision and Change: A Call to Action*. Retrieved October 1, 2021, from https://www.visionandchange.org/VC_report.pdf

Aristigueta, M. P. (1997). Strategy and theory for intrapersonal development in public administration education. *Journal of Public Administration Education*, *3*(2), 163-176.

Auchincloss, L. C., Laursen, S. L., Branchaw, J. L., Eagan, K., Graham, M., Hanauer, D. I., ... & Dolan, E. L. (2014). Assessment of course-based undergraduate research experiences: a meeting report. *CBE—Life Sciences Education*, **13**(1), pp. 29-40.

Austin, A. E., Campa III, H., Pfund, C., Gillian-Daniel, D. L., Mathieu, R., & Stoddart, J. (2009). Preparing STEM doctoral students for future faculty careers. *New Directions for Teaching and Learning*, *117*, 83-95.

Avery, Z. K., & Reeve, E. M. (2013). Developing effective STEM professional development programs. *Journal of Technology Education*, *25*(1), 55-69.

Bangera, G., & Brownell, S. E. (2014). Course-based undergraduate research experiences can make scientific research more inclusive. *CBE—Life Sciences Education*, *13*(4), 602-606.

Bartholomew, L. K., Parcel, G. S., & Kok, G. (1998). Intervention mapping: a process for developing theory and evidence-based health education programs. *Health education & behavior*, *25*(5), 545-563.

Bell, J. K., Eckdahl, T. T., Hecht, D. A., Killion, P. J., Latzer, J., Mans, T. L., ... & Ellis Bell, J. (2017). CUREs in biochemistry—where we are and where we should go. *Biochemistry and Molecular Biology Education*, *45*(1), 7-12.

Bencze, L., & Hodson, D. (1999). Changing practice by changing practice: Toward more authentic science and science curriculum development. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *36*(5), 521-539.

Boyer, E. L. (1990). *Scholarship reconsidered: Priorities of the professoriate*. Lawrenceville, NJ: Princeton University Press.

Brownell, S. E., Kloser, M. J., Fukami, T., & Shavelson, R. (2012). Undergraduate Biology Lab Courses: Comparing the Impact of Traditionally Based" Cookbook" and Authentic Research-Based Courses on Student Lab Experiences. *Journal of College Science Teaching*, *41*(4).

Buck, L. B., Bretz, S. L., & Towns, M. H. (2008). Characterizing the level of inquiry in the undergraduate laboratory. *Journal of college science teaching*, *38*(1), 52-58.

Cascella, B., & Jez, J. M. (2018). Beyond the teaching assistantship: CURE leadership as a training platform for future faculty. *Journal of Chemical Education*, *95*(1), 3-6.

Cashmore, A., Cane, C., & Cane, R. (2013). Rebalancing promotion in the HE sector: Is teaching excellence being rewarded. *York: Higher Education Academy*, *109*.

Center for the Improvement of Mentored Experiences in Research. (2021). *CIMER Project*. Retrieved November 30, 2021, from https://cimerproject.org/

Chen, X. (2013). STEM Attrition: College Students' Paths into and out of STEM Fields. Statistical Analysis Report. NCES 2014-001. *National Center for Education Statistics*.

Chopin, S. F. (2002). Undergraduate research experiences: The translation of science education from reading to doing. *The Anatomical Record: An Official Publication of the American Association of Anatomists*, *269*(1), 3-10.

Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational researcher*, *32*(6), 3-12.

Cochran, K. F., DeRuiter, J. A., & King, R. A. (1993). Pedagogical content knowing: An integrative model for teacher preparation. *Journal of teacher Education*, *44*(4), 263-272.

Cohen, D. K., & Ball, D. L. (1999). Instruction, capacity, and improvement.

Cohen, D. K., & Mehta, J. D. (2017). Why reform sometimes succeeds: Understanding the conditions that produce reforms that last. *American educational research journal*, *54*(4), 644-690.

Cohen, D., & Crabtree, B. (2006). Semi-structured interviews. Qualitative Research Guidelines Project.

Cole, D., & Espinoza, A. (2008). Examining the academic success of Latino students in science technology engineering and mathematics (STEM) majors. *Journal of College Student Development*, *49*(4), 285-300.

Conley, D. T. (2003). *Understanding University Success. A Report from Standards for Success*. Center for Educational Policy Research, 720 East 13th Avenue, Suite 201, Eugene, OR 97401.

Connolly, M., Lee, Y., & Savoy, J. (2018). The effects of doctoral teaching development on early-career STEM scholars' college teaching self-efficacy. *CBE-Life Sciences Education*, *17*(1), ar14.

Connolly, M., Savoy, J., Lee, Y., & Hill, L. (2016). *Building a better future STEM faculty: How doctoral teaching programs can improve undergraduate education*. Madison, WI: Wisconsin Center for Education Research, University of Wisconsin-Madison.

Connors, P. K., Lanier, H. C., Erb, L. P., Varner, J., Dizney, L., Flaherty, E. A., Duggan, J. M., Yahnke, C. J., & Hanson, J. D. (2021). Connected while distant: Networking CUREs across classrooms to create community and empower students. *Integrative and Comparative Biology*. https://doi.org/10.1093/icb/icab146.

Cooper, K. M., Gin, L. E., Akeeh, B., Clark, C. E., Hunter, J. S., Roderick, T. B., Elliott, D. B., Gutierrez, L. A., Mello, R. M., & Pfeiffer, L. D. (2019). Factors that predict life sciences student persistence in undergraduate research experiences. *PloS one, 14*(8), e0220186.

Cooper, K. M., Knope, M. L., Munstermann, M. J., & Brownell, S. E. (2020). Students who analyze their own data in a course-based undergraduate research experience (CURE) show gains in scientific identity and emotional ownership of research. *Journal of Microbiology & Biology Education*, *21*(3), doi: 10.1128/jmbe.v21i3.2157.

Corwin, L. A., Graham, M. J., & Dolan, E. L. (2015a). Modeling course-based undergraduate research experiences: An agenda for future research and evaluation. *CBE-Life Sciences Education*, *14*(1), es1.

Corwin, L. A., Runyon, C., Ghanem, E., Sandy, M., Clark, G., Palmer, G. C., Reichler, S., Rodenbusch, S. E., & Dolan, E. L. (2018). Effects of discovery, iteration, and collaboration in laboratory courses on undergraduates' research career intentions fully mediated by student ownership. *CBE-Life Sciences Education*, *17*(2), ar20.

Corwin, L. A., Runyon, C., Robinson, A., & Dolan, E. L. (2015b). The Laboratory Course Assessment Survey: A tool to measure three dimensions of research-course design. *CBE-Life Sciences Education*, *14*(4), ar37.

Costa, A. L., & Kallick, B. (Eds.). (2008). *Learning and leading with habits of mind: 16 essential characteristics for success*. ASCD.

Crane, C., Ganguli, P., Ball, S., Taylor, L., Blakemore, S. J., Byford, S., ... & Williams, J. M. G. (2020). Training school teachers to deliver a mindfulness program: exploring scalability, acceptability, effectiveness, and cost-effectiveness. *Global advances in health and medicine*, *9*, 2164956120964738.

Czerniak, C. M. (1989). *An investigation of the relationships among science teaching anxiety, self-efficacy, teacher education variables, and instructional strategies* (Doctoral dissertation, The Ohio State University).

D'Arcy, C. E., Martinez, A., Khan, A. M., & Olimpo, J. T. (2019). Cognitive and non-cognitive outcomes associated with student engagement in a novel brain chemoarchitecture mapping course-based undergraduate research experience. *Journal of Undergraduate Neuroscience Education*, *18*(1), A15.

Dahlberg, C. L., Wiggins, B. L., Lee, S. R., Leaf, D. S., Lily, L. S., Jordt, H., & Johnson, T. J. (2019). A short, course-based research module provides metacognitive benefits in the form of more sophisticated problem solving. *Journal of College Science Teaching*, *48*(4), 22-30.

Darling-Hammond, L. (1997). *Doing what matters most: Investing in quality teaching*. National Commission on Teaching & America's Future, Kutztown Distribution Center, 15076 Kutztown Road, PO Box 326, Kutztown, PA 19530-0326.

De, S., & Arguello, G. (2020). STEM Education in College: An Analysis of Stakeholders' Recent Challenges and Potential Solutions. *FDLA Journal, 5*(1), 9.

DeChenne, S. E., Enochs, L. G., & Needham, M. (2012). Science, technology, engineering, and mathematics graduate teaching assistants teaching self-efficacy. *Journal of the Scholarship of Teaching and Learning*, *12*(4), 102-123.

DeChenne, S. E., Koziol, N., Needham, M., & Enochs, L. (2015). Modeling sources of teaching self-efficacy for science, technology, engineering, and mathematics graduate teaching assistants. *CBE-Life Sciences Education, 14*(3), ar32.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational researcher, 38*(3), 181-199.

Desimone, L. M., & Garet, M. S. (2015). Best practices in teacher's professional development in the United States. *Psychology, Society, & Education*, *7*(3), 252-263.

Desimone, L.M. And Garet, M.S., (2015). Best practices in teacher's professional development in the United States.

Dewsbury, B., & Brame, C. J. (2019). Inclusive teaching. *CBE-Life Sciences Education*, *18*(2), fe2.

Diaz-Martinez, L. A., Fisher, G. R., Esparza, D., Bhatt, J. M., D'Arcy, C. E., Apodaca, J., ... & Olimpo, J. T. (2019). Recommendations for effective integration of ethics and responsible conduct of research (E/RCR) education into course-based undergraduate research experiences: A meeting report.

Dolan, E. L. (2016). Course-based undergraduate research experiences: Current knowledge and future directions. Retrieved October 1, 2021, from https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_177288.pdf

Domin, D. S. (1999). A review of laboratory instruction styles. *Journal of chemical education*, *76*(4), 543.

Duran, E., Ballone-Duran, L., Haney, J., & Beltyukova, S. (2009). The impact of a professional development program integrating informal science education on early childhood teachers' self-efficacy and beliefs about inquiry-based science teaching. *Journal of elementary science education*, *21*(4), 53-70.

Esparza, D., Wagler, A. E., & Olimpo, J. T. (2020). Characterization of instructor and student behaviors in CURE and Non-CURE learning environments: Impacts on student motivation, science identity development, and perceptions of the laboratory experience. *CBE-Life Sciences Education*, *19*(1), ar10.

Feldon, D. F., Jeong, S., Peugh, J., Roksa, J., Maahs-Fladung, C., Shenoy, A., & Oliva, M. (2017). Null effects of boot camps and short-format training for PhD students in life sciences. *Proceedings of the National Academy of Sciences*, *114*(37), 9854-9858.

Feldon, D. F., Peugh, J., Timmerman, B. E., Maher, M. A., Hurst, M., Strickland, D., Gilmore, J. A., & Stiegelmeyer, C. (2011). Graduate students' teaching experiences improve their methodological research skills. *Science*, *333*(6045), 1037-1039.

Fernandez, M. E., Ruiter, R. A., Markham, C. M., & Kok, G. (2019). Intervention mapping: theory-and evidence-based health promotion program planning: perspective and examples. *Frontiers in Public Health*, 209.

Fisher, G. R., Olimpo, J. T., McCabe, T. M., & Pevey, R. S. (2018). The Tigriopus CURE–A course-based undergraduate research experience with concomitant supplemental instruction. *Journal of Microbiology & Biology Education*, *19*(1), 19-1.

Fleming, M., House, M. S., Shewakramani, M. V., Yu, L., Garbutt, J., McGee, R., Kroenke, K., Abedin, M. Z., & Rubio, D. M. (2013). The mentoring competency assessment: Validation of a new instrument to evaluate skills of research mentors. *Academic Medicine: Journal of the Association of American Medical Colleges*, *88*(7), 1002-1008.

Foley, R.P. (1974). Microteaching for teacher training. *Public health papers,* (61), pp. 80-88.

Freedman, T. S., Headley, M. B., Serwas, N., Ruhland, M., Castellanos, C. A., Combes, A. J., & Krummel, M. F. (2020). Lessons of COVID-19: A roadmap for post-pandemic science. *Journal of Experimental Medicine*, *217*(9).

Fung, D., & Gordon, C. (2016). Rewarding educators and education leaders in research-intensive universities.

Gardner, G. E., & Jones, M. G. (2011). Pedagogical preparation of the science graduate teaching assistant: Challenges and implications. *Science Educator*, *20*(2), 31-41.

Gin, L. E., Rowland, A. A., Steinwand, B., Bruno, J., & Corwin, L. A. (2018). Students who fail to achieve predefined research goals may still experience many positive outcomes as a result of CURE participation. *CBE-Life Sciences Education*, *17*(4), ar57.

Golde, C. M., & Dore, T. M. (2001). *At cross purposes: What the experiences of today's doctoral students reveal about doctoral education*. Retrieved October 1, 2021, from https://files.eric.ed.gov/fulltext/ED450628.pdf

Goodwin, E. C., Anokhin, V., Gray, M. J., Zajic, D. E., Podrabsky, J. E., & Shortlidge, E. E. (2021). Is this science? Students' experiences of failure make a research-based course feel authentic. *CBE-Life Sciences Education*, *20*(1), ar10.

Goodwin, E. C., Cao, J., Fletcher, M., Flaiban, J., & Shortlidge, E. E. (2018). Catching the wave: Are biology graduate students on board with evidence-based teaching? *CBE-Life Sciences Education*, *17*(3), ar43.

Goodwin, E. C., Cary, J. R., & Shortlidge, E. E. (2021). Enthusiastic but Inconsistent: Graduate Teaching Assistants' Perceptions of Their Role in the CURE Classroom. CBE—Life Sciences Education, 20(4), ar66.

Gormally, C., Sullivan, C. S., & Szeinbaum, N. (2016). Uncovering barriers to teaching assistants (TAs) implementing inquiry teaching: Inconsistent facilitation techniques, student resistance, and reluctance to share control over learning with students. *Journal of Microbiology & Biology Education*, *17*(2), 215-224.

Graham, R. (2015). *Does teaching advance your academic career?: perspectives of promotion procedures in UK higher education*. Royal Academy of Engineering.

Gudmundsdottir, S. (1987). Pedagogical Content Knowledge: Teachers' Ways of Knowing.

Gunn, V., & Fisk, A. (2013). Considering teaching excellence in higher education: 2007-2013: A literature review since the CHERI report 2007.

Gustafson, D. H., Sainfort, F., Eichler, M., Adams, L., Bisognano, M., & Steudel, H. (2003). Developing and testing a model to predict outcomes of organizational change. *Health services research*, *38*(2), 751-776.

Hardré, P. L., & Burris, A. O. (2012). What contributes to teaching assistant development: differential responses to key design features. *Instructional Science*, *40*(1), 93-118.

Hark, A. T., Bailey, C. P., Parrish, S., Leung, W., Shaffer, C. D., & Elgin, S. C. (2011). Undergraduate research in the Genomics Education Partnership: A comparative genomics project exploring genome organization and chromatin structure in Drosophila. *The FASEB Journal*, *25*(1), 576.3.

Harrison, M., Dunbar, D., Ratmansky, L., Boyd, K., & Lopatto, D. (2011). Classroom-based science research at the introductory level: changes in career choices and attitude. *CBE—Life Sciences Education*, *10*(3), 279-286.

Harwood, W. (2004). An activity model for scientific inquiry. *The Science Teacher*, *71*(1), 44.

Hattie, J. (2008). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. routledge.

Haworth, J. G. (1996). Assessment in Graduate and Professional Education: Present Realities, Future Prospects. *New Directions for Institutional Research*, *92*, 89-97.

Heim, A. B., & Holt, E. A. (2019). Benefits and challenges of instructing introductory biology course-based undergraduate research experiences (CUREs) as perceived by graduate teaching assistants. *CBE—Life Sciences Education*, *18*(3), ar43.

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

Holt, C. E., Abramoff, P., Wilcox, L. V., & Abell, D. L. (1969). Investigative laboratory programs in biology: A position paper of the commission on undergraduate education in the biological sciences. *BioScience*, *19*(12), 1104-1107.

Hooker, S. (2019). Addressing a Major Barrier to Dual Enrollment: Strategies to Staff Up and Scale Up. *Jobs for the Future*.

Howard, S. K., Schrum, L., Voogt, J., & Sligte, H. (2021). Designing research to inform sustainability and scalability of digital technology innovations. *Educational Technology Research and Development*, *69*(4), 2309-2329. (Howard et al, 2021)

Hubers, M. D. (2020). Paving the way for sustainable educational change: Reconceptualizing what it means to make educational changes that last. *Teaching and teacher education*, *93*, 103083.

Hunter, A. B., Laursen, S. L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36-74.

Hurley, A., Chevrette, M. G., Acharya, D. D., Lozano, G. L., Garavito, M., Heinritz, J., Balderrama, L., Beebe, M., DenHartog, M. L., & Corinaldi, K. (2021). Tiny Earth: A big idea for STEM education and antibiotic discovery. *MBio*, *12*(1), e03432-03420.

Indorf, J. L., Weremijewicz, J., Janos, D. P., & Gaines, M. S. (2019). Adding authenticity to inquiry in a first-year, research-based, biology laboratory course. *CBE-Life Sciences Education*, *18*(3), ar38.

Ing, M., Burnette III, J. M., Azzam, T., & Wessler, S. R. (2021). Participation in a course-based undergraduate research experience results in higher grades in the companion lecture course. *Educational Researcher*, *50*(4), 205-214.

Johnson, K., Hays, C., Center, H., & Daley, C. (2004). Building capacity and sustainable prevention innovations: a sustainability planning model. *Evaluation and program planning*, *27*(2), 135-149.

Jordan, T. C., Burnett, S. H., Carson, S., Caruso, S. M., Clase, K., DeJong, R. J., Dennehy, J. J., Denver, D. R., Dunbar, D., & Elgin, S. C. (2014). A broadly implementable research course in phage discovery and genomics for first-year undergraduate students. *MBio*, *5*(1), e01051-01013.

Kampylis, P., Law, N., Punie, Y., Bocconi, S., Brecko, B., Han, S., Chee-Kit Looi, & Miyake, N. (2013). ICT-enabled innovation for learning in Europe and Asia. Exploring conditions for sustainability, scalability and impact at system level (No. JRC83503; JRC Working Papers). https://doi.org/https://doi.org/10.2791/25303. (Kampylis et al, 2013).

Kendall, K. D., & Schussler, E. E. (2012). Does instructor type matter? Undergraduate student perception of graduate teaching assistants and professors. *CBE-Life Sciences Education*, *11*(2), 187-199.

Kendall, K. D., Niemiller, M. L., Dittrich-Reed, D., & Schussler, E. E. (2014). Helping graduate teaching assistants in biology use student evaluations as professional development. *The american biology Teacher*, *76*(9), 584-588.

Krueger, R. A. (2014). *Focus groups: A practical guide for applied research*. Sage publications.

Kuenzi, J. J. (2008). Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action.

Kurdziel, J. P., Turner, J. A., Luft, J. A., & Roehrig, G. H. (2003). Graduate teaching assistants and inquiry-based instruction: Implications for graduate teaching assistant training. *Journal of Chemical Education*, *80*(10), 1206-1210.

Kusmawan, U. (2017). Online microteaching: A multifaceted approach to teacher professional development. *Journal of Interactive Online Learning*, *15*(1).

Labov, J., Brenner, K.A. & Middlecamp, C.H. (2019). Integrating Undergraduate Research in STEM with Civic Engagement.

Lanning, S., & Brown, M. (2019). Undergraduate research as a high impact practice in higher education. *Education Sciences*, *9*(160), doi:10.3390/edusci9030160.

Leonard-Barton, D., & Kraus, W. A. (1985). Implementing new technology. *Harv. Bus. Rev.;(United States)*, *63*(6).

Limeri, L. B., Asif, M. Z., Bridges, B. H. T., Esparza, D., Tuma, T. T., Sanders, D., Morrison, A. J., Rao, P., Harsh, J. A., Maltese, A. V., & Dolan, E. L. (2019). “Where’s my mentor?!”

Characterizing negative mentoring experiences in undergraduate life science research. *CBE-Life Sciences Education*, *18*(4), ar61.

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education*, *3*(4), 270-277.

Lopatto, D. (2006). Undergraduate research as a catalyst for liberal learning. *Peer Review*, *8*(1), 22-26.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE—Life Sciences Education*, *6*(4), 297-306.

Lopatto, D. (2010). Undergraduate research as a high-impact student experience. *Peer Review*, *12*(2), 27.

Lopatto, D., & Tobias, S. (2010). *Science in solution: The impact of undergraduate research on student learning*. Tucson, AZ: Research Corporation on Science Advancement.

Luft, J. A., Kurdziel, J. P., Roehrig, G. H., & Turner, J. (2004). Growing a garden without water: Graduate teaching assistants in introductory science laboratories at a doctoral/research university. *Journal of research in science teaching*, *41*(3), 211-233.

Malcom, S. (2008). Chat transcript on STEM: The push to improve science, technology, engineering, and mathematics education. *Retrieved Wells*.

McCabe, T. M., & Olimpo, J. T. (2020). Advancing Metacognitive Practices in Experimental Design: A Suite of Worksheet-Based Activities To Promote Reflection and Discourse in Laboratory Contexts. *Journal of Microbiology & Biology Education*, *21*(1), 130.

McDonald, K. K., Martin, A. R., Watters, C. P., & Landerholm, T. E. (2019). A faculty development model for transforming a department's laboratory curriculum with course-based undergraduate research experiences. *Journal of College Science Teaching*, *48*(3), 14-23.

McDonald, S. K., Keesler, V. A., Kauffman, N. J., & Schneider, B. (2006). Scaling-up exemplary interventions. *Educational Researcher, 35*(3), 15-24.

McFarland, J., Hussar, B., Wang, X., Zhang, J., Wang, K., Rathbun, A., ... & Mann, F. B. (2018). The Condition of Education 2018. NCES 2018-144. *National Center for Education Statistics*.

McKenzie, J. A., Alexander, S. A., Harper, C., & Anderson, S. (2005). Dissemination, adoption and adaptation of project innovations in higher education.

Morales, D. X., Grineski, S. E., & Collins, T. W. (2017). Increasing research productivity in undergraduate research experiences: Exploring predictors of collaborative faculty-student publications. *CBE-Life Sciences Education*, *16*(3), ar42.

Moy, M. K., Hammrich, P. L., & Kabnick, K. (2019). Developing a Tiered Mentoring Model for Teaching Assistants Instructing Course-Based Research Experiences. *Journal of College Science Teaching*, *48*(5), 59-67.

Mutambuki, J. M., & Schwartz, R. (2018). We don't get any training: The impact of a professional development model on teaching practices of chemistry and biology graduate teaching assistants. *Chemistry Education Research and Practice*, *19*(1), 106-121.

National Academies of Sciences, Engineering, and Medicine [NASEM]. (2015). *Integrating discovery-based research into the undergraduate curriculum: Report of a convocation*. Washington, DC: The National Academies Press.

National Academies of Sciences, Engineering, and Medicine [NASEM]. (2017). *Undergraduate research experiences for STEM students: Successes, challenges, and opportunities*. National Academies Press.

National Commission on Excellence in Education (1983). *A nation at risk: the imperative for educational reform. An open letter to the American people. A report to the nation and the Secretary of Education*.

National Research Council. (2003). BIO2010: Transforming undergraduate education for future research biologists.

National Research Council. (2006). *America's lab report: Investigations in high school science*. National Academies Press.

Nepeina, K., Istomina, N., & Bykova, O. (2020). The role of field training in STEM education: Theoretical and practical limitations of scalability. *European Journal of Investigation in Health, Psychology and Education*, *10*(1), 511-529.

Niederhauser, D. S., Howard, S. K., Voogt, J., Agyei, D. D., Laferriere, T., Tondeur, J., & Cox, M. J. (2018). Sustainability and scalability in educational technology initiatives: Research-informed practice. *Technology, Knowledge and Learning*, *23*(3), 507-523. (Niederhauser et al, 2018)

Nyquist, J. D., Manning, L., Wulff, D. H., Austin, A. E., Sprague, J., Fraser, P. K., ... & Woodford, B. (1999). On the road to becoming a professor: The graduate student experience. *Change: The Magazine of Higher Learning*, *31*(3), 18-27.

O'Donnell, K., Botelho, J., Brown, J., González, G. M., & Head, W. (2015). Undergraduate research and its impact on student success for underrepresented students. *New Directions for Higher Education*, *2015*(169), 27-38.

Olimpo, J. T., Fisher, G. R., & DeChenne-Peters, S. E. (2016). Development and evaluation of the Tigriopus course-based undergraduate research experience: impacts on students' content knowledge, attitudes, and motivation in a majors introductory biology course. *CBE—Life Sciences Education*, *15*(4), ar72.

Olimpo, J.T., & Kern, A. M. (2021). The DoC IT: A professional development tool to support and articulate alignment of one's course with the five dimensions of CUREs. *Journal of Microbiology & Biology Education*, *22*(3), https://journals.asm.org/doi/epdf/10.1128/jmbe.00162-21.

O'neal, C., Wright, M., Cook, C., Perorazio, T., & Purkiss, J. (2007). The impact of teaching assistants on student retention in the sciences: Lessons for TA training. *Journal of College Science Teaching*, *36*(5), 24-29.

Ost, B. (2010). The role of peers and grades in determining major persistence in the sciences. *Economics of Education Review*, *29*(6), 923-934.

Peteroy-Kelly, M. A., Marcello, M. R., Crispo, E., Buraei, Z., Strahs, D., Isaacson, M., Jaworski, L., Lopatto, D., & Zuzga, D. (2017). Participation in a year-long CURE embedded into major core genetics and cellular and molecular biology laboratory courses results in gains in foundational biological concepts and experimental design skills by novice undergraduate researchers. *Journal of Microbiology & Biology Education*, *18*(1), https://journals.asm.org/doi/pdf/10.1128/jmbe.v18i1.1226.

President's Council of Advisors on Science and Technology [PCAST], (2012). Report to the President—*Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics Executive Office of the US President*.

Project Kaleidoscope. (2002). Recommendations for action in support of undergraduate science, technology, engineering, and mathematics: Report on reports.

Prunuske, A. J., Wilson, J., Walls, M., & Clarke, B. (2013). Experiences of mentors training underrepresented undergraduates in the research laboratory. *CBE-Life Sciences Education*, *12*(3), 403-409.

Rahm, J., Miller, H. C., Hartley, L., & Moore, J. C. (2003). The value of an emergent notion of authenticity: Examples from two student/teacher–scientist partnership programs. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *40*(8), 737-756.

Ramírez-Lugo, J. S., Toledo-Hernández, C., Vélez-González, I., & Ruiz-Diaz, C. P. (2021). CREARE: A course-based undergraduate research experience to study the responses of the endangered coral *Acropora cervicornis* to a changing environment. *Journal of Microbiology & Biology Education*, *22*(1), https://journals.asm.org/doi/pdf/10.1128/jmbe.v22i1.2253C.

Rask, K. (2010). Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences. *Economics of Education Review*, *29*(6), 892-900.

Reeves, T. D., Marbach-Ad, G., Miller, K. R., Ridgway, J., Gardner, G. E., Schussler, E. E., & Wischusen, E. W. (2016). A conceptual framework for graduate teaching assistant professional development evaluation and research. *CBE—Life Sciences Education*, *15*(2), es2.

Remesh, A. (2013). Microteaching, an efficient technique for learning effective teaching. *Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences*, *18*(2), 158.

Rodenbusch, S. E., Hernandez, P. R., Simmons, S. L., & Dolan, E. L. (2016). Early engagement in course-based research increases graduation rates and completion of science, engineering, and mathematics degrees. *CBE—Life Sciences Education*, *15*(2), ar20.

Romm, I., Gordon-Messer, S., & Kosinski-Collins, M. (2010). Educating young educators: A pedagogical internship for undergraduate teaching assistants. *CBE—Life Sciences Education*, *9*(2), 80-86.

Rowland, S., Pedwell, R., Lawrie, G., Lovie-Toon, J., & Hung, Y. (2016). Do we need to design course-based undergraduate research experiences for authenticity? *CBE-Life Sciences Education*, *15*(4), ar79.

Rushin, J. W., De Saix, J., Lumsden, A., Streubel, D. P., Summers, G., & Bernson, C. (1997). Graduate teaching assistant training: A basis for improvement of college biology teaching & faculty development?. *The American biology teacher*, 86-90.

Russell, C. B., Bentley, A. K., Wink, D., Weaver, G. C., & Basu-Dutt, S. (2010). The center for authentic science practice in education: Integrating science research into the undergraduate laboratory curriculum. *Making Chemistry Relevant: Strategies for Including All Students in a Learner-Sensitive Classroom Environment*, pp.193-206.

Russell, J. A. (2009). A survey of basic instructional program graduate teaching assistant development and support processes. *Research Quarterly for Exercise and Sport*, *80*(4), 792-795.

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science*, *316*, 548-549.

Ryker, K., & McConnell, D. (2014). Can graduate teaching assistants teach inquiry-based geology labs effectively?. *Journal of College Science Teaching*, *44*(1), 56-63.

SABER. (2019). Society for the Advancement of Biology Education Research. [ONLINE] Available at: https://saberbio.wildapricot.org/. [Accessed 20 August 2019].

Sauermann H, Roach M (2012). Science PhD career preferences: levels, changes, and advisor encouragement. PLoS One 7, e36307.

Schneider, K. R., Nair, U., Straney, R., Lancey, P., & Tripp, M. (2021). First-Year STEM Research Program Facilitates Long-Term Academic Success Breadcrumb. *Journal of College Science Teaching*, *50*(4).

Schussler, E. E., Read, Q., Marbach-Ad, G., Miller, K., & Ferzli, M. (2015). Preparing biology graduate teaching assistants for their roles as instructors: An assessment of institutional approaches. *CBE—Life Sciences Education*, *14*(3), ar31.

Schwab, J. J. (1960). Inquiry, the science teacher, and the educator. *The school review*, *68*(2), 176-195.

Science Education Research Center. (2021). *CUREnet*. Retrieved November 30, 2021, from https://serc.carleton.edu/curenet/index.html

Seymour, E., & Hewitt, N. M. (1999). [BOOK REVIEW] Talking about leaving, why undergraduates leave the sciences. *Signs*, *25*(1), 294-297.

Seymour, E., Hunter, A.-B., Laursen, S. L., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education*, *88*(4), 493-534.

Shapiro, C., Moberg-Parker, J., Toma, S., Ayon, C., Zimmerman, H., Roth-Johnson, E. A., Hancock, S. P., Levis-Fitzgerald, M., & Sanders, E. R. (2015). Comparing the impact of course-based and apprentice-based research experiences in a life science laboratory curriculum. *Journal of Microbiology & Biology Education*, *16*(2), 186-197.

Shortlidge, E. E., & Eddy, S. (2018). The trade-off between graduate student research and teaching: A myth? *PloS one*, *13*(6), e0199576.

Shortlidge, E. E., Bangera, G., & Brownell, S. E. (2016). Faculty perspectives on developing and teaching course-based undergraduate research experiences. *BioScience*, *66*(1), 54-62.

Shortlidge, E. E., Bangera, G., & Brownell, S. E. (2017). Each to their own CURE: faculty who teach course-based undergraduate research experiences report why you too should teach a CURE. *Journal of Microbiology & Biology Education*, *18*(2), 18-2.

Shortlidge, E.E. And Brownell, S.E., 2016. How to assess your CURE: a practical guide for instructors of course-based undergraduate research experiences. *Journal of microbiology & biology education*, **17**(3), pp. 399.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review*, *57*(1), 1-23.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher*, *15*(2), 4-14.

Sirum, K. L., & Madigan, D. (2010). Assessing how science faculty learning communities promote scientific teaching. *Biochemistry and Molecular Biology Education*, *38*(3), 197-206.

Sparks, D. (2002). Designing powerful professional development for teachers and principals.

Spell, R. M., Guinan, J. A., Miller, K. R., & Beck, C. W. (2014). Redefining authentic research experiences in introductory biology laboratories and barriers to their implementation. *CBE—Life Sciences Education*, *13*(1), 102-110.

Starr, L. J., & DeMartini, A. (2015). Addressing the Needs of Doctoral Students as Academic Practitioners: A Collaborative Inquiry on Teaching in Higher Education. *Canadian Journal of Higher Education*, *45*(3), 68-83.

Sundberg, M. D., Armstrong, J. E., & Wischusen, E. W. (2005). A reappraisal of the status of introductory biology laboratory education in US colleges & universities. *The American Biology Teacher*, *67*(9), 525-529.

Sykes, G. (1996). Reform of and as professional development. *Phi delta kappan*, *77*(7), 464.

Tanner, K., & Allen, D. (2006). Approaches to biology teaching and learning: On integrating pedagogical training into the graduate experiences of future science faculty. *CBE—Life Sciences Education*, *5*(1), 1-6.

Tesch, R. (2013). *Qualitative research: Analysis types and software*. Routledge.

Thiry, H., Laursen, S. L., & Hunter, A.-B. (2011). What experiences help students become scientists?: A comparative study of research and other sources of personal and professional gains for STEM undergraduates. *The Journal of Higher Education*, *82*(4), 357-388.

Tsoukas, H., & Papoulias, D. B. (2005). Managing third-order change: the case of the Public Power Corporation in Greece. *Long Range Planning*, *38*(1), 79-95.

Tuma, T. T., Adams, J. D., Hultquist, B. C., & Dolan, E. L. (2021). The dark side of development: A systems characterization of the negative mentoring experiences of doctoral students. *CBE-Life Sciences Education*, *20*(2), ar16.

UTEP. (n.d.). *At a glance*. Quick Facts. Retrieved March 28, 2022, from https://www.utep.edu/initiatives/at-a-glance/

van den Boom-Muilenburg, S. N., de Vries, S., van Veen, K., Poortman, C. L., & Schildkamp, K. (2021). Understanding sustainable professional learning communities by considering school leaders' interpretations and educational beliefs. *International Journal of Leadership in Education*, 1-28.

Velasco, J. B., Knedeisen, A., Xue, D., Vickrey, T. L., Abebe, M., & Stains, M. (2016). Characterizing instructional practices in the laboratory: The laboratory observation protocol for undergraduate STEM. *Journal of Chemical Education*, *93*(7), 1191-1203.

Weaver, G. C., Russell, C. B., & Wink, D. J. (2008). Inquiry-based and research-based laboratory pedagogies in undergraduate science. *Nature chemical biology*, *4*(10), 577-580.

Wilson, S.M., Shulman, L.S., Richert, A.E., & Calderhead, J., (1987). *Exploring teachers' thinking* London: Cassell.

Winter, K., Kent, J., & Bradshaw, R. (2018). Preparing Future Faculty: A Framework for Program Design and Evaluation at the University Level. *Council of Graduate Schools: Washington DC.*

Zamboni, K., Schellenberg, J., Hanson, C., Betran, A. P., & Dumont, A. (2019). Assessing scalability of an intervention: Why, how and who?. *Health Policy and Planning*, *34*(7), 544-552.

Zehnder, C. (2016). Assessment of graduate teaching assistants enrolled in a teaching techniques course. *Journal of College Science Teaching*, *46*(1), 76.

Appendix 3.1. SMART CUREs post-semester survey items.

Please note that a PDF copy of the questionnaire can be accessed at: https://bit.ly/3IHMZ7B.

Appendix 3.2. SMART CUREs focus group interview protocol.

1. What did you find most valuable about participating in SMART CUREs this semester, and why?
2. How has the opportunity to interact with other CURE TAs as part of the SMART CUREs experience benefited you, if at all?
3. In your opinion, how has your participation in SMART CUREs influenced the way in which you plan to approach instruction for the Spring 2021 semester and/or beyond?
    a. **Follow-Up:** Tell me more about why you selected that tactic/approach.
    b. **Possible Follow-Up:** Did the online learning environment influence your decision process?

Appendix 4.1. SMART CUREs sustainability and scalability study interview protocol.

1. Do you feel that it is valuable to provide professional development (PD) for GTAs? Why, or why not?
2. What type of GTA PD programs exist in your department, if any? Are they effective?
3. Do you feel there is evidence to support the need for targeted PD programs for CURE GTAs, in particular? Why, or why not?
4. Would a targeted PD program for CURE GTAs complement existing PD within the/your [graduate school; department; etc.]?
5. Do you think a targeted PD program for CURE GTAs would be more advantageous for participants than existing departmental programs? Why, or why not?
6. How might faculty [members of the graduate school; etc.] encourage and support CURE GTA PD participation within your department/division/on campus?
7. Do you think there would be community buy in if current GTA programming were expanded to support other STEM CURE GTAs? Why, or why not?
8. If GTA programming were expanded to support other STEM CURE GTAs, how might such programming be adapted to suit their needs?
9. At what point (year) in their program should CURE GTAs be engaging in and seeking PD opportunities?
10. How might this type of targeted PD program benefit CURE GTAs? Departments? UTEP? Other institutions?
11. What do you perceive to be the challenges/obstacles associated with the scalability and sustainability of PD opportunities for CURE GTAs?

Vita

Amie M. Kern was raised at the Masonic Home and School of Texas, a children's home formerly located in Fort Worth, where she lived from the age of five until she graduated high school in 1997. Spending her formative years in an institution away from family was an immense challenge. Amie spent her early adult life in Dallas, Texas, later moving to El Paso, Texas, in 2009 to be closer to her remaining family. Amie resumed her college education and earned her Bachelor of Science degree in Microbiology with a minor in Chemistry from The University of Texas at El Paso in 2016. During graduate school, Amie has had the privilege of presenting her work at national and international professional development conferences and other workshops. Amie aspires to continue in academia and hopes to one day be an assistant professor where she can mentor other students from challenging backgrounds like her own to achieve their academic goals.

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