Research in Practice:
PREPARING AND RETAINING K-12 STEM TEACHERS IN HIGH-NEED SCHOOL DISTRICTS

A research compilation from the National Science Foundation’s Noyce Research Track
Research in Practice: Preparing and Retaining K–12 STEM Teachers in High-Need School Districts

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Preface

Sandra Richardson and Kathleen Bergin
National Science Foundation

To paraphrase an adage, if it is worth doing, it is worth studying and learning from. The National Science Foundation (NSF) is where discoveries begin. The NSF Robert Noyce Teacher Scholarship (Noyce) Program is vital because it allows researchers to discover and generate knowledge that can transform the future of science, technology, engineering, and mathematics (STEM) teacher education.

The importance of educational research directly related to discovering, studying, and promoting pathways for STEM teacher education is critically important to informing actions in teacher education, generating evidence for the broader STEM and STEM education communities, and contributing to the development of a robust research community that integrates research and education and supports excellence in STEM teacher education.

Congress authorized the Noyce Program in 2002 under the NSF Authorization Act, and the program has continued to be reauthorized under subsequent legislations. Its original goal of supporting STEM majors to become well-qualified K–12 classroom teachers is a driving force in providing high-need schools and districts with well-prepared STEM teachers who possess a depth of content knowledge in their respective STEM disciplines in concert with evidence-based pedagogies to support K–12 learners in experiencing success in STEM. The Noyce Program targets all areas of the teacher preparation and retention pipeline. The
primary focus of the Noyce Program is the support of undergraduates and post-baccalaureate students who have or wish to obtain a STEM degree through scholarship, stipends, and teaching fellowships. Projects provide induction support to new teachers and support and develop master teacher leaders across the following program tracks: Track 1: Scholarships and Stipends, Track 2: NSF Teaching Fellowships, and Track 3: NSF Master Teaching Fellowships. The program has granted over 800 awards across Tracks 1, 2, and 3 that have produced over 12,000 teachers who are currently teaching or have previously taught in high-need schools. As of 2020, there were upward of an additional 1,500 teachers who were on track to start their teaching careers after completion of the program. Noyce funds can also support the introduction of freshman and sophomore students to teaching through internships.

From the Noyce Program’s inception, Noyce-funded projects have utilized research-based evidence on the recruitment of STEM undergraduate majors and STEM teacher leaders and their preparation, induction into teaching, and leadership development. Starting in 2006, with solicitation NSF 06-528 and subsequent Noyce solicitations, several Phase II Noyce projects conducted investigations mirroring educational research, but often with small sample sizes that limited the generalizability or transferability of the findings to other preservice STEM teacher preparation programs or settings. Therefore, to support a more targeted and robust educational research agenda in the Noyce Program, in 2015, Noyce solicitation 15-530 included a new funding opportunity, Track 4: Research on the Preparation, Recruitment, and Retention of K–12 STEM Teachers. The first solicitation for Track 4 projects was broad in its invitation to support planning, exploratory research, and full-scale research proposals that addressed a set of research priorities identified by and stated in the 2010 National Research Council report Preparing Teachers: Building Evidence for Sound Policy as well as issues identified in the literature on effective teachers and the retention of effective STEM teachers and teacher leaders. This new Noyce research track provided funding for two categories of proposals: Type A—Noyce Partnerships
for Research on STEM Teacher Preparation and Type B—Research on Preparing STEM Teachers for the Future.

Over time, a key area of interest to the Noyce Program and its stakeholders has centered on the question of whether Noyce funding produces STEM teachers who remain in the teaching profession in high-need schools and districts longer than average. To more deeply explore this question, in 2016, through Noyce solicitation 16-559, the Noyce Program narrowed its research agenda in Track 4 to target the specific issues of teacher effectiveness, persistence, or retention of both Noyce and non-Noyce STEM teachers in high-need schools and districts. This explicit call for such proposals built on prior Noyce Program solicitations that welcomed proposals that carried out longitudinal research of the general experience of Noyce scholars. In later Noyce solicitations, through the time of publication of this book, the Noyce Research Track persists in its focus on STEM teacher effectiveness and retention in high-need school districts.

Because STEM teacher education is central to student success, studying all aspects of STEM teacher effectiveness and retention are important national issues. In its first 2 decades, the Noyce Program has supported hundreds of institutions and organizations with the expectation of increasing the number of qualified STEM teachers and teacher leaders in high-need schools and districts while also supporting exploratory studies and other research projects that contribute to the knowledge base of scholarly research in STEM teacher education. The Noyce Program has had a productive 7 years since the inception of the Noyce Research Track 4. As of 2022, 84 awards, encompassing a total of 39 projects over 66 distinct institutions in 29 U.S. states, have been funded through Track 4. Of these institutions, over 33% are minority-serving institutions, including one Historically Black College or University (HBCU); four Asian American-, Native American-, and Pacific Islander-Serving Institutions (AANAPISIs), nine Hispanic-Serving Institutions (HSIs), one Alaska Native- and Native Hawaiian-Serving Institution (ANNH), and seven institutions that are both AANAPISIs and HSIs. Awards to Minority Serving Institutions (MSIs)
support the need to serve groups that are historically underrepresented and underserved in STEM. The addition of Track 4 has successfully contributed to the Noyce Program by supporting educational research on STEM teacher education of both Noyce and non-Noyce teachers as well as research projects that involved Noyce projects. Thus, the Noyce research agenda has allowed for examination of sufficiently robust data to generate evidence-based trends and findings. While more research is needed to conclusively determine the impact of the Noyce Research Track on STEM teacher outcomes, effectiveness, and retention, including the enhancement of teacher effectiveness and retention of ethnically and racially diverse teachers, key findings highlighted in this book suggest promising outcomes of STEM teachers who have passed through the Noyce pipeline. Track 4 projects have touched on several important educational themes, including, but not limited to, the connection between job application and teacher retention, the effects of culturally responsive teaching, the role and effectiveness of teacher social networks and systems of support, and the impact of mentoring systems on the STEM teacher experience. The Noyce Program looks forward to continuing to fund new and exciting research on STEM teacher education.

The chapters of this book represent the ongoing research investment of the Noyce Program. The chapter authors, as well as the Noyce Program, are hopeful that those reading this book will see it as an invitation to use the findings in productive ways and an invitation to join in advancing the educational research on STEM teacher effectiveness and retention in high-need schools and districts.

Plato is quoted as saying true philosophers are “those who love to see the truth—a desire to seek and expose fundamental knowledge. But those who love the truth in each thing are to be called lovers of wisdom and not lovers of opinion.” Those involved in the Noyce Research Track 4 research agenda, and who are contributing to this book, are demonstrating their love of truth and their commitment to studying, learning, and seeking to generate knowledge that will be of use to others engaged in preparing and retaining effective STEM teachers.
Introduction

Travis T. York, Lauren Manier, and Betty Calinger
American Association for the Advancement of Science (AAAS)

The NSF has been funding innovative proposals that address the critical need for recruiting, preparing, and retaining highly effective elementary and secondary mathematics and science teachers and teacher leaders in high-need school districts through the Noyce Program for the past two decades.

In this volume, we provide eight research chapters, each study funded as part of the program’s research track (i.e., Noyce Research Track 4). As editors of this compilation, our goal for this volume was to provide a space for Noyce Research Track 4 researchers to highlight their emerging work to inform the field and, ultimately, to spark innovation and the adaptation of promising practices to support inclusive STEM teaching and learning in elementary and secondary schools, and in particular to support underrepresented students’ access and success.

Through the Noyce Research Track, NSF aims to fund research related to teacher effectiveness and persistence and to teacher retention in high-need local educational agencies. The program supports proposals that investigate the effectiveness or persistence of STEM teachers in high-need school districts and encourages studies that include substantive collaboration among STEM faculty, STEM education faculty, and educational researchers. The program also encourages studies that are conducted in collaboration with multiple institutions to increase the generalizability and implications of the study for the field of STEM teaching and learning. This volume has been developed as part of our
AAAS Noyce and Advancing Research and Innovation in the STEM Education of Preservice Teachers in High-Need School Districts (ARISE) initiatives (DUE-2041597 and DUE-1548986). These programs are housed within AAAS’s Inclusive STEMM Ecosystems for Equity and Diversity (ISEED) program unit, which seeks to reimagine and reconstruct the continuum of education and career development to achieve a just, equitable, and inclusive STEMM enterprise that leverages society’s diversity to advance science and serve society.

Chapter 1 explores the role of Noyce early career teachers’ personal support networks and self-efficacy on teacher retention in high-need schools. Authors Meltem Alemdar, Jessica Gale, Christopher Cappelli, and Katherine Boice used a mixed-method design (a quantitative component guided by social network analysis) and a survey. Interviews with nine Noyce teachers were conducted to follow up on survey responses and to gather reflections on the teachers’ experiences related to self-efficacy, retention, and their specific Noyce programs. Results show that teachers who have more connected networks are likely to remain in high-need schools and emphasize the importance of expanding teachers’ networks and the significance of receiving unique and different types of support from the people who make up their networks.

The research described in Chapter 2 by Stacey L. Carpenter, Erik Arevalo, Meghan Macias, and Julie A. Bianchini focuses on teacher recruitment, an overlooked and understudied phase of the learning-to-teach continuum. The authors investigated how CalTeach, the University of California teacher recruitment and preparation program, influenced undergraduate STEM majors’ decisions to pursue or not pursue teaching as a career; shaped their understanding of science or mathematics teaching; and, for CalTeach alumni pursuing a teaching credential, helped prepare them for teaching. Survey and interview data were collected from current and former CalTeach participants and analyzed. Findings show that strategic and comprehensive recruitment programs with purposeful field experiences connected to coursework can positively influence undergraduate STEM students’ aspirations and preparation for teaching.
Caroline Long, Soo-Yean Shim, Mark Windschitl, and Karin Lohwasser present their analysis of the learning opportunities for teacher candidates navigating the “two-worlds pitfall”—being placed in clinical experiences that have low congruence with their university preparation—in Chapter 3. They describe their mixed-method multi-case approach that included survey and interview data from 50 preservice secondary science teachers from four different teacher education graduate-level programs. The stories of three preservice teachers, Joseph, Yichen, and Emily, vividly describe how university structures, candidate agency, and mentor openness can work together to open up new learning opportunities for teacher candidates facing the two-worlds pitfall. The authors recommend how teacher educators, preservice teachers, and mentors can stimulate new opportunities to learn about teaching during the clinical placement, even when the host classroom and the university are not fully aligned.

In Chapter 4 we see a synthesis of three Noyce Research Track 4 studies that examine the impact of STEM Teacher and Researcher (STAR) Programs, which support summer research experiences for preservice and early-career science and mathematics teachers at national laboratories and other research facilities. Authors Sanlyn Buxner, Stamatis Vokos, John Keller, Catherine Good, Dermot Donnelly-Hermosillo, Larry Horvath, Deidre Sessoms, Elsa Bailey, Martyna Citkowicz, Melissa Yisak, Dan Moreno, Bo Zhu, Eleanor Fulbeck, Charlotte Chen, and Max Pardo present evidence that these teacher experiences are linked to increased positive subsequent academic and affective outcomes for their students and increase the retention of those teachers within high-need school districts. The researchers delve into a discussion of the implications of these findings and how support for summer research experiences for preservice and early-career science and mathematics teachers can be leveraged specifically to cultivate productive mind-sets for these teachers and their students.

In Chapter 5, STEM teacher employment and retention are explored by Toni Templeton, Chaunté White, Michelle Tran, and Catherine Horn. Taking a comprehensive view of the state of Texas, where 61% of the
5.4 million public school students are from economically disadvantaged backgrounds, the researchers examine the employment rate of Noyce recipient teachers versus non-Noyce recipient teachers at highest-need schools and compare these subgroups’ retention into their second year of teaching. Findings indicate a disproportionate decrease in retention of Noyce recipient teachers compared to non-Noyce recipient teachers at the same schools. The authors explore this trend and additional nuances in their analysis to better understand the factors that may be influencing teachers’ decisions about their employment. Finally, the authors engage in a critical discussion of the intended aims of the Noyce Program and how the accomplishment of these aims might be increased.

In Chapter 6, authors Douglas B. Larkin, Liz Carletta, Suzanne Poole Patzelt, and Khadija Ahmed look at factors that aid in the retention of novice teachers through the lens of teacher embeddedness. The chapter begins by describing a two-phased research project in which authors identified districts with high retention rates in four states. Looking at these districts, the authors then describe data collection efforts and findings on how factors such as fit in the organization and community, links within the organization and community, and assets in the organization and community impact teacher retention. The chapter concludes with a discussion of the factors influencing teacher retention and implications for designing supports for novice science teachers.

Similarly, Chapter 7 looks at early-career teachers. Authors Joshua A. Ellis, Natalie Carro, Andrew Marichal, Preethi Titu, and Gillian H. Roehrig discuss their Noyce Track 4 research on teacher induction to understand how and if new teachers’ reform-based beliefs change or adapt in their first year in the classroom. The chapter walks the reader through an explanatory mixed-methods study that looks at how 16 beginning science teachers (all part of the researchers’ online induction program) navigate their own beliefs on teaching and learning with teaching in the classroom. Throughout the collected data, themes of increased capacity for making learning meaningful, exercising agency in planning, and listening to
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student conversations emerged. Researchers conclude their chapter with a call for ongoing research on teachers' beliefs and practices during induction.

In Chapter 8, authors Brett Criswell, Wendy M. Smith, Jan Yow, Christine Lotter, Sally Ahrens, Gregory Rushton, Amanda Gonczi, S. Justin Polizzi, and Steve Barth discuss findings from their collaborative research grant looking at how communities of practice support teachers to become leaders. The mixed-methods study looks at teacher leaders and aims to identify factors influencing retention and the development of leadership identity. Throughout the chapter, researchers highlight accounts of how communities of practice impacted teacher leadership, identity, and networks. In summary, authors discuss how allowing teachers to lead outside of their classroom and create communities that develop leadership identities can result in greater confidence in teachers’ professional identity.

Finally, this volume ends with a Closing from the AAAS’ ISEED staff and book organizers that provides a closing and acknowledgement to the researchers featured throughout the chapters.
CHAPTER 1

An Exploratory Study: The Role of Social Networks and Self-Efficacy in the Retention of Noyce Teachers
An Exploratory Study: The Role of Social Networks and Self-Efficacy in the Retention of Noyce Teachers

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NSF DUE-1660597

Findings of this study explore interconnections among personal support networks, retention, and self-efficacy in a national sample of Noyce teachers.
ABSTRACT

The purpose of our Noyce Track 4 research, funded in 2016, was to conduct an exploratory study investigating Noyce early career teachers’ retention in high-need schools. A sequential explanatory mixed-method design was used to investigate personal networks, teaching self-efficacy, and retention among a convenience sample of early career Noyce teachers from across the nation. The quantitative component of this study was guided by social network analysis (SNA). Based on network and graph theories, SNA is a method used to investigate and interpret patterns of social ties among network individuals. Additionally, a previously validated instrument and open-ended survey items were used to measure teaching self-efficacy. Following the survey, we conducted interviews with purposively selected teachers to follow-up on their experiences related to teaching self-efficacy, retention, and their Noyce programs. Our results showed that teachers who have more connected networks are more likely to remain in high-need schools. Additionally, our study identified a set of nine characteristics of Noyce programs that were positively correlated with retention. This indicates that when a teacher was exposed to these program characteristics, there was an overall increase in the likelihood that they would remain in a high-need school. Although self-efficacy was not significantly correlated with retention, we did find correlations between teaching self-efficacy and several Noyce program characteristics. The study carries implications for educational research spanning multiple areas including SNA, teacher education, and teacher self-efficacy. This study provides novel findings documenting the nuanced ways in which the social networks of Noyce program participants and various aspects of Noyce programs themselves may influence retention among early-career teachers in high-need schools. Additionally, our results show the importance of expanding teachers’ networks and the significance of receiving unique types of support from the various people within teachers’ networks.
Introduction

Ensuring that American schools are adequately staffed with high-quality teachers is a costly and persistent challenge (Carver-Thomas & Darling-Hammond, 2019; Darling-Hammond, 1984, 1997; Goldring et al., 2014; Ingersoll et al., 2021; Milanowski & Odden, 2007). Sparked by concerns of an aging teacher population preparing for retirement, a labor-market approach to this issue resulted in calls for an “overhaul” of policies and programs aimed at recruiting teachers (Darling-Hammond, 1997, p. 4).

However, comparison of student enrollment rates, teacher retirement rates, and turnover rates of preretirement teachers shows that staffing issues are primarily due to the challenge of retaining teachers (Ingersoll, 2001). Staffing challenges continue despite an increase in the overall number of elementary and secondary teachers in the United States since the late 1980s, outpacing the increase in students during the same period (Ingersoll et al., 2021). About one-fifth of the overall increase in public school teachers during this time was due to an increase among mathematics and science teachers (Ingersoll et al., 2021). However, as the teacher population was “ballooning” over the past 3 decades, so was the instability within the teaching force, particularly among new teachers (Ingersoll et al., 2021, p. 3). Indeed, over 40% of teachers leave the teaching profession within the first five years of teaching (Ingersoll et al., 2021). Losing high-quality teachers is costly for school districts, schools, and students (Milanowski & Odden, 2007; Ronfeldt et al., 2013). Thus, recent efforts have focused on understanding why teachers, particularly early career teachers, are leaving the field and how to support teachers to improve retention. With programs such as the National Science Foundation...
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The Robert Noyce Teacher Scholarship Program, which seeks to fund projects that place teachers in high-need school districts, questions of retention become even more important. Further, the Noyce Program provides funding to institutions of higher education to offer scholarships, stipends, and programmatic support to recruit and prepare STEM majors and professionals to become K–12 teachers. The program’s overall goal is to increase the number of K–12 teachers with strong STEM content knowledge who teach in high-need school districts.

Noyce projects are designed to create a community of support, or network, for teachers. Each funded project is designed to build mentoring relationships among Noyce Program participants, referred to as Noyce Scholars, and STEM faculty. Each project is unique, corresponding to the different teacher preparation programs at each participating university and the variety of proposed components of the projects. However, little research has examined how particular elements of a Noyce project, such as the structure of the induction programs, the nature of the student teaching experience, support for finding jobs in high-need school districts, or the extent of networking opportunities, affect teacher retention or persistence in high-need schools.

Numerous studies (Vangrieken et al., 2015) show that teacher effectiveness and retention are affected by the strength and nature of teachers’ collaborative networks, both inside and outside of their school settings. When teachers have strong support networks, they are more likely to teach effectively and to remain in high-need schools. Furthermore, research has shown that teacher self-efficacy is a critical factor that impacts teacher effectiveness and retention (Bray-Clark & Bates, 2003). Decades of research provides evidence linking teachers’ self-efficacy beliefs to student achievement, the quality of teachers’ instruction, and student motivation (Klassen & Tze, 2014; Klassen et al., 2011; Zee & Koomen, 2016). Moreover, research has revealed associations between teaching self-efficacy and teachers’ psychological well-being such that self-efficacious teachers tend to be more satisfied, more committed to the profession and less susceptible to burnout than teachers with low self-efficacy (Aloe
An Exploratory Study: The Role of Social Networks and Self‑Efficacy in the Retention of Noyce Teachers

et al., 2014; Brown, 2012; Chesnut & Burley, 2015; Zee & Koomen, 2016). However, the relationship among teacher support networks, teaching self-efficacy, Noyce projects’ characteristics, and retention (intention to stay) has never been explored. The purpose of our Noyce Track 4¹ research, funded in 2016, was to conduct an exploratory study investigating the role of Noyce teachers’ personal support networks and teaching self-efficacy on teacher retention in high-need schools. Retention was defined and measured by teachers’ perceived likelihood that they would be teaching in a high-need school 3 years following the point at which they responded to the survey. The study focused on Track 1 and Track 2² Noyce early-career teachers and explored (1) whether and how Noyce teachers’ personal support networks and self-efficacy impact teacher retention in high-need schools and (2) whether and how individual Noyce program characteristics impact teachers’ personal networks and retention.

In this chapter, we present results addressing the two main research questions our study explored:

1. How do teacher personal networks and teaching self-efficacy affect early-career teacher retention in high-need schools?

2. To what extent and in what ways are Noyce program³ characteristics associated with early-career teachers’ self-efficacy beliefs, the structure of their personal networks, and retention in high-need schools?

¹ Track 4: Noyce research that focuses on effectiveness and retention of K–12 STEM teachers in high-need school districts.

² Track 1 programs fund scholarships and stipends for individuals with eligible STEM undergraduate majors and STEM professionals.

³ Track 2 programs fund teaching fellowships for eligible STEM professionals. More information on the Noyce funding tracks can be found here: https://beta.nsf.gov/funding/opportunities/robert-noyce-teacher-scholarship-program.

In the context of our study, we use the term “Noyce program” to refer to an NSF Noyce Program-funded project at a university. In preliminary interviews, we found that teachers typically referred to experiences in their “Noyce programs” and did not tend to use the term “Noyce project.” Therefore, we use the term Noyce program in our survey and description of survey findings.
A Social Network Perspective

Social network studies demonstrate that the relationship between support and teacher retention is nuanced. Educational researchers have commonly used a personal network approach to explore teacher social capital, or the resources and information available to the teacher through their connections (Baker-Doyle, 2010; Carmichael et al., 2006; Coburn et al., 2012). Other examples of teacher networks and their influence on teacher outcomes can be found in a comprehensive review by Baker-Doyle (2010), which stresses the importance of looking at social factors when examining teacher retention, especially among high-quality teachers. Baker-Doyle (2010) shows that early-career teachers' personal networks (e.g., knowledge-exchange networks) influence teachers' ability to locate support and implement curricula. Such supports help teachers navigate school politics and the ever-changing needs and demands of the school, and therefore help prevent teacher burnout and turnover. Another study found that early career teachers who developed close support networks with people similar to them with regard to race and gender (homophily, similar race and gender) were more confident in their understanding of the school environment and felt they had more social capital within their school (Baker-Doyle, 2012). Further, a study of social networks of teachers in Belgium found that it was not the frequency with which teachers received support, but the size (number of individuals in one’s network) and perceived usefulness of a teacher’s support network that was positively related to job satisfaction and intrinsic motivation to teach (Thomas et al., 2019). Understanding who provides support to teachers is also important for understanding retention. This is demonstrated in a study of teacher burnout in which levels of burnout among early career teachers at the end of the school year were related to burnout among mentors and colleagues within their social network, even after controlling for initial burnout at the beginning of the school year (Kim et al., 2017).

Social network analysis (SNA) provides a unique mechanism for understanding teacher retention by investigating the quantity and quality of connections between teachers within their organization and how these
connections may influence teachers’ decisions to remain in the field of teaching (Baker-Doyle, 2010). Social capital is important for a teacher’s professional learning, job satisfaction, and retention (for systematic review, see Demir, 2021). Different aspects of a teacher’s connections may be examined to capture variations in social capital, such as the number of other individuals in the network, frequency of connections, depth of connections, quality or value of connections, or expertise of connections (Baker-Doyle, 2010; Carmichael et al., 2006). For instance, Coburn et al. (2012) examined the personal networks of elementary school teachers over 3 years to see the impact of networks on the sustainability of a mathematics reform initiative after resources and funding for the initiative had ended. They studied how often teachers talked about mathematics with those in their networks, and used their findings to understand the strength of the relationships between the teachers. They discovered that not only was the strength of ties and expertise within the network important, but the depth of the interactions was crucial (i.e., teachers engaging in discussions with network colleagues about substantial issues concerning new mathematics curricula and innovative ways of teaching, rather than just engaging in surface issues). They also found that these characteristics were more important in the first 2 years of the initiative, when teachers were first introduced to new curricula, than in year 3. Similarly, Carmichael et al. (2006) found that the “value,” or utility, of ties as perceived by the individual was more important than the strength (i.e., frequency) of the tie when examining impact on teacher practice. This review and the previous studies cited clearly show the importance of the nature and quality of social network structure in impacting teacher outcomes, including retention and effectiveness.
Self-Efficacy

Our interest in exploring the self-efficacy of Noyce teachers is grounded in decades of educational research exploring the relationship between self-efficacy and teacher effectiveness (Bakker & Bal, 2010; Bandura, 1986; Klassen & Tze, 2014; Skaalvik & Skaalvik, 2007). According to Bandura, “teachers’ beliefs in their personal efficacy to motivate and promote learning affect the types of learning environments they create and the level of academic progress their students achieve” (1993, p. 117). One meta-analysis reviewed 43 studies and found strong associations between teacher self-efficacy and evaluations of teaching effectiveness (Klassen & Tze, 2014). Self-efficacious teachers tend to be rated more highly in terms of instruction, managing student behavior, and creating a positive classroom environment (Almog & Shechtman, 2007; Guo et al., 2012; Justice et al., 2008). Relationships between teachers’ self-efficacy and effectiveness may be reciprocal, such that teachers who have been effective can, in turn, become even more self-efficacious in the future (Bandura, 1997). Our exploration of teaching self-efficacy as a potential factor influencing retention among Noyce teachers is grounded in previous research suggesting self-efficacy may predict teacher retention (Chesnut & Burley, 2015; Wang et al., 2015). Studies exploring the correlates of teaching self-efficacy have found that self-efficacious teachers tend to report reduced levels of burnout, increased intent to persist in the teaching profession, and higher job satisfaction, relative to teachers with low self-efficacy (Caprara et al., 2006; Wang et al., 2015). In considering factors that may motivate effective teaching among Noyce Scholars, it is imperative to recognize that teachers’ self-efficacy beliefs exist not in isolation but in relation to other belief structures and the real-world teaching context. Thus, in our study we took a mixed methods approach to measuring teaching self-efficacy, utilizing validated instruments to measure teachers’ self-efficacy for instruction, classroom management, and student engagement as well as open-ended survey items and interviews to develop more nuanced, contextualized understandings of the factors influencing Noyce teachers’ self-efficacy.
Methods

A sequential explanatory mixed-method design was used to investigate early career teachers’ personal networks, self-efficacy, and retention at the national level. Data collection was sequenced to enable researchers to follow up quantitative findings with qualitative data. Thus, in this study, qualitative interview data gathered during the spring semester of the 2019–2020 school year is used in the subsequent interpretation and clarification of the results from the quantitative survey data collected in the spring of 2019.

The quantitative component of this study was guided by SNA, a method used to detect and interpret patterns of social ties among network individuals such as teachers (De Nooy et al., 2005). While traditional social science methodologies assess outcomes based on variables within individuals, network theory is unique in that it examines the relationships between individuals (Borgatti & Ofem, 2010; Wasserman & Faust, 1994). SNA provides a method to analyze these social relationships, combining quantitative, qualitative, and graphical data to provide a more complete analysis of social phenomena (Borgatti & Ofem, 2010). A network, or the resulting map of relationships, is defined as “a set of nodes or actors (individuals), along with a set of ties of a single type that connect the nodes” (Hawe et al., 2004, p. 19). One can examine networks in a few ways, taking either a personal network approach or a whole network approach. In a whole network approach, the researcher is interested in examining the network structure in a predetermined, bounded network, how this network structure influences the individual actors within it, and how an individual’s position in the network affects outcomes. In contrast, a personal network approach, which can also be referred to as an ego network approach, examines an individual’s networks from their perspective, and the networks are not predetermined by the researcher.
Participants

All teacher participants included in this study participated in a project funded by NSF’s Noyce Program. Researchers compiled a database of Noyce projects and contacted each project principal investigator with an invitation to forward study information to teachers who had completed their program within the past 5 years. This email recruitment strategy resulted in a sample of teachers from 147 Noyce projects across 30 states within the United States. As is recommended for studies of personal networks, any teacher who responded to the survey and identified only one other person in their network was removed from the data set (Perry et al., 2018). As a result, the sample in this study included 144 Noyce teachers (hereby referred to as “egos”). All were early-career teachers, defined as having taught for 5 years or less at the time the survey was administered during the spring semester of 2019. In the survey, Noyce teachers (egos) were asked to identify individuals in their support networks. A total of 1,031 individuals (henceforth referred to as “alters”) were identified by responding egos. Additionally, the network size (number of people in their support network) of the 144 egos ranged from 2 to 20, with an average of 7.16 (SD = 4.77) alters across the 144 independent personal networks. TABLE 1 provides the demographics of teachers, as well as the perceived demographics of their alters.
### TABLE 1
**Demographics of Teacher Participants and the Perceived Demographics of Their Alters**

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<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>101</td>
<td>70.1%</td>
</tr>
<tr>
<td>Male</td>
<td>43</td>
<td>29.9%</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White (Non-Hispanic)</td>
<td>104</td>
<td>73.2%</td>
</tr>
<tr>
<td>Black/African American</td>
<td>11</td>
<td>7.7%</td>
</tr>
<tr>
<td>Latino/a</td>
<td>11</td>
<td>7.7%</td>
</tr>
<tr>
<td>Asian American or Pacific Islander</td>
<td>7</td>
<td>4.9%</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>1.4%</td>
</tr>
<tr>
<td>Multiple Races</td>
<td>7</td>
<td>4.9%</td>
</tr>
<tr>
<td><strong>Grade Level Taught</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle School</td>
<td>33</td>
<td>23.2%</td>
</tr>
<tr>
<td>High School</td>
<td>95</td>
<td>66.9%</td>
</tr>
<tr>
<td>Both Middle and High School</td>
<td>14</td>
<td>9.9%</td>
</tr>
<tr>
<td><strong>Subject Taught</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td>76</td>
<td>52.8%</td>
</tr>
<tr>
<td>Mathematics</td>
<td>54</td>
<td>37.5%</td>
</tr>
<tr>
<td>Both Science and Mathematics</td>
<td>14</td>
<td>9.7%</td>
</tr>
<tr>
<td><strong>Alter Demographics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>654</td>
<td>63.7%</td>
</tr>
<tr>
<td>Male</td>
<td>372</td>
<td>36.3%</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White (Non-Hispanic)</td>
<td>815</td>
<td>81.7%</td>
</tr>
<tr>
<td>Black/African American</td>
<td>92</td>
<td>9.2%</td>
</tr>
<tr>
<td>Latino/a</td>
<td>38</td>
<td>3.8%</td>
</tr>
<tr>
<td>Asian American or Pacific Islander</td>
<td>20</td>
<td>2.0%</td>
</tr>
<tr>
<td>American Indian/Alaska Native/ Native Hawaiian</td>
<td>2</td>
<td>0.2%</td>
</tr>
<tr>
<td>Other</td>
<td>13</td>
<td>1.3%</td>
</tr>
<tr>
<td>Multiple Races</td>
<td>17</td>
<td>1.7%</td>
</tr>
</tbody>
</table>
Teachers who completed the survey indicated whether they would be willing to participate in a follow-up interview. Using a maximum variation strategy (Miles et al., 2019), a purposive sample of nine interview participants was recruited from the pool of volunteers. Specifically, the research team selected interview participants representing a range of teaching experience levels and self-efficacy and, to the extent possible, a balanced sample regarding subject area taught (mathematics or science), level taught (middle or high school), and gender. Interview participant demographics are provided in TABLE 2 below.

**TABLE 2**

*Interview Participant Demographics*

<table>
<thead>
<tr>
<th>Teacher (pseudonym)</th>
<th>Gender</th>
<th>Race/Ethnicity</th>
<th>Years Teaching</th>
<th>Undergraduate Major</th>
<th>Subject(s)</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joe</td>
<td>M</td>
<td>White</td>
<td>3</td>
<td>Physics</td>
<td>Math, Physics</td>
<td>HS</td>
</tr>
<tr>
<td>Brian</td>
<td>M</td>
<td>White</td>
<td>5</td>
<td>Biology</td>
<td>Science</td>
<td>HS</td>
</tr>
<tr>
<td>Steve</td>
<td>M</td>
<td>White</td>
<td>5</td>
<td>Chemistry</td>
<td>Chemistry, Physics</td>
<td>HS</td>
</tr>
<tr>
<td>Katy</td>
<td>F</td>
<td>White</td>
<td>2</td>
<td>Ecology, Evolutionary Biology</td>
<td>Science</td>
<td>MS</td>
</tr>
<tr>
<td>Nicole</td>
<td>F</td>
<td>White</td>
<td>2</td>
<td>Biology</td>
<td>Math</td>
<td>MS</td>
</tr>
<tr>
<td>Craig</td>
<td>M</td>
<td>White</td>
<td>3</td>
<td>Physics</td>
<td>Physics</td>
<td>HS</td>
</tr>
<tr>
<td>Alicia</td>
<td>F</td>
<td>Multi-racial</td>
<td>3</td>
<td>Math/Science Education (4th–8th grades)</td>
<td>Math</td>
<td>MS</td>
</tr>
<tr>
<td>Stephanie</td>
<td>F</td>
<td>African American</td>
<td>2</td>
<td>Secondary Math Education</td>
<td>Math</td>
<td>MS</td>
</tr>
<tr>
<td>Andrea</td>
<td>F</td>
<td>White</td>
<td>5</td>
<td>Biology</td>
<td>Biology</td>
<td>HS</td>
</tr>
</tbody>
</table>
Survey Instrument

To conduct this research, it was necessary to develop an SNA survey that is unique to the Noyce Program. The Teacher Personal Network Survey (TPNS) was primarily designed to collect information regarding teachers’ personal support networks, including the characteristics of their ties to members of their support network (e.g., strength of ties, relationship of alters to ego, type of support provided), perceived alter demographic information (e.g., alter gender), and ties among alters. Other details surrounding participants’ individual Noyce programs, such as various program characteristics and their program experiences, were also collected through the survey. Additionally, the TPNS included survey items regarding participants’ demographics, school climate, self-efficacy, and likelihood of retention. Guided by an exploratory sequential study design (Creswell & Plano Clark, 2007), the survey instrument was developed using a three-stage approach where qualitative interviews were used to inform the primarily quantitative TPNS, and the TPNS was further validated with additional cognitive interviews. A manuscript that outlines the validation of the survey is under review. A copy of the survey is provided in APPENDIX A.

Measures

Each of the measures included in the TPNS is described below.

**Name Generator**

The name generator question, where Noyce teachers were asked to identify individuals in their support network, is the most important question to set up the study. The study was designed primarily as a means to collect data regarding teachers’ personal networks. To develop teachers’ personal support networks, Noyce teachers were first asked a name generator question (“Who has supported you as a teacher?”). A name generator is used to elicit alters, or within the context of this study, the individuals who are in teachers’ support networks. For the purposes of this study, the name generator question was developed to encourage a
broad range of support alters in an effort to capture both strong and weak ties and to develop an understanding of network composition. Based on the results of the pilot study and the subsequent cognitive interviews, the final TPNS was designed to constrain the number of alters provided in the name generator to a maximum of 20 individuals. Teachers were instructed to consider people both within and outside their school and within and outside education, and to list as many names as needed to accurately depict their support network.

**Survey Questions About Noyce Support Group**

Following the name generator question, the survey included “name interpreter” items to elicit more specific information regarding the alters in a teacher’s support network, such as modes of communication, demographic information, and other questions specific to the research questions of interest. For each name interpreter question, the survey items were auto-filled with the names entered by the respondent in the name generator question, and the respondent was then able to provide information on each alter individually. The formatting of the name interpreter questions followed the recommendations of Corominas and Coenders (2006), who suggest designing the survey so that respondents answer questions on one characteristic for all alters at the same time.

For the purposes of the research presented here, information was included from two name interpreter questions that measured the strength of the connections (or “ties”) between teachers and their alters. Teachers were asked to rank how close (CLOSE) they felt to the alters in their support network on a scale from (1) Distant to (4) Especially Close. Additionally, teachers were asked to indicate how frequently they were in contact with each alter (FREQ) and were given four choices: (4) Daily, (3) Weekly, (2) Monthly, and (1) Less Often. These data were also used to create an aggregated variable (FREQ) represented by the average frequency score across all alters in an ego’s network. Teachers were also asked demographic questions regarding the alters in their network, including alter gender and race. Alter gender and race, rather than being explored
as main impacts on retention, were used to assess network homophily, which assesses the extent to which all alters in an ego’s network are similar to each other in terms of race and gender. Here, gender homophily (GENDER_HOM) represents the propensity with which the ego associated with alters in the support network that were the same gender as the ego. Race homophily (RACE_HOM) refers to the extent to which alters in the network were the same race as the ego.

**Teachers’ Network Characteristics**

Two important pieces of information about teachers’ support networks were calculated from the survey data for each respondent: the network degree (i.e., the number of individuals in the network) and the effective size (i.e., a measure of redundant ties within the network). The effective size of each network (EFFECTIVE) is a continuous variable calculated by subtracting the number of alters in a network from the mean number of ties each alter has to other alters in the network. Thus, effective size measures the connectivity or redundancy in a network, such that a network with more ties that are “redundant” (i.e., members of a participant’s network are also connected to each other) would have a lower effective size, and thus the respondent has less access to unique information but has a network of people who are more connected to each other. Conversely, a larger effective size suggests, for example, that a teacher may be receiving more unique sources of support from the members of a network of people who are less connected to each other.

**Characteristics of Noyce-Funded Programs**

Through the survey validation process, 13 characteristics were identified that are common across Noyce-funded programs (see TABLE 7). A series of independent variables representing these characteristics were used to represent participants’ exposure to characteristics of Noyce programs. Respondents were asked a series of yes or no questions to determine which characteristics they had experienced in their Noyce program. In addition, a continuous variable (CUMU_CHAR) ranging from 0 to
13 was created to represent the cumulative exposure a teacher had to the identified program characteristics. This variable was used to understand how exposure to multiple program characteristics may influence retention. Teachers were also asked to rate the effectiveness of their program’s characteristics.

**Self-Efficacy**

Self-efficacy was measured using the Teachers’ Sense of Efficacy Scale (TSES, Tschannen-Moran & Woolfolk Hoy, 2001), which asked teachers to rate their agreement with self-efficacy items along a 9-point continuum with anchors at (1) None at All, (3) Very Little, (5) Some Degree, (7) Quite a Bit, or (9) A Great Deal. The TSES has been widely utilized and is generally accepted as a valid and reliable measure of teachers’ self-efficacy beliefs (Klassen & Chiu, 2011; Zee & Koomen, 2016). Teachers completed the TSES as part of a much longer survey; therefore, this study used the 12-item short form of the instrument. The TSES included three subscales measuring self-efficacy for instructional strategies (INSTRUCT), classroom management (MANAGE), and student engagement (ENGAGE). Tschannen-Moran and Woolfolk Hoy (2001) reported strong evidence of construct validity as well as reliability values (alphas) of .90 for the scale and for each of the subscales (alphas ranging from .81 to .86).

**Retention (Dependent Variable)**

The specific interest of this study was to explore how teachers’ personal networks and teaching self-efficacy may impact retention (likelihood of staying in teaching) in high-need schools. For the purposes of this study, the dependent variable of interest was teachers’ perceived likelihood that they would be teaching in a high-need school 3 years following the point at which they responded to the survey (RET_HN). RET_HN was a continuous dependent variable on a 5-point Likert scale, ranging from (1) Very Unlikely to (5) Very Likely. Teacher responses on the dependent variable skewed toward Very Likely ($M = 4.16, SD = 1.17$).
Interviews
Nine semi-structured interviews lasting approximately 60 minutes were conducted by one of three members of the research team. Interviews were conducted by telephone during a 1-month period in the spring of the 2020 school year, which was the school year following teachers’ completion of the survey. Interviewers utilized a protocol designed to follow up on teachers’ survey responses and elicit additional reflections on teachers’ experiences related to their teaching self-efficacy, retention, and Noyce program experiences. Selected questions from the interview protocol are presented in APPENDIX B. All interviews were audio-recorded and transcribed.

Data Analysis
Descriptive analysis, correlations, and ordinary least square (OLS) regression were conducted. Descriptive and correlation analyses were conducted to further explore the data and understand possible connections among Noyce program characteristics, self-efficacy, and retention. Descriptive information was especially important to understand network composition, providing context to the teachers’ networks included as a part of this study. A series of Pearson correlations were also examined to explore possible associations between the dependent variable and the 13 Noyce program characteristics as well as the TSES subscales for self-efficacy.

Following this exploration of the data, a series of OLS regressions were conducted to examine the relationship among Noyce program characteristics, self-efficacy, characteristics of teachers’ personal networks, and retention. In this chapter, the results of two final regression models are presented, which included only statistically significant variables. One regression model was used to understand the degree to which network metrics and self-efficacy could predict retention, while the other model was used to understand the degree to which network metrics
and cumulative exposure to Noyce program characteristics could predict retention. A backward-elimination model was conducted in both models.

Interview data were subjected to sequential qualitative analysis (Miles et al., 2019). In a first round of coding, interview data were coded by one member of the research team to categorize the data according to the major topics under investigation: self-efficacy and the sources of self-efficacy, retention, and Noyce program experiences and characteristics. The next round of coding sought to identify salient patterns, themes, and stories illustrating relationships between teachers’ experiences, self-efficacy beliefs, Noyce program characteristics, and retention. A second member of the research team then reviewed all of the coded data, and any ambiguities in the coding were resolved through discussion. Following coding, partially ordered and case-ordered matrices were constructed and used to draft narrative descriptions of patterns and themes that emerged from the interview data (Miles et al., 2019). As interview findings on self-efficacy and the sources of self-efficacy have been reported previously (Gale et al., 2021), interview findings presented here focus on retention and teachers’ Noyce program experiences.

Results

The following results section is organized by research question. The first research question explores Noyce teachers’ support networks and teaching self-efficacy. The second question addresses the possible relationships among Noyce program characteristics, teachers’ networks, and self-efficacy.
Research Question 1: Personal Networks and Teaching Self-Efficacy

In this section, we describe our findings pertaining to the composition and structure of Noyce teachers’ support networks, self-efficacy, and relationships between teachers' personal networks and self-efficacy.

**Exploring Noyce Teachers’ Support Networks**

Descriptive statistics were examined to explore the network composition for all early career Noyce teachers. On average, 36.6% of alters (nominated by the teachers) in a teacher’s network were individuals employed at the same pre-K–12 school as the responding teacher and 21.3% were individuals employed at a different pre-K–12 school than the responding teacher. In previous social network studies of science and mathematics teachers, between one-third and one-half of alters were from the same school as the nominating teacher (Polizzi et al., 2016; Polizzi et al., 2021). Among all alters in the sample, those who were employed by a pre-K–12 school were primarily teachers (41.5%). To a lesser extent, alters were also principals (4.9%), assistant principals (3.8%), instructional coaches (1.7%), or para-professionals/other support professionals (1.0%). Additionally, an average of 42.1% of alters in a teacher’s network were people other than those employed by a pre-K–12 school. Among all alters in the sample, 25.2% were the egos’ former professors or advisors. To a lesser extent, alters were also spouses (3.5%), family members other than a spouse (5.7%), friends (1.5%), or former colleagues (2.1%).

Further, teachers were asked to indicate whether or not the individuals in their personal network were or are affiliated with the Noyce program. Across all networks, an average of 28.6% of alters were or are affiliated with the Noyce program, and the majority of those were identified as university faculty affiliated with the Noyce program.

In addition to network composition, other social network metrics were explored to understand the structure of teachers’ support networks (TABLE 3). Three of these network metrics had statistically significant correlations with a teacher’s perceived likelihood of retention in a
high-need school. Network degree, which provides information regarding the network size (number of individuals in a teacher’s support network), was statistically significantly negatively correlated with retention in a high-need school, as was the effective size of teachers’ networks (or the redundancy of ties between network alters). It is predictable that both network degree and effective size were significantly correlated with retention in a high-need school since effective size and network degree are highly related. In this context, where the interest is in examining teachers’ support networks, effective size provides a more meaningful measure than network degree because it provides information on how many unique sources of information, or “buckets” of support, a teacher has access to through their network. For example, family and friends may be connected to each other and represent one bucket of unique support, while other teachers and colleagues within the same school as the teacher may represent another bucket of unique support. Lastly, the correlation between the average closeness of a teacher to the individuals in their network and a teacher’s perceived likelihood of retention in a high-need school approached statistical significance ($p = .0456$). No other network metrics were found to have a substantial correlation with retention.

**Noyce Teachers’ Self-Efficacy**

The results of the TSES were explored to understand teachers’ self-efficacy overall and in each of the domains represented by the TSES subscales (i.e., classroom management, instructional strategies, and student engagement). Overall, teacher ratings of their self-efficacy were high, with overall TSES scores averaging 6.91 and ranging from 4.75 to the maximum possible score of 9.00 ($M = 6.91$, $SD = 0.86$). In regard to the subscales, on average, teachers in our study were most self-efficacious in instructional strategies (TABLE 3). Scores on the TSES were slightly lower for classroom management and student engagement subscales. As in other studies using the TSES (Klassen et al., 2009), each of the subscales had moderately positive correlations with the others, with correlation coefficients ranging from .42 to .66, indicating...
that as teachers became more self-efficacious in one area, they tended to also be more self-efficacious in others. In this sample of early career teachers, there was little correlation between self-efficacy and a teacher’s likelihood of retention in a high-need school 3 years following the survey.

### TABLE 3

*Correlation Between Retention, Teacher Self-Efficacy, and Network Metrics*

<table>
<thead>
<tr>
<th>Construct</th>
<th>Mean</th>
<th>SD</th>
<th>( r )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Efficacy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Self-Efficacy Score</td>
<td>6.91</td>
<td>0.86</td>
<td>.02</td>
</tr>
<tr>
<td>Instruction Strategies</td>
<td>7.31</td>
<td>0.98</td>
<td>-.11</td>
</tr>
<tr>
<td>Classroom Management</td>
<td>6.97</td>
<td>1.06</td>
<td>.09</td>
</tr>
<tr>
<td>Student Engagement</td>
<td>6.47</td>
<td>1.07</td>
<td>.06</td>
</tr>
<tr>
<td><strong>Network Metrics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree</td>
<td>7.19</td>
<td>4.75</td>
<td>-.26**</td>
</tr>
<tr>
<td>Density</td>
<td>0.26</td>
<td>0.14</td>
<td>.02</td>
</tr>
<tr>
<td>Heterogeneity in Alter Relationships</td>
<td>0.45</td>
<td>0.20</td>
<td>.02</td>
</tr>
<tr>
<td>Gender Homophily</td>
<td>59.19</td>
<td>26.46</td>
<td>.01</td>
</tr>
<tr>
<td>Race Homophily</td>
<td>68.32</td>
<td>36.70</td>
<td>.03</td>
</tr>
<tr>
<td>Effective Size</td>
<td>4.41</td>
<td>3.38</td>
<td>-.23**</td>
</tr>
<tr>
<td>Average Alter Closeness</td>
<td>2.76</td>
<td>0.55</td>
<td>.17*</td>
</tr>
</tbody>
</table>

Note. \( r \) = Pearson correlation coefficient representing the correlation between the specified variable and retention in a high-need school 3 years following the survey.

\* \( p < .10 \), ** \( p < .05 \)

**Noyce Teachers’ Personal Networks, Self-Efficacy, and Retention**

While we did not find substantial direct associations between each of the self-efficacy measures and retention, using characteristics of teachers’ support networks as covariates in a regression model did reveal a statistically significant relationship between one self-efficacy subscale and teachers’ perceived likelihood of retention. Self-efficacy in classroom management and student engagement, as well as network
metrics such as gender homophily, race homophily, and frequency, had no discernible impact on retention. However, the regression analysis results showed that self-efficacy in instructional practice, which had the largest correlation with retention, explains a statistically significant proportion of variance in retention when included in the model with two network metrics, closeness and effective size, $R^2 = 0.07, F(3, 129) = 4.42, p < .01$ (TABLE 4). Specifically, these results suggest that when controlling for self-efficacy in instructional practices, closeness with alters and the effective size of a teacher’s network are strongly associated with the teacher’s likelihood of retention. Recall that effective size measures redundancy in a network, such that in a network with a small effective size, there is greater connectivity among individuals in a teacher’s network, creating redundancy in the network that results in access to fewer unique buckets of support. Conversely, a network with a larger effective size, and lower redundancy within the network, suggest that a teacher is receiving more unique sources of support from the members of their network because there are fewer connections among individuals in the network. The regression results here indicate that for every unit increase in the effective size of a teacher’s network (i.e., for every additional unique source of support caused by alters who are less connected to each other), there is a statistically significant decrease in the teacher’s likelihood of retention. Put simply, when the individuals in a teacher’s network are less connected to each other, teachers are less likely to remain in a high-need school. Although one may expect that receiving support from many different “buckets” would foster retention, our data suggest that variation in the sources within a teacher’s network may be less important than connectivity among the sources.
A teacher’s perceived closeness to the individuals in their network was not statistically significantly related to retention when controlling for self-efficacy and effective size (TABLE 4). Specifically, as teachers feel closer to the alters in their network, they believe that they are more likely to remain in a high-need school 3 years following the time of the survey. Looking at this more descriptively, there is effectively no correlation between how close a teacher feels to the individuals in their network and whether those individuals are associated with their school or with another school. However, there is a small correlation between how close a teacher feels to the individuals in their network and whether those individuals are from outside of education (e.g., spouses, faculty advisors, family members, friends, etc.). Although these relationships are not statistically significant, descriptive findings in TABLE 5 provide additional information on how close teachers feel to individuals within their schools, from different schools, and outside their career. Taken together, these findings suggest that there may be some important implications of having different types of individuals in teachers’ support networks.

### TABLE 4

Regression Results With Self-Efficacy and Network Metrics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept (Closeness x Retention)</td>
<td>4.59***</td>
<td>0.89</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INSTRUCT</td>
<td>–0.14</td>
<td>0.10</td>
</tr>
<tr>
<td>Personal Network</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLOSE</td>
<td>0.35*</td>
<td>0.18</td>
</tr>
<tr>
<td>EFFECTIVE</td>
<td>–0.08***</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Adjusted $R^2$ .07

Note. SE = standard error. * $p < .10$, ** $p < .05$, *** $p < .01$
TABLE 5
How Close Teachers Feel to Different Types of Individuals in Their Networks

<table>
<thead>
<tr>
<th>Perceived Closeness of Alters</th>
<th>Distant (%)</th>
<th>Less Than Close (%)</th>
<th>Close (%)</th>
<th>Especially Close (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Know From My School</td>
<td>18 (1.8)</td>
<td>104 (10.1)</td>
<td>172 (16.8)</td>
<td>68 (6.6)</td>
</tr>
<tr>
<td>Know From a Different School</td>
<td>45 (4.4)</td>
<td>66 (6.4)</td>
<td>70 (6.8)</td>
<td>66 (6.4)</td>
</tr>
<tr>
<td>Know From Outside My Career</td>
<td>58 (5.7)</td>
<td>115 (11.2)</td>
<td>115 (11.2)</td>
<td>129 (13.6)</td>
</tr>
</tbody>
</table>

Note. n = 1026

Research Question 2: Noyce Program Characteristics, Self-Efficacy, and Personal Networks

Noyce program characteristics were explored to understand how they might relate to teachers’ self-efficacy, personal networks, and retention. TABLE 6 provides descriptive statistics for the Noyce program characteristics and correlations between each program characteristic and the likelihood of retention in a high-need school 3 years following the survey. Results indicate that fewer than 50% of participants in this study had regular meetings, were provided a STEM mentor, had student teaching experience in a school that was not considered to be a high-need school, or were provided a guaranteed job. Over 60% of teachers reported student teaching experience in a high-need school as part of their Noyce program and approximately 27% of teachers reported student teaching in a school that was not considered high-need. Correlations examining the relationship between a teacher’s exposure to each program characteristic and the likelihood of retention were calculated. Program characteristics that indicated participants were provided with any of the three types of mentor asked about in the survey (STEM faculty, STEM professionals, or other type of mentor [not faculty or STEM professional]), that they taught in a high-need school, or that they had Noyce faculty observe their
teaching resulted in the strongest positive correlations, suggesting that when a teacher was exposed to these program characteristics, there was an overall increase in the likelihood that they would remain in a high-need school 3 years following the survey. Additionally, the majority of the teachers (92%) indicated that these components were implemented effectively as part of their program. Similarly, when teachers indicated that they had an induction program, participated in a Professional Learning Community (PLC), observed others teaching, or that their Noyce program provided them with assistance finding a job, there was an increase in the likelihood that they would remain in a high-need school 3 years following the survey. Exposure to other program characteristics was not significantly correlated to the likelihood of retention.

**TABLE 6**

*C*orrelation Between Noyce Program Characteristics and Retention

<table>
<thead>
<tr>
<th>Program Characteristic</th>
<th>n</th>
<th>%</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Meetings With Noyce Scholars</td>
<td>72</td>
<td>50.3</td>
<td>.09</td>
</tr>
<tr>
<td>Regular Meetings With Mixed Attendees</td>
<td>53</td>
<td>37.0</td>
<td>.10</td>
</tr>
<tr>
<td>Provided Faculty Mentor</td>
<td>110</td>
<td>76.9</td>
<td>.28*</td>
</tr>
<tr>
<td>Provided STEM Mentor</td>
<td>60</td>
<td>42.0</td>
<td>.25*</td>
</tr>
<tr>
<td>Provided Other Mentor</td>
<td>81</td>
<td>56.6</td>
<td>.24*</td>
</tr>
<tr>
<td>Student Teaching Experience</td>
<td>38</td>
<td>26.6</td>
<td>.03</td>
</tr>
<tr>
<td>Student Teaching Experience in a High-Need School</td>
<td>86</td>
<td>60.1</td>
<td>.27*</td>
</tr>
<tr>
<td>Participated in PLC</td>
<td>75</td>
<td>52.4</td>
<td>.24*</td>
</tr>
<tr>
<td>Noyce Faculty Observed My Teaching</td>
<td>97</td>
<td>67.8</td>
<td>.30*</td>
</tr>
<tr>
<td>I Observed Others' Teaching</td>
<td>80</td>
<td>56.0</td>
<td>.23*</td>
</tr>
<tr>
<td>Provided a Guaranteed Job</td>
<td>26</td>
<td>18.2</td>
<td>.08</td>
</tr>
<tr>
<td>Provided Assistance Finding a Job</td>
<td>83</td>
<td>58.0</td>
<td>.20*</td>
</tr>
<tr>
<td>Participated in Induction Program</td>
<td>73</td>
<td>51.0</td>
<td>.23*</td>
</tr>
</tbody>
</table>

*Note. r = Pearson correlation coefficient representing the correlation between exposure to a Noyce program characteristic and the likelihood of teaching in a high-need school 3 years following the survey. n = number of teachers exposed to a given program characteristic. *p < .05
TABLE 7 presents the correlations between exposure to each Noyce program characteristic and a teacher’s total self-efficacy score as measured by the TSES. Teachers’ total self-efficacy score was statistically significantly positively correlated with being provided a mentor who was not considered a faculty or a STEM mentor, having student teaching experience in a high-need school, participating in a PLC, having faculty related to the Noyce program observe their teaching, and being provided with assistance finding a job. This suggests that being exposed to each of these characteristics may be related to higher overall self-efficacy scores among early career teachers. No other program characteristics were significantly correlated with overall self-efficacy.

**TABLE 7**

*Correlation Between Noyce Program Characteristics and Self-Efficacy*

<table>
<thead>
<tr>
<th>Program Characteristic</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Meetings With Noyce Scholars</td>
<td>.06</td>
</tr>
<tr>
<td>Regular Meetings With Mixed Attendees</td>
<td>.04</td>
</tr>
<tr>
<td>Provided Faculty Mentor</td>
<td>.02</td>
</tr>
<tr>
<td>Provided STEM Mentor</td>
<td>.05</td>
</tr>
<tr>
<td>Provided Other Mentor</td>
<td>.26*</td>
</tr>
<tr>
<td>Student Teaching Experience</td>
<td>.03</td>
</tr>
<tr>
<td>Student Teaching Experience in a High-Need School</td>
<td>.20*</td>
</tr>
<tr>
<td>Participated in PLC</td>
<td>.20*</td>
</tr>
<tr>
<td>Noyce Faculty Observed My Teaching</td>
<td>.17*</td>
</tr>
<tr>
<td>I Observed Others’ Teaching</td>
<td>.08</td>
</tr>
<tr>
<td>Provided a Guaranteed Job</td>
<td>.03</td>
</tr>
<tr>
<td>Provided Assistance Finding a Job</td>
<td>.16*</td>
</tr>
<tr>
<td>Participated in Induction Program</td>
<td>.06</td>
</tr>
</tbody>
</table>

*Note. r = Pearson correlation coefficient representing the correlation between exposure to a Noyce program characteristic and total self-efficacy score.

*p < .05*
Given the lack of strong correlations between overall self-efficacy or the self-efficacy subscales with retention in a high-need school, as well as the nonsignificant regression results previously described, self-efficacy variables were removed from further analyses. When individual program characteristics (listed in TABLE 6) were examined to assess their relationship with retention, no statistically significant results were found. Therefore, a regression was conducted to assess cumulative exposure to Noyce program characteristics (i.e., how many characteristics, in total, a teacher was exposed to). Given the statistical significance of the effective size of a teacher’s network, this variable was also included in the regression. The results suggest a statistically significant proportion of variance in retention is explained by the effective size of a network and cumulative exposure to Noyce characteristics, $R^2 = 0.10, F(2, 132) = 8.67, p < .01$ (TABLE 8). Specifically, as a teacher’s network becomes less redundant (i.e., members of a respondent’s network are less connected to each other), the likelihood of a teacher indicating that they will remain in a high-need school decreases. Additionally, when controlling for the effective size of a network, as teachers were exposed to a greater number of Noyce characteristics, they were more likely to indicate that they would remain in a high-need school 3 years following the survey. Given that

### TABLE 8

Regression Results With the Inclusion of Noyce Program Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.83</td>
<td>0.27</td>
</tr>
<tr>
<td>Personal Network</td>
<td>EFFECTIVE</td>
<td>–0.06**</td>
</tr>
<tr>
<td>Characteristics</td>
<td>CUMU_CHAR</td>
<td>0.06***</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td></td>
<td>.10</td>
</tr>
</tbody>
</table>

Note. SE = standard error. * $p < .10$, ** $p < .05$, *** $p < .01$
individual program characteristics were not statistically significant, it is possible that it is more important for teachers to be exposed to multiple characteristics than it is for them to be exposed to any single program characteristic.

Interview Findings
Overall, teachers’ reflections on Noyce-funded program experiences in interviews were consistent with survey findings. Teachers discussed a variety of ways in which their Noyce programs influenced their decisions to remain in the teaching profession. Specifically, interview data indicated three major categories of ways in which Noyce programs strengthened participants’ commitment to teaching: support from Noyce mentors, support from Noyce teacher networks, and training and support from Noyce programs. Interview data related to each of these areas are summarized below.

Support From Noyce Faculty Mentors
A number of teachers described how mentorship they received from faculty through their Noyce programs played a crucial role in their development as teachers and, in some cases, their decisions about remaining in the teaching profession. For example, Nicole described how, when she was on the verge of leaving the classroom, encouragement from family and trusted Noyce mentors convinced her to “give it one more chance”:

> About this time last year, I was trying to decide if I really wanted to continue teaching because I just felt completely beaten down and not valued in any way. Luckily, my husband is also an educator, and he plus my mentors from my Noyce Program, they basically were like, “just give it one more chance. Just one more chance.” So, I was like, “Okay, I trust y’all. So, I’m going to get one more chance.” And I interviewed at different schools and got the job. I was offered the job, and now I love teaching again. So, I completely have done a 180 because I’ve had these positive
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influences in my life. So, without this program, I probably wouldn’t be teaching right now because I would’ve given up. But because they had that support and that outreach to help me, I was able to find a better school and then be happy in my job.

Nicole goes on to contrast her experience with her Noyce mentors with her observations of support afforded to colleagues who did not participate in the Noyce program, drawing a connection between these teachers’ quitting and a lack of support:

So, I am thankful that I had the support that I had because there are several people that I graduated with who were not in this program, and after that two years of teaching, they quit because they didn’t have any support. They didn’t have anyone to reach out to when they felt like I felt. So, this program has just been probably the most profound experience because I have had that support.

Elaborating on her relationship with the faculty who facilitated her Noyce program, Nicole noted that “just being able to go to them for any advice and always having them support us really did help with my confidence,” adding that “knowing that they believed in us really did allow me to push forward and not just give up.”

As in the following reflection by Katy, a number of teachers specifically discussed support provided in conjunction with observations conducted by Noyce mentors during their first year in the classroom as an especially helpful form of support:

I think definitely that first year when I had [a mentor] who would come and observe me from Noyce and she would also provide me a lot of support throughout the school year, especially my first year with all the changes going on and the stress from it. So just having that support from Noyce my first year really did help and kept me teaching.
In a similar vein, asked to describe how her experience in her Noyce program influenced her confidence as a teacher, Nicole expressed appreciation for the sustained support she received from her Noyce mentor:

*I will say the fact that my first year teaching I had a mentor from the Noyce Program that came in and watched me teach and then gave me some really good feedback. And then he came back the next semester, and he told me that he had seen tons of growth. And even to this day, he still tells me that if I need anything to email or call him. And having that support, a physical person that I know has my back, is just . . . it’s hard to measure how beneficial that’s been.*

Although she doesn’t draw an explicit connection between mentorship and retention, Nicole’s comment that “it’s hard to measure how beneficial” the support from her mentor has been underscores the important role that Noyce mentors can play as teachers are beginning their careers.

**Support From Noyce Teacher Networks**

Teachers also credited support received from fellow Noyce Scholars, often discussing how ongoing relationships with teachers in their Noyce networks provided an outlet for discussing challenges they encountered in their first years of teaching. Interestingly, in discussing the role of their Noyce teacher networks, teachers highlighted both the benefit of engaging with other teachers enduring similar experiences and their appreciation for a community of teachers outside of their immediate school context. Asked to share how her Noyce program influenced her early teaching experiences, Andrea highlighted her Noyce teacher network, noting, “the friends that I made with the Noyce Program, always having to be able to go to them if anything was ever bothering you, and knowing they were going through the same thing.” Similarly, Katy shared that she felt that her experiences with the Noyce program definitely increased the likelihood that she will stay in the classroom, describing the role her network of fellow Noyce Scholars played as a “judgment-free,” “outside community”: 
Because I think with some of the challenges I’ve faced, talking about them in-house, in my school, in the place where the problems are happening, does benefit me, but being able to have a nonbiased, outside community to share with in a judgment-free, supporting environment about things that happen in my building is really, really, really important.

In addition to lending insight into the ways in which networks of Noyce teachers provide support during the early years of teaching, teachers’ descriptions of their Noyce networks were also consistent with the relationship between the effective size of teacher networks and retention we found in our survey data. Teachers were not asked to give detailed accounts of their networks in our interviews. However, like Katy’s description of her Noyce community above, when teachers discussed receiving support from other Noyce teachers, they almost always described an interconnected group of teachers rather than relationships with individual Noyce Scholars. For example, in the following interview excerpt, Brian contrasts the teacher shortage with retention among his Noyce cohort, which he characterizes as having “camaraderie”:

People are just not wanting to go into education right now, and I don’t know if it’s gotten any better. I’m going to guess it’s probably not. But, not us, because we had a good camaraderie between us I feel. And I feel like as new Scholars came in, I feel like the camaraderie between our class was great.

Training and Support From Noyce Programs

In addition to discussing supportive relationships with Noyce mentors and other Noyce Scholars, teachers often cited training and support provided by their Noyce programs as strengthening their resolve to stay in teaching. In the following interview excerpt, Alex describes the impact of Noyce classes offered by a particular faculty member, noting that, if not for this particular experience, she “probably would not be teaching right now”: 
An Exploratory Study: The Role of Social Networks and Self-Efficacy in the Retention of Noyce Teachers

The program in general helped me out a lot, especially with the classes by [Noyce faculty member]. She incorporated a lot of panels where guest teachers would come in and talk about just how to survive your first couple of years, and I honestly feel like if that was not provided to me, I probably would not be teaching right now. They taught so many things, such as how to manage my time in the classroom, outside of the classroom, how to have a life, how to lesson plan, what to look for when aggressively monitoring, how to manage a classroom, and things of that nature. So, I feel like my confidence level, it was kind of shaky when I first started, but looking back, I feel like if I were not given those tools, I would not know where to start.

Teachers mentioned other specific forms of support from Noyce programs, including arranging student teaching placement in high-need schools, assistance searching for and applying to teaching positions, opportunities to attend conferences, and financial support. As illustrated in the following reflection by Rachel, a few teachers described how receiving a Noyce scholarship influenced their motivation to continue teaching:

I always felt supported and people believed in me. I felt [this way] initially even when I wasn’t sure if I was going to be good at this or I could handle it, the people that gave me the Noyce scholarship, if nothing else, showed me financially. I almost got a full ride to my master’s program. That showed me that they believed in me. They were willing to devote the resources they had to see me succeed. I thought that was really meaningful. Every time I was having a bad day, I would sit there and think, someone paid for me to go to grad school, because they believed in me. I need to live up to that. I can’t let them down. Someone invested a lot in me. I need to be the person that they thought I could be.
Thus, Rachel saw the scholarship support afforded by her Noyce program not merely as a way to make a teaching degree affordable, but also as a meaningful investment that signaled that the program believed in her.

Discussion

In the following section, we share interpretations of results for each research question, followed by a discussion of limitations of the study and the significance of our findings for research, policy, and practice.

Noyce Teachers’ Network Composition

Building on previous social network studies, our analysis of the composition of teachers’ networks extends prior work by looking specifically at the networks of early career Noyce teachers and how these networks relate to teachers’ perceived retention decisions. Findings suggest that Noyce teachers rely heavily on fellow teachers in their schools for support, but they also rely on relationships established during their preservice Noyce programs. Indeed, more than a quarter of all alters identified by teachers were affiliated with Noyce. Similarly, former professors and advisors represented a quarter of all alters identified by teachers.

Among the teachers in this study, the support networks included individuals from within and outside of their schools as well as within and outside of education more generally. Often, the members of teachers’ support networks were individuals within their school (e.g., other teachers). It is therefore likely that within a network, these individuals are more connected to each other than, for example, a spouse may be to an individual within a teacher’s school. Our results suggest that the perceived likelihood of retention increases as the connections between individuals in a network increase (i.e., lower effective size). Therefore, it is possible that, in terms of retention, teachers’ connections to individuals
who are also well connected to each other may be more important than having access to many different “buckets” of unique support. In their study of the social networks of nine Noyce Master Teaching Fellows, Polizzi et al. (2016) gathered teachers’ perspectives on the benefits of well-connected or “high density” networks. Teachers indicated that well-connected networks foster collaboration among teachers, a shared vision or culture, and ease of enacting new initiatives (Polizzi et al., 2016). In a later study by Polizzi et al. (2021), the authors explored mathematics and science teachers’ perceptions of how connected the contacts within their networks were by showing teachers images of network maps and having them rate which map most closely resembled how connected the contacts within their own network were. Teachers’ perceptions of the connections between others in their network were significantly correlated with aspects of positive science and mathematics identity (Polizzi et al., 2021). These studies, though not exploring retention specifically, can be used to further understand how highly connected networks, while lacking many different buckets of support, may influence teacher retention.

**FIGURE 1** provides an example of a teacher in this study with a network that demonstrates this idea. This teacher indicated that they are “likely” to remain in a high-need school 3 years following the time of the survey. As is apparent in this teacher’s personal network, the majority of individuals are from within their own school, while a lesser number of individuals they identified as being a part of their support network are from another school or are individuals from outside education (e.g., friends, family, faculty advisors, etc.). **FIGURE 2** shows another example of a teacher in the study with low interconnectedness in their support network. This teacher reported that they are less likely to stay in a high-need school. Importantly, the grouping of individuals circled was identified as the largest clique in this network, which most simply can be described as the subset of the network where individuals are more closely connected to each other than they are to other individuals within the support network. Note that this subnetwork of highly connected individuals mainly consists of colleagues within the teacher’s school who are well connected to
each other but not as well connected to colleagues from outside of this teacher’s school or to those individuals whom the teacher does not consider a colleague. This clique could be considered one “bucket” of unique information available for this teacher to access in their network.

FIGURE 1
Example of Network Diagram Illustrating Sources of Support With High Interconnectedness

FIGURE 2
Example of Network Diagram Illustrating Sources of Support With Low Interconnectedness
Our analysis of Noyce teachers’ networks also provides some preliminary evidence that, in addition to having a network with fewer unique “buckets” of support, how close teachers feel to the people in their network may matter. Specifically, although the correlation between closeness and retention only approached significance, our descriptive results and interview data suggest that cultivating close relationships within schools and communities of teachers, such as Noyce program cohorts, may influence teachers’ decisions about whether and how long to stay in the profession. Additionally, our results suggest that maintaining close relationships with those outside their school settings, including Noyce faculty and advisors, may be linked to increased retention at 3 years.

Self-Efficacy and Retention

Noyce teachers in our sample reported fairly high self-efficacy, with an average TSES score of 6.91 on a 9-point scale. The level of self-efficacy reported by teachers in our sample may be an indication of Noyce projects’ success when it comes to fostering teaching self-efficacy during the induction period. At the same time, it should be noted that it is not unprecedented for teachers to report high self-efficacy early in their careers. For example, in their study comparing self-efficacy beliefs of novice and experienced teachers, Tschannen-Moran and Woolfolk Hoy (2007) found that novice teachers with 3 or fewer years of experience scored similarly to our sample, with an average TSES score of 6.87, but significantly lower than experienced teachers, who reported an average TSES score of 7.29. Notably, other studies have reported somewhat lower TSES values, such as Chang and Engelhard’s study of the psychometric quality of the TSES (2016) that reported average ratings on TSES items between 4.0 and 5.87 and invariance across years of teaching experience. Still other studies report patterns indicating fluctuations in self-efficacy over the course of teachers’ careers. Studies of self-efficacy and teaching experience have found that self-efficacy does not always develop linearly (Klassen & Chiu, 2010; Woolfolk Hoy & Burke Spero, 2005). For example, in one longitudinal study, Woolfolk Hoy and Burke Spero (2005) found
that beginning teachers’ self-efficacy increased initially before decreasing over the course of their first year of teaching. Klassen and Chiu (2010) found a nonlinear relationship between years of experience and self-efficacy, with self-efficacy increasing from early to mid-career before declining later in teachers’ careers. We share additional analyses of our self-efficacy data, including patterns in the sources of self-efficacy according to teachers’ experience levels, in a recent publication (Gale et al., 2021). Future studies could advance our understanding of teaching self-efficacy among Noyce teachers by exploring the development and trajectory of teaching self-efficacy among Noyce teachers longitudinally, with particular attention to how teachers’ Noyce program experiences may influence self-efficacy at different stages of teachers’ careers.

Given previous research indicating relationships between self-efficacy and teachers’ commitment to the profession, job satisfaction, and incidence of burnout (e.g., Aloe et al., 2014; Chesnut & Burley, 2015), it was interesting that we did not find a relationship between self-efficacy and retention in our sample. One explanation may be that the unique context of Noyce programs introduces other factors and incentives for retention, such as fulfilling requirements for program stipends, which may eclipse teachers’ beliefs about their teaching ability as they make retention decisions. Specifically, as a condition of their scholarship, alumni of Noyce programs are asked to commit to teaching in a high-need school for a specified number of years. Teachers who do not fulfill these requirements risk having scholarships converted to loans. For many teachers, the financial incentive to avoid the burden of student loan debt may be a salient factor in their decision to continue teaching in a high-need school. Additionally, given their relatively high self-efficacy and their newness to the profession, it may have been the case that few teachers in our study have endured experiences negative enough to pose a threat to their self-efficacy and, in turn, their commitment to teaching. Finally, although we aimed to achieve a diverse national sample of Noyce teachers, it is possible that teachers who volunteered for the study are not necessarily representative of all Noyce teachers with regard to the
level of their self-efficacy and commitment to teaching. Future studies that include a larger cross-sectional sample of Noyce teachers, either by identifying Noyce teachers within larger national datasets measuring self-efficacy or by systematically including consistent measurement of self-efficacy as a standard within Noyce projects nationally, would yield greater insight into the range of self-efficacy outcomes among early career teachers. Additionally, longitudinal studies that explore relationships between early self-efficacy and longer-term retention outcomes would help establish whether the patterns seen in other studies examining self-efficacy over the course of teachers’ careers (Klassen & Chiu, 2010; Woolfolk Hoy & Burke Spero, 2005) hold true for Noyce teachers or whether, perhaps, Noyce offers experiences that may result in different trajectories with regard to teachers’ self-efficacy development.

Noyce Program Characteristics and Retention

In spite of their common vision of recruiting, supporting and preparing STEM teachers for high-need schools, Noyce programs are diverse and unique, each with their own characteristics and priorities. Our data suggest that most of the common strategies employed by Noyce programs (providing mentors, opportunities to student-teach in a high-need school, observations by Noyce faculty, assistance finding a job, induction, participating in a PLC, and observing others’ teaching) could make a difference for teachers’ decisions to stay in the classroom. At the same time, there were a few program characteristics that did not appear to be related to retention. For example, while there was a correlation between student teaching in a high-need school and retention, we did not see the same relationship for student teaching generally. Almost all teacher preparation programs offer some type of student teaching as part of their degree/certification programs (National Research Council, 2010). Numerous studies have examined the relationship among student teaching, preparedness to teach, and teacher retention (Ronfeldt, 2021). Ronfeldt highlights that only three studies (Goldhaber
et al., 2020; Goldhaber et al., 2016; Ronfeldt, 2012) have examined the relationship between student teaching field placement, school characteristics, and retention (2021). Two of these studies found a correlation between student teaching learning experiences and retention (Goldhaber et al., 2016; Ronfeldt, 2012). These studies further discuss the importance of field placement schools with strong professional learning environments, which refers to quality teacher collaboration and employing instructionally effective faculty. Our study adds to this area of research by also highlighting the correlation between student teaching experiences in high-need schools and the desire to stay in teaching. This finding lends further support to research describing benefits for teacher effectiveness when the demographics of a teacher’s school match those of the school where they completed their student teaching (Goldhaber et al., 2016).

In addition to correlations with particular program characteristics, we found a cumulative effect such that, as teachers were exposed to a greater number of program characteristics, they were more likely to report that they intended to remain in a high-need school. This finding suggests a combined influence of program characteristics, rather than any one type of Noyce experience, being critical for retention. Although the exploratory nature of our study means that we cannot draw definitive conclusions about the relationship between certain Noyce program characteristics and retention, our results may be informative for programs as they consider how to organize and structure Noyce Scholars’ experiences. For example, given the likely importance of experiencing a range of program characteristics, programs may strategically opt to offer a range or a certain combination of mentoring experiences, types of resources, and preservice teaching experiences rather than focusing more intensively on just a few strategies. Further, that teachers who intended to remain in a high-need school reported exposure to a greater number of program characteristics may also be an indication that teachers respond differentially to various opportunities offered by their programs. A study of early career teachers in Australia revealed that
those who intended to remain in the field valued different opportunities for support than those who intended to leave (Burke et al., 2015). This suggests that preservice teachers may also gravitate toward different types of support or opportunities provided by their preparation programs as they consider their future teaching career. All program characteristics may not make a significant difference for all teachers’ prospects in high-need schools; however, preservice teachers who are afforded many, varied program experiences may be more likely to encounter a greater number of quality program elements that resonate with them and inform their intentions to remain in the teaching profession. Previous studies have explored aspects of teacher preparation programs that are associated with retention, such as student teaching experiences and coursework (see Ronfeldt, 2021, for review). However, our exploratory findings suggest that more research is needed to understand the interplay of these variables and their cumulative effects on teacher retention.

Noyce Program Characteristics and Self-Efficacy

Our study finds positive relationships between Noyce teachers’ overall TSES scores and several Noyce program characteristics: mentorship, high-need preservice teaching experience, PLC participation, being observed by Noyce faculty, and job-finding assistance. The frequency with which teachers reported participating in these Noyce program experiences may help explain the relatively strong self-efficacy in our sample. Indeed, with the exception of job-finding assistance, each of these program characteristics maps onto one or more of the sources of self-efficacy hypothesized by Bandura (1997). While completing a preservice teaching assignment in a high-need school, a Noyce teacher is quite likely to have had many opportunities to experience mastery experiences, in which they overcome a challenge or achieve a particular goal they have set for their instruction. Receiving mentorship, participating in a PLC, and being observed by Noyce faculty are all experiences likely to facilitate social persuasions in which teachers receive feedback or other messages about their teaching. Additionally, PLC sessions in which
teachers model or share their experiences may offer opportunities for vicarious experiences in which teachers observe others performing a teaching task. These findings may be useful to those developing future Noyce projects or similar programs aimed at supporting early career teachers’ self-efficacy. For additional results describing the sources of self-efficacy identified by Noyce teachers in our study, we refer readers to our recent publication of self-efficacy findings (Gale et al., 2021).

Limitations

Although we believe this study will prove informative for research and practice, it is not without limitations. Given the exploratory nature of our study, we are not able to make causal claims or draw definitive conclusions about relationships between teacher networks, retention, and self-efficacy. Our study represents a rare endeavor to analyze data across a national sample of Noyce projects, and we attempted to recruit teachers from a geographically diverse array of programs. However, given that our dataset still includes a relatively small sample of Noyce teachers that was not particularly diverse with regard to teacher demographics, our results cannot necessarily generalize beyond the participants and projects included in the study, and we were limited in our ability to analyze survey results within participant subgroups. Additionally, because our sampling relied on Noyce project faculty voluntarily sharing study information and on teachers volunteering to participate in the survey, teachers who chose to participate in the study are not representative of all Noyce teachers. Finally, our study is limited by the difficulty of measuring teacher retention. Specifically, our findings regarding retention are based not on teachers’ actual retention (e.g., whether they actually remain a teacher) but rather on teachers’ self-reported predictions about whether they will remain in the classroom in the future. In addition to the possibility of response bias, with teachers being reluctant to report that they plan to leave the profession, there is the obvious possibility that teachers’ plans regarding whether they remain a pre-K–12 teacher may change. Given the scope and design of our
study, we were not able to include data documenting the actual retention rate of Noyce teachers in our study. Studies that utilize longitudinal or archival data to examine relationships between Noyce teacher retention, Noyce teacher networks, and Noyce program characteristics would be an interesting avenue for future research.

Significance

This study provides new insights around possible interconnections between Noyce teacher networks, Noyce program characteristics, self-efficacy, and retention. Our study explored the importance of the relationship between retention and Noyce program characteristics, such as providing a STEM faculty mentor, having student teaching experience in a high-need school, or having Noyce faculty observe early-career teachers’ teaching—all play an important role in preparing STEM teachers to succeed in high-need school districts. Although there is a need for additional research on the particular Noyce program characteristics or combination of program characteristics that are most beneficial for Noyce teachers, our exploratory findings may begin to guide Noyce program development. At the same time, as investments in teacher education programs like Noyce are finite, beginning to identify program characteristics most likely to enhance the likelihood of teachers’ long-term success in high-need settings provides useful data for policy makers charged with making difficult decisions about how to allocate scarce resources.

The study carries implications for educational research spanning multiple areas including SNA, teacher education, and self-efficacy. The study’s findings regarding network composition and, in particular, the use of effective size as a metric when analyzing teachers’ personal support networks, may inform future work by researchers employing social network methods to examine how K–12 teacher networks are established and develop. Results highlighting both individual Noyce program characteristics and the effectiveness of a constellation of program characteristics on retention will likely be of interest to researchers.
exploring the efficacy of various approaches to teacher education. Finally, our finding that, among Noyce teachers in our sample, self-efficacy was not significantly related to retention but was related to certain program characteristics, provides an interesting counter-example to extant research linking self-efficacy and retention and a jumping-off point for future research exploring the development of self-efficacy in early career teachers.

Conclusion

Retaining high-quality teachers remains a persistent challenge for the field of education, and STEM education, in particular. The ever-changing landscape of education requires that researchers and scholars continue to collect data to inform decisions about how to prepare and retain qualified STEM teachers, particularly those in their early years of teaching. Through the use of SNA and the inclusion of both qualitative and quantitative methodologies, this study provides novel findings documenting the nuanced ways in which the social networks of Noyce program participants and various aspects of Noyce programs themselves may influence retention among early career teachers in high-need schools. The results of our study show the importance of expanding teachers’ networks and the significance of teachers receiving support from those within a highly connected network. Whether teachers reported that they expect to be teaching in 3 years also depended on the range of Noyce program characteristics they were exposed to, suggesting the need to carefully consider both the quality and variety of learning experiences teachers encounter in Noyce programs. These findings reinforce the importance of examining teachers’ social networks to better understand how various relationships and forms of support can influence teachers’ decisions to remain or not remain in the field of teaching. Our study also highlights links between early teacher preparation experiences, self-efficacy, and
retention. Specifically, in our analysis, preservice teaching experience in high-need schools emerged as one program characteristic that may make a difference for early career teachers’ self-efficacy and retention in high-need schools. Taken together with our findings on the structure and composition of teachers’ support networks, the evidence in this research supports models of teacher preparation that center practice opportunities in high-need schools with the support of STEM faculty mentors while also helping teachers develop strong support networks.
References


An Exploratory Study: The Role of Social Networks and Self-Efficacy in the Retention of Noyce Teachers


Appendix A:
Noyce Teacher Personal Network Survey

1. Are you currently a student teacher? *
   a. Yes [If “Yes,” participant was disqualified from the survey.]
   b. No

2. Are you a current or former teaching scholar/fellow in the Robert Noyce Scholarship Program? *
   a. I am currently a teaching scholar/fellow.
   b. I am a former teaching scholar/fellow.
   c. I don’t know what the Robert Noyce Scholarship Program is.
      [If “I don’t know what the Robert Noyce Scholarship Program is,” participant
      was disqualified from the survey.]

Demographics

3. At what college or university are (were) you a Noyce Scholar/Fellow? *
   [Participants selected from a list of colleges/universities. If their college/ university
   was not listed, they could select “Other” and provide the name of their college/university.]

4. Which of the following best describes your teacher certification program for which you completed or will complete your Noyce program?
   a. Undergraduate program leading to a bachelor’s degree
   b. Teacher credential (no degree)
   c. Post-baccalaureate or graduate program (no master’s degree awarded)
   d. Graduate program leading to a master’s degree

5. In what year did you graduate with your most recent degree from your teacher certification program?
   a. 2012  
   b. 2013  
   c. 2014  
   d. 2015  
   e. 2016  
   f. 2017  
   g. 2018
6. Are you currently a full-time classroom teacher? *
   a. Yes [If “Yes,” participant progressed to section “Current Teachers.”]
   b. No

7. Were you formerly a full-time classroom teacher?
   a. Yes [If “Yes,” participant progressed to section “Former Teachers.”]
   b. No [If “No,” participant was disqualified from the survey.]

Current Teachers

8. What grade level(s) do you currently teach? *
   Please check all that apply.
   a. Kindergarten  f. 5th Grade  k. 10th Grade
   b. 1st Grade g. 6th Grade  l. 11th Grade
   c. 2nd Grade h. 7th Grade  m. 12th Grade
   d. 3rd Grade i. 8th Grade
   e. 4th Grade j. 9th Grade

   [If participant selected “6th Grade,” “7th Grade,” “8th Grade,” “9th Grade,” “10th Grade,” “11th Grade,” and/or “12th Grade,” participant progressed to item 9.

   If participant selected “Kindergarten,” “1st Grade,” “2nd Grade,” “3rd Grade,” “4th Grade,” and/or “5th Grade,” participant progressed to item 10.]

9. What subject area(s) do you teach as a 6th-12th-grade teacher?
   Please check all that apply.
   a. Pre-Algebra  i. Chemistry
   b. Algebra j. Physics
   c. Geometry k. STEM
   d. Trigonometry l. Social Studies/History
   e. Calculus m. English Language Arts
   f. Basic Math n. Other Math—Write In
   g. Biology o. Other Science—Write In
   h. Life Science p. Other Subject—Write In

10. What subject area(s) do you teach as a K–5th-grade teacher?
    Please check all that apply.
    a. Science  d. English Language Arts
    b. Mathematics  e. Other—Please Specify
    c. Social Studies/History
An Exploratory Study: The Role of Social Networks and Self-Efficacy in the Retention of Noyce Teachers

11. How many years have you been working as a full-time classroom teacher?  
   a. 0–1 years  
   b. 2–3 years  
   c. 4–5 years  
   d. 6+ years  
   [If “6+ years,” participant was disqualified from the survey.]

12. Do you currently teach in a high-need school? *  
    A high-need school is defined as being located in an area which is characterized by at least one of the following: 1. a high percentage of individuals from families with incomes below the poverty line; 2. a high percentage of secondary school teachers not teaching in the content area in which they were trained to teach; or 3. a high teacher turnover rate.  
    a. Yes  
    b. No

Former Teachers

13. What grade level(s) do you currently teach? *  
    Please check all that apply.  
    a. Kindergarten  
    b. 1st Grade  
    c. 2nd Grade  
    d. 3rd Grade  
    e. 4th Grade  
    f. 5th Grade  
    g. 6th Grade  
    h. 7th Grade  
    i. 8th Grade  
    j. 9th Grade  
    k. 10th Grade  
    l. 11th Grade  
    m. 12th Grade  
    (If participant selected “6th Grade,” “7th Grade,” “8th Grade,” “9th Grade,” “10th Grade,” “11th Grade,” and/or “12th Grade,” participant progressed to item 14.)  
    If participant selected “Kindergarten,” “1st Grade,” “2nd Grade,” “3rd Grade,” “4th Grade,” and/or “5th Grade,” participant progressed directly to item 15.)

14. What subject area(s) do you teach as a 6th–12th-grade teacher?  
    Please check all that apply.  
    a. Pre-Algebra  
    b. Algebra  
    c. Geometry  
    d. Trigonometry  
    e. Calculus  
    f. Basic Math  
    g. Biology  
    h. Life Science  
    i. Chemistry  
    j. Physics  
    k. STEM  
    l. Social Studies/History  
    m. English Language Arts  
    n. Other Math—Write In  
    o. Other Science—Write In  
    p. Other Subject—Write In
15. What subject area(s) did you teach as a K–5th-grade teacher?
   a. Science
   b. Mathematics
   c. Social Studies/History
   d. English Language Arts
   e. Other—Please Specify

16. For how many years were you a full-time classroom teacher?
   a. 0–1 years
   b. 2–3 years
   c. 4–5 years
   d. 6+ years
      [If “6+ years,” participant was disqualified from the survey.]

Support Network

17. Who has supported you as a teacher? *

   *Please list each person’s first name and last initial (Example: John Doe is John D.) in the space provided below.*
   • Consider people both within and outside of your school as well as people within and outside of education.
   • You can list as many names as you’d like.
   • Please do not list organizations, clubs, etc., only individual people.
   • The order of the names is not important.
   • After you list a name, click “yes” to add another and you will be provided with an additional space to enter names one at a time until you have listed the names of all the people who have supported you as a teacher.
   a. Name:

   ____________________________________________________________
   ____________________________________________________________

18. Would you like to add another name? *
   a. Yes [If “Yes,” participant was prompted to list another name.]
   b. No [If “No,” participant progressed to item 19.]
Person Associations

19. Which of the following categories best describes each person?

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>This person currently works at my school</th>
<th>This person currently works in another PreK–12 school</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

20. For each person you listed, are they associated with the Noyce Program, either currently or formerly?

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

21. For each person that you indicated is (was) associated with the Noyce Program, what is (was) their role in Noyce?

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>Fellow or Scholar</th>
<th>University Faculty</th>
<th>Program Administrator</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

[If participant selected “Other” for any names, participant progressed to item 22. Otherwise, participant progressed directly to item 23.]

22. If you checked “Other” for any person in the previous question, please provide a short description of their role in the Noyce Program.

If you have marked “Other” for more than one person, please include their names before the description in the comment box.
23. For those people who you indicated work either in your school or in another school, what is their role? Check all that apply.

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>Teacher</th>
<th>Assistant Principal</th>
<th>Principal</th>
<th>Guidance Counselor</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Instructional Coach</td>
<td>☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraprofessional/Support Staff</td>
<td>☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td>I Don’t Know</td>
</tr>
</tbody>
</table>

24. What is your relationship to each person you indicated does not work in your school?

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>Spouse or Partner</th>
<th>Family, Other Than Spouse or Partner</th>
<th>Friend</th>
<th>Former Colleague</th>
<th>Former Professor or Academic Advisor</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

[For items 23 and 24, if participant selected “Other” for any names, participant progressed to item 25. Otherwise, participant progressed directly to item 26.]

25. If you selected “Other” for any person in the previous question, please list your relationship to that person.

If you have marked “Other” for more than one person, please include their names before the description in the comment box.

26. For each person you listed, please indicate which type of support the person provides you with as a teacher.

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>Emotional Support</th>
<th>Administrative Support</th>
<th>Monetary Support</th>
<th>Mentorship/Coaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>☐</td>
<td>Collegial Support (i.e., sharing lesson plans, professional learning communities, etc.)</td>
<td>☐</td>
<td>Advice</td>
</tr>
<tr>
<td></td>
<td>☐</td>
<td>Other</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

[If participant selected “Other” for any names, participant progressed to item 27. Otherwise, participant progressed directly to item 28.]
27. If you checked “Other” for any person in the previous question, please describe the type of support that they provide you.

28. How close are you to each person?

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>Distant (1)</th>
<th>Less Than Close</th>
<th>Close</th>
<th>Especially Close (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

29. How often are you in contact with this person?

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>Daily</th>
<th>Weekly</th>
<th>Monthly</th>
<th>Less Often</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

30. For each person, please specify their sex.

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>Female</th>
<th>Male</th>
<th>Prefer not to answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

31. For each person you listed, what is their race/ethnicity? Please check all that apply.

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>White (Non-Hispanic/Caucasian)</th>
<th>Black/African American</th>
<th>Latino/Latina</th>
<th>Asian American or Pacific Island (Non-Hawaiian)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Name(s) submitted in Q. 17]</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>American Indian/Alaska Native/Native Hawaiian</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Unknown</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

I prefer not to answer for this person

32. Does [Name 1] know [Name 2]?
   a. Yes
   b. No

This question was repeated for each possible pairing of names provided by the participant in Q. 17.
33. Are you a current or former full-time teacher? *
   a. I am currently a full-time teacher
   [If “I am currently a full-time teacher,” participant progressed to section “Respondent Characteristics—Current Teachers.”]
   b. I am a former teacher
   [If “I am a former teacher,” participant progressed to section “Respondent Characteristics—Former Teachers.”]

Respondent Characteristics—Current Teachers

34. What is your sex?
   a. Male
   b. Female
   c. Prefer not to answer

35. What is your race/ethnicity? Check all that apply.
   a. White (Non-Hispanic)
   b. Black/African American
   c. Latino/Latina
   d. Asian American or Pacific Islander (Non-Hawaiian)
   e. American Indian/Alaska Native/Native Hawaiian
   f. Other
   g. Unknown
   h. Do not wish to answer

36. How old are you?
   a. 20–25
   b. 26–30
   c. 31–35
   d. 36–40
   e. 41–45
   f. 46–50
   g. 51–55
   h. 56–60
   i. 61–65
   j. 65+

37. During which academic year (August to May) did you begin your Noyce Program?
   a. Prior to the 2008 to 2009 academic year
   b. 2008 to 2009
   c. 2009 to 2010
   d. 2010 to 2011
   e. 2011 to 2012
   f. 2012 to 2013
   g. 2013 to 2014
   h. 2014 to 2015
   i. 2015 to 2016
   j. 2016 to 2017
   k. 2017 to 2018
38. Did you complete all of the requirements of your Noyce Program?
   a. Yes
   b. No

39. Did you hold another career outside of education prior to becoming a Noyce Scholar?
   a. Yes
   b. No

40. What was your undergraduate major?

41. How likely is it that you will continue to be employed as a K–12 teacher in the future?

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Very unlikely</th>
<th>Unlikely</th>
<th>Neutral</th>
<th>Likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year from now (2018–2019)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 years from now (2020–2021)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 years from now (2022–2023)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 years from now (2027–2028)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

[If participant selected “Very unlikely” or “Unlikely,” they progressed to item 42. If they did not select “Very unlikely” or “Unlikely,” they progressed directly to item 43.]

42. Why is it “Very unlikely” or “Unlikely” that you will continue to be employed as a K–12 teacher in the future?
43. How likely is it that you will be teaching in a high-need school in the future?  

A high-need school is defined as being located in an area which is characterized by at least one of the following: 1. a high percentage of individuals from families with incomes below the poverty line; 2. a high percentage of secondary school teachers not teaching in the content area in which they were trained to teach; or 3. a high teacher turnover rate.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Very unlikely</th>
<th>Unlikely</th>
<th>Neutral</th>
<th>Likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year from now (2018–2019)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 years from now (2020–2021)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 years from now (2022–2023)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 years from now (2027–2028)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[If participant selected “Very unlikely” or “Unlikely,” they progressed to item 44. If they did not select “Very unlikely” or “Unlikely,” they progressed directly to item 45.]

44. Why is it “Very unlikely” or “Unlikely” that you will be teaching in a high-need school in the future?

45. How likely is it that you will remain employed in the field of education, but not as a teacher, in the future?

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Very unlikely</th>
<th>Unlikely</th>
<th>Neutral</th>
<th>Likely</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year from now (2018–2019)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 years from now (2020–2021)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 years from now (2022–2023)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 years from now (2027–2028)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Respondent Characteristics—Former Teachers

46. What is your gender?
   a. Man
   b. Woman
   c. Gender not listed
   d. Prefer not to answer

47. What is your race/ethnicity?
   a. White (Non-Hispanic)
   b. Black/African American
   c. Latino/Latina
   d. Asian American or Pacific Islander (Non-Hawaiian)
   e. American Indian/Alaska Native/Native Hawaiian
   f. Other
   g. Unknown
   h. Prefer not to answer

48. How old are you?
   a. 20–25
   b. 26–30
   c. 31–35
   d. 36–40
   e. 41–45
   f. 46–50
   g. 51–55
   h. 56–60
   i. 61–65
   j. 65+

49. During which academic year (August to May) did you begin your Noyce Program?
   a. Prior to the 2008 to 2009 academic year
   b. 2008 to 2009
   c. 2009 to 2010
   d. 2010 to 2011
   e. 2011 to 2012
   f. 2012 to 2013
   g. 2013 to 2014
   h. 2014 to 2015
   i. 2015 to 2016
   j. 2016 to 2017
   k. 2017 to 2018

50. Did you complete all of the requirements of your Noyce Program?
   a. Yes
   b. No

51. Did you hold another career outside of education prior to becoming a Noyce Scholar?
   a. Yes
   b. No
52. What was your undergraduate major?

53. Are you currently employed full time?
   a. Yes [If “Yes,” participant progressed to item 54.]
   b. No [If “No,” participant progressed directly to item 55.]

54. How would you categorize your current profession?
   a. Education
   b. Full-Time Student (Not in Education)
   c. Business
   d. Law
   e. Health/Medicine
   f. Other Social Scientist (Public Health, Sociology, etc.)
   g. Other
   h. Unknown

**Noyce Program Characteristics**

55. Some Noyce Programs only provided monetary support to the program participants. Did your program provide any support beyond monetary support (for example, Professional Development, Mentoring, Conference Attendance, etc.)?
   a. Yes
   b. No

56. As a part of your Noyce program, have you participated in or received any of the following? *

   *Please limit your “Yes” responses to only those that were organized and provided by the Noyce program. In other words, do not check “Yes” for those activities/resources provided by your general university/college curriculum.*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular meetings (at least once per month) in attendance by only Noyce Scholars/Fellows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular meetings (at least once per month) in attendance by both Noyce Scholars/Fellows and other non-Noyce university students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support for professional conferences</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*continues next page*
### An Exploratory Study: The Role of Social Networks and Self-Efficacy in the Retention of Noyce Teachers

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing manuscripts for peer-reviewed publication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mentoring by faculty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mentoring by STEM professionals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mentoring by others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student teaching (not in a high-need school)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student teaching (in a high-need school)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional learning community (PLC)</td>
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<tr>
<td>Observation and feedback regarding my teaching</td>
<td></td>
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</tr>
<tr>
<td>Opportunity to observe other teachers in my subject area</td>
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</tr>
<tr>
<td>Summer research opportunities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-classroom, “live” coaching provided while I was teaching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A guaranteed job (assuming successful completion of the degree program)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support to find a job in a high-need school</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Induction (support following graduation from my degree program)</td>
<td></td>
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</tr>
</tbody>
</table>

[If participant selected “Yes” for any items related to mentoring support (i.e., “Mentoring by faculty,” “Mentoring by STEM professionals,” or “Mentoring by others”), participant progressed to item 57. If participant selected “No” for all items related to mentoring support, participant progressed directly to item 58.]

57. Which of the following best describes the role of the person assigned as your mentor?

a. University Faculty/Staff
b. Veteran Teacher
c. School Administrator (i.e., Principal, Assistant Principal, etc.)
d. Instructional Coach
e. Other—Write In
58. For each activity or resource provided by your Noyce Program, to what extent do you agree or disagree that your Noyce Program effectively implemented the activity?

<table>
<thead>
<tr>
<th>Activity</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular meetings (at least once per month) in attendance by only Noyce Scholars/Fellows</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Regular meetings (at least once per month) in attendance by both Noyce Scholars/Fellows and other non-Noyce university students</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Support for professional conferences</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Writing manuscripts for peer-reviewed publication</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Mentoring by faculty</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Mentoring by STEM professionals</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Mentoring by others</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Professional learning community (PLC)</td>
<td>☐</td>
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</tr>
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<td>☐</td>
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<td>☐</td>
<td>☐</td>
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<td>☐</td>
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<tr>
<td>Summer research opportunities</td>
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<td>☐</td>
<td>☐</td>
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<td>☐</td>
</tr>
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<td>☐</td>
<td>☐</td>
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<td>☐</td>
</tr>
<tr>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Support to find a job in a high-need school</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
</tr>
<tr>
<td>Induction (support following graduation from my degree program)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
59. To what extent do you agree or disagree with each of the following statements?

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>My Noyce Program fostered a community of teachers among participating scholars.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My Noyce Program supported me in finding a job teaching in a high-need school.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

60. Directions: Please indicate your opinion about each of the questions below by marking any one of the nine responses in the columns on the right side, ranging from (1) None at all to (9) A Great Deal as each represents a degree on the continuum. *

*Please respond to each of the questions by considering the combination of your current ability, resources and opportunity to do each of the following in your present position.*

<table>
<thead>
<tr>
<th>Question</th>
<th>None at all (1)</th>
<th>Very Little (3)</th>
<th>Some Degree (5)</th>
<th>Quite a bit (7)</th>
<th>A Great Deal (9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>How much can you do to control disruptive behavior in the classroom?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>How much can you do to motivate students who show low interest in schoolwork?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>How much can you do to calm a student who is disruptive or noisy?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much can you do to help your students value learning?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>To what extent can you craft good questions for your students?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much can you do to get children to follow classroom rules?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much can you do to get students to believe they can do well in schoolwork?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

continues next page
### An Exploratory Study: The Role of Social Networks and Self-Efficacy in the Retention of Noyce Teachers

<table>
<thead>
<tr>
<th>Question</th>
<th>None at all (1)</th>
<th>Very Little (2)</th>
<th>Some Degree (3)</th>
<th>Quite a bit (4)</th>
<th>A Great Deal (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>How well can you establish a classroom management system with each group of students?</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>To what extent can you use a variety of assessment strategies?</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>To what extent can you provide an alternative explanation or example when students are confused?</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>How much can you assist families in helping their children do well in school?</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>How well can you implement alternative teaching strategies in your classroom?</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

61. **What experiences in your professional life as a teacher have made you more confident in your teaching ability? Please explain why these experiences made you feel more capable as a teacher.**

62. **What experiences in your professional life have lowered your confidence in your teaching ability? Please explain why these experiences made you feel less capable as a teacher.**
School Characteristics

For the following questions, please answer in reference to the school where you currently teach. If you are a former teacher (you are not currently teaching), please answer the following questions in reference to the school you most recently taught at.

63. To what extent do you agree or disagree with each of the following statements?

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel supported by other teachers at my school.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I get along well with other staff members at my school.</td>
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<tr>
<td>I feel like I am an important part of my school.</td>
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<tr>
<td>I enjoy working in teams (e.g., grade level, content) at my school.</td>
<td></td>
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<tr>
<td>I feel like I fit in among other staff members at my school.</td>
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<td></td>
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<tr>
<td>I feel connected to the teachers at my school.</td>
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<tr>
<td>I feel safe at my school.</td>
<td></td>
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<tr>
<td>I have been concerned about my physical safety at my school.</td>
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<tr>
<td>If I report unsafe or dangerous behaviors, I can be sure the problem will be taken care of.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>I feel safe when entering and leaving my school building.</td>
<td></td>
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</tr>
<tr>
<td>Some students carry weapons (e.g., guns or knives) at my school.</td>
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</tr>
<tr>
<td>Students at my school get along well with the teachers and other adults.</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Students at my school demonstrate behaviors that allow teachers to teach and students to learn.</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Students at my school would help another student who is being bullied.</td>
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</tr>
</tbody>
</table>

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An Exploratory Study: The Role of Social Networks and Self-Efficacy in the Retention of Noyce Teachers

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students at my school get along well with one another.</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
</tr>
<tr>
<td>Students at my school treat each other with respect.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Students at my school treat other students fairly regardless of race, ethnicity or culture.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Students at my school show respect to other students regardless of their academic ability.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
</tr>
</tbody>
</table>

64. Which one of these best describes your school’s student demographics?
   a. Majority ethnic minority
   b. Majority White
   c. Equal balance of ethnic minority students and White students

65. Which one of these best describes your school’s teacher demographics?
   a. Majority ethnic minority
   b. Majority White
   c. Equal balance of ethnic minority students and White students

66. In order to receive your $50 stipend for completing this survey, you will need to provide us with your preferred email address. This information will not be used for anything other than for providing you with directions on how to receive your stipend.
   Please provide your email address below. *

67. Are you interested in participating in an interview if we have any further questions regarding your survey responses? *
   a. Yes
   b. No

Thank you!
Thank you for taking our survey.
Appendix B:  
Noyce Follow-Up Self-Efficacy Interview Protocol

(Adapted from Morris, 2011)

Introduction
We are conducting interviews with teachers who completed our survey last year. Through these interviews, we hope to learn more about your teaching experiences and how they have influenced your confidence as a teacher. This interview is expected to take approximately 45 minutes. With your permission, I’d like to record the interview; however, we will not share the recording outside of our research team and your name or any other identifying information will not be used when we share our research findings. Do you have any questions before we begin?

I. Confirm Background Information
1. Before we jump into interview questions, I just wanted to confirm a few details from our survey and see if anything has changed since you filled it out. Confirm:
   • Noyce program the teacher completed—anything else we want to ask about programs?
   • Current teaching placement (grade level, subject)

Additional Background Questions:
• What experiences related to teaching did you have prior to entering the classroom?
• How many schools have you taught at?
• Are you at the same school where you did your student teaching?

II. Confirmation of Retention Responses
2. In our survey, you responded that you were (summarize retention responses, e.g., “very likely to be in education in the next 5 years, but unlikely to be in 10 years”).
   • Is this still the case?
• Tell me more about these plans.
• What factors do you think about when deciding whether to stay in the classroom and for how long?

III. Sources of Self-Efficacy

One of the things we are very interested in is teachers’ confidence in their teaching and all the experiences that influence teachers’ confidence over the course of their careers. The rest of the interview will consist of questions about your confidence in your teaching ability.

CONFIDENCE RATING

3. If I asked you to rate your overall confidence in your teaching ability on a scale from 1 to 10, what number would you select?
   • Can you tell me the reasons that you selected this number?
   • Which of the things you mentioned do you believe had the most important influence on your confidence?
   • Why?

Follow up on open-ended questions (you will need to review and have the teachers’ responses on hand prior to the interview).

4. In our survey, we asked you what experiences in your professional career increased and decreased your confidence in your teaching.
   • You said that ____________ increased your confidence. Tell me more about that.
   • You said that ____________ decreased your confidence. Tell me more about that.

Probe to get at source.
   • What information/input are teachers using to make judgments about their confidence? (EX: How did you know students understood?)
   • Follow up if teachers just talk about experiences without connecting to confidence: “Tell me about how ____________ influenced your confidence.”

5. How do you know that a particular lesson has gone well?
   • Does that influence your confidence as a teacher? How so?
   • Do these positive teaching experiences affect you differently now than they did when you first started teaching? If yes, tell me about that.
6. How do you know that a particular lesson has not gone well?
   • Does that influence your confidence as a teacher? How so?
   • Has the way you handle tough days changed since you started teaching? If yes, tell me about that.

VICARIOUS EXPERIENCES
7. According to the theory we are exploring in this study, there are many vicarious influences on the confidence we have in our teaching. These include things we’ve seen, things we’ve read or things we have observed. Can you share any vicarious experiences that have influenced your confidence as a teacher?
   • Probe: What about observing other teachers? Tell me about any experiences you’ve had observing other teachers.
     – How have these observations influenced your confidence?

SOCIAL
8. Tell me some of the things other people have said about your teaching.
   • Of the things that people have said, which ones stand out for you as positive comments that boosted your confidence?
   • Why did they boost your confidence?
   • Of the things people have said, which ones stand out for you as negative comments that decreased your confidence?
   • Why did they decrease your confidence?
     – Do you trust feedback on your teaching from some people over others? Tell me about that.
     – How influential is feedback you receive from students?

AFFECTIVE
9. Tell me about some of the most prominent feelings and emotions that you experience when you are teaching and when you are preparing to teach.
   • Which of these feelings or emotions would you say have raised your confidence?

10. Which of these feelings or emotions would you say have decreased your confidence?
CONFIDENCE STORY

11. Tell me a memorable story that would help me understand how you developed the confidence that you have teaching (including grade level, e.g., high school students).
   • If the teacher has trouble thinking of something, prompt with something like: “It can be about a particular teaching experience, student or anything else that has occurred over the course of your teaching career that relates to your confidence.”

12. How would you say your experience in the Noyce program affected your confidence as a teacher? Any examples?

CHALLENGES

13. Even expert teachers occasionally run into teaching challenges and setbacks. Tell me about some of the setbacks you have faced in your teaching.

14. We may have already touched on this, but I’d like to revisit this if you don’t mind. What is the most negative teaching-related experience that you’ve had?
   • How did you respond?
   • How did it affect your confidence? Explain.
   • Did this negative experience affect your subsequent teaching performance?

WRAP-UP QUESTIONS

15. Are there other things we have not addressed that you feel influenced your confidence as a teacher?

16. I would like to close by asking you to think broadly about your confidence as a teacher and give me what you believe have been the three most important influences on your teaching confidence. They can be either positive experiences that increased your confidence or negative experiences that decreased your confidence. Begin with the most important influence on your confidence.
CHAPTER 2

Impacts of an Undergraduate STEM Teacher Recruitment and Preparation Program on Prospective Teachers’ Aspirations and Understanding
Impacts of an Undergraduate STEM Teacher Recruitment and Preparation Program on Prospective Teachers’ Aspirations and Understanding

Stacey L. Carpenter, Erik Arevalo, Meghan Macias, and Julie A. Bianchini
University of California, Santa Barbara
NSF DUE-1557283

We found that STEM teacher recruitment programs can make an impact on undergraduate STEM students’ decisions to pursue teaching and their self-reported preparation for teaching. More specifically, we found that a systematic recruitment program, with field experiences in a variety of K–12 schools and grade levels in conjunction with university-based coursework, helped undergraduates decide whether to pursue a teaching career, increased their awareness of standards-based science and mathematics teaching, and increased their appreciation for teachers.
ABSTRACT

We investigated how participating in a STEM teacher recruitment program impacted undergraduate students’ decisions to pursue teaching and their self-reported preparation for teaching. We collected and analyzed survey and interview data from current and former participants of a University of California system-wide STEM teacher recruitment program called CalTeach. We found a significant relationship between undergraduates’ decision to pursue a career in teaching and the number of undergraduate education courses they completed. We also found that undergraduates who decided to pursue a career in teaching reported various ways that CalTeach influenced their decision. Undergraduates reported that participating in CalTeach reinforced or strengthened their decision to pursue teaching and that the classroom-based field experiences were especially helpful in shaping their decision. Indeed, the field experience component of CalTeach provided participants with opportunities to gain experience working with students in a variety of grade levels and classroom contexts, gain a teacher’s perspective of classrooms, and gain opportunities to practice teaching or to apply theory and methods. Further, we found that undergraduates who decided not to pursue a teaching career also reported ways that CalTeach influenced their decision. For many in this latter group, CalTeach helped them realize that a career in teaching was not aligned with their strengths or interests. Finally, we found that CalTeach participants reported gaining more knowledge of current science and mathematics standards and a greater appreciation of teachers. However, fewer participants reported gaining an understanding of teaching multilingual learners. Our findings strengthen the argument for the implementation of STEM teacher recruitment programs and suggest ways to improve these programs. Recruitment programs should attend to the types of field experiences offered and how field experiences and coursework can deepen prospective teachers’ understanding of reform-based instruction for linguistically diverse students.
Introduction

Scholars view the process of learning to teach as a continuum that spans a teacher’s career (Feiman-Nemser, 2001; McDiarmid & Clevenger-Bright, 2008). The need to research the preparation of STEM teachers at the beginning phases of this learning-to-teach continuum remains high (Bell et al., 2019).

Indeed, an often overlooked and understudied phase is the recruitment phase, which encompasses opportunities that precede formal teacher education programs to increase interest in STEM teaching and the number of applicants to formal teacher education programs (Luft et al., 2005; Luft et al., 2011). As Luft et al. (2011) noted, despite the pressing and persistent need for effective STEM teachers in K–12 classrooms, there are a limited number of empirical studies on STEM recruitment programs and how these programs influence teacher development.

To deepen the field’s understanding of this critical phase of teacher learning, we investigated how a STEM teacher recruitment and preparation program, the University of California (UC) System’s CalTeach initiative, impacted undergraduate students’ decisions to pursue teaching and their understanding of reform-based and equitable instruction. CalTeach aims to recruit diverse, talented STEM undergraduates into the teaching profession by augmenting their majors with a sequence of courses and fieldwork experiences that introduce them to teaching; most teacher education programs in California are at the post-baccalaureate level. CalTeach recognizes that the challenges of recruiting and preparing STEM teachers to effectively teach culturally and linguistically diverse students in reform-based ways are complex and that solutions to these challenges require coordinated efforts from the teacher education
community, the K–12 school system, and higher education institutions (Newton et al., 2010). As one example of such challenges, research makes clear that preservice STEM teachers are not adequately prepared to teach multilingual learners (Rutt et al., 2021), yet approximately 20% of K–12 students in California are multilingual learners (National Center for Education Statistics, 2020). Other STEM teacher recruitment programs similar to CalTeach include the California State University System’s MSTI (Math and Science Teacher Initiative), the University of Texas at Austin’s UTeach, the related HBCU Teach at 11 Historically Black Colleges and Universities, and the National Science Foundation’s (NSF) Robert Noyce Teacher Scholarship Program.

The study reported here was part of the larger Science and Mathematics Teacher Research Initiative (SMTRI, pronounced “symmetry”) funded by an NSF Noyce Track 4 grant to research STEM teacher effectiveness, persistence, and/or retention. SMTRI was a collaboration among six UC campuses with the goal of understanding how undergraduate and post-baccalaureate teacher preparation shape beginning science and mathematics teachers’ knowledge and practices. To examine the impact of a STEM teacher recruitment program on prospective and preservice teachers, we analyzed survey data from enrolled CalTeach undergraduates along with survey and interview data from CalTeach alumni. The purpose of our study was to determine how teacher recruitment influenced both undergraduate STEM majors’ decisions to pursue teaching and their understanding of reform-based instruction for culturally and linguistically diverse students, including multilingual learners.
Literature Review

As stated above, there is limited research on STEM teacher recruitment programs and how these programs influence teacher learning and development (see again Luft et al., 2011). The studies that do exist tend to examine single-institution programs or courses (e.g., Carpenter, 2016; Choi & Linton, 2020; Czworkowski & Seethaler, 2013; Fletcher & Luft, 2011; Luft et al., 2005; Morrell & Salomone, 2017; Swanson & Coddington, 2016; Whang-Sayson et al., 2017). In particular, we found few existing studies that examine the influence of recruitment programs on STEM undergraduates’ decisions to pursue a career in teaching, one of the two main purposes of our study (e.g., Morrell & Salomone, 2017; Worsham et al., 2014). As an example, Morrell and Salomone (2017) investigated a recruitment program that provided first- and second-year STEM undergraduates at one university with a summer teaching internship at an informal science organization. They found that, although the internship provided interns insights into teaching, the program was not successful at recruiting them into the teaching profession. Indeed, although a number of interns expressed an interest in teaching in some form, for example as an outreach volunteer, in higher education or down the road as a second career, only one participant went on to pursue a teaching credential.

Several other studies examine the influence of recruitment activities on the development of constructs related to teaching, more specifically how recruitment activities shape prospective STEM teachers’ identities and confidence about teaching (e.g., Choi & Linton, 2020; Czworkowski & Seethaler, 2013; Swanson & Coddington, 2016). As one example, Swanson and Coddington (2016) investigated a recruitment experience that paired undergraduate STEM majors with high school science or mathematics teachers to help both the undergraduates and classroom teachers learn about teaching aligned with the Next Generation Science Standards (NGSS) or the Common Core State Standards in Mathematics
Impacts of an Undergraduate STEM Teacher Recruitment and Preparation Program on Prospective Teachers’ Aspirations and Understanding

Swanson and Coddington found that the undergraduates developed stronger teacher identities during the program, where they grew to see themselves as future teachers. As a second example, Choi and Linton (2020) examined a recruitment program that provided community college students with STEM content and pedagogy courses at a nearby 4-year university along with exposure to project-based teaching and curricula through a field experience with an elementary summer school program. These researchers found that community college participants increased their confidence in content knowledge and content-based pedagogy as a result of the program.

Additional studies examine the ways recruitment programs influence STEM undergraduates’ understanding of science and mathematics teaching, our study’s second purpose. Researchers have reported mixed results on how experiences in the recruitment phase of teacher preparation impact prospective STEM teachers’ conceptions of reform-based instruction (e.g., Carpenter, 2016; Choi & Linton, 2020; Fletcher & Luft, 2011; Luft et al., 2005; Swanson & Coddington, 2016). Luft et al. (2005), for example, studied the experiences and beliefs of undergraduates who completed a secondary STEM teacher recruitment course and associated field experience at one university. These researchers found that positive aspects of this recruitment activity included the field experience and the relationships that undergraduates formed with mentor teachers, course instructors, program advisors, and other undergraduates in the course. However, Luft et al. also found that most undergraduate participants still held traditional beliefs about teaching and the nature of science; they clarified that the course and field experience emphasized reform-based science teaching but were not designed to challenge participants’ existing knowledge and beliefs. In a longitudinal study, Fletcher and Luft (2011) followed the development of five prospective secondary science teachers’ beliefs about science teaching and learning from the recruitment phase to their first year of teaching. Fletcher and Luft found that although the early field experiences in the recruitment phase provided the prospective teachers with positive experiences working with
children, their conceptions about teaching remained in the traditional to transitional categories. In contrast, Carpenter (2016) found that early field experiences in high school STEM academies exposed prospective teachers to high-leverage science teaching practices and that these prospective teachers developed ideas aligned with the more common high-leverage practices as they progressed through the experience.

Researchers reported primarily positive impacts on prospective teachers’ understanding of other aspects of science and mathematics teaching as a result of teacher recruitment efforts (e.g., Czworkowski & Seethaler, 2013; Whang-Sayson et al., 2017). Czworkowski and Seethaler (2013), for example, surveyed 210 STEM undergraduate majors enrolled in three secondary science education courses. They found that the recruitment program helped to lay a foundation for undergraduates’ development of content-specific pedagogical knowledge and skills needed to teach in ways consistent with how people learn science. Whang-Sayson et al. (2017) also analyzed survey data from an undergraduate recruitment program; they examined surveys completed by 226 current or former undergraduate participants. Researchers found participants reported increased knowledge and awareness of K–12 issues as a result of their recruitment experiences. Moreover, for those who were not planning to pursue teaching as a profession, they reported intending to continue to support education through volunteer and/or outreach activities.
Methods

Research Questions
In response to the limited research on how STEM teacher recruitment programs influence teacher learning and development, we asked the following research questions: (1) How did participation in a STEM teacher recruitment program influence undergraduates’ decisions to pursue or not pursue teaching as a career? (2) How did these undergraduates’ recruitment program participation shape their self-reported understanding of science or mathematics teaching, particularly their understanding of reform-based instruction for culturally and linguistically diverse students, including multilingual learners? (3) For alumni pursuing a teaching credential, how did their recruitment program participation inform their decision to teach and their self-reported understanding of science or mathematics teaching?

To answer these questions, we collected survey and interview data from current and former CalTeach participants. We used both quantitative and qualitative methods to analyze the survey data and qualitative methods to analyze the interview data. We relied more heavily on qualitative methods because our goal was to deeply explore the complex phenomenon of how STEM teacher recruitment shapes undergraduates’ aspirations and preparation for teaching (Creswell & Clark, 2007; Johnson & Onwuegbuzie, 2004; Smith, 2006). Findings from our study provide additional insight into how STEM teacher recruitment programs influence prospective teachers’ career choices and understanding of reform-based instruction for diverse students. Findings also suggest ways to strengthen future teacher recruitment efforts to better address the critical shortage of effective STEM teachers.
Study Context

This study spanned the more specific context of the UC-wide CalTeach teacher recruitment and preparation program and the larger context of teacher preparation in California. In California, prospective teachers must complete a bachelor’s degree in a specific discipline (e.g., mathematics, biology) before pursuing a credential. The purpose of this is to ensure that prospective teachers have a comprehensive understanding of the subject(s) they will teach. Teaching credentials are then typically awarded through teacher education programs (TEPs) that are situated at the post-baccalaureate level. However, there are some experimental TEPs in California that integrate credential training into baccalaureate programs, for example, programs at UC Berkeley and UC Irvine.

To elaborate, the STEM teacher recruitment program that served as the context of our study, CalTeach, was launched by the UC system in 2005 to address the shortage of effective science and mathematics teachers needed to serve the culturally and linguistically diverse students of California. CalTeach was instituted at all nine undergraduate UC campuses and aimed to motivate diverse, talented STEM undergraduates to explore careers as science or mathematics teachers (https://calteach.universityofcalifornia.edu). Each campus’ program invites students majoring in science, mathematics, and engineering to augment their studies with a sequence of CalTeach courses and fieldwork experiences that introduce them to teaching while they concurrently complete their undergraduate degrees. This focus on recruiting and preparing undergraduates to pursue teaching is notable for California where, as explained above, prospective teachers are typically required to complete a bachelor’s degree prior to entering formal teacher credentialing programs.

The UC campuses share a common framework that structures their CalTeach program. A central design feature is the integration of (1) STEM disciplinary coursework, (2) education coursework focused on science and mathematics learning and pedagogy, and (3) simultaneous opportunities for apprentice teaching through early and continuous field placements. Another central design feature is a foundational
two-to-three-course sequence that introduces students to science and mathematics teaching pedagogy; focuses on supporting culturally and linguistically diverse learners; and is accompanied by fieldwork of increasing teaching responsibility at different schools and grade levels, including elementary, middle, and high school classrooms. Additional CalTeach-sponsored courses provide undergraduates with an opportunity to accumulate credits for an academic minor in science and mathematics education and/or to fulfill requirements toward earning a teaching credential on their campus. It is important to clarify that undergraduates can enroll in CalTeach courses as electives without completing a minor or credential. Enrollment in CalTeach courses has steadily increased since the program’s inception, and as of spring 2019, a total of more than 17,000 undergraduates have participated in this program (University of California Office of the President, 2021).

UC campuses also offer one of two types of TEPs. At most campuses, including five of the six campuses in this study, the TEPs are at the post-baccalaureate level. However, two UC campuses, including the sixth campus studied here, offer TEPs at the undergraduate level that are integrated with their CalTeach programs. Undergraduates pursuing a credential at these latter campuses first complete CalTeach courses to satisfy a minor in science and mathematics education and then continue to a final semester of apprentice teaching and seminars to earn a credential. The number of CalTeach graduates who have gone on to earn teaching credentials has continued to grow over the years (University of California Office of the President, 2021). In 2018–2019, more than 23% of all mathematics and science single-subject credentials in California were awarded to CalTeach alumni.

As stated in the Introduction, this study was part of a larger research project called SMTRI, a collaboration among researchers and faculty from six of the nine UC campuses. Over 4 years, from 2016 to 2020, the SMTRI project collected various types of data from undergraduates, preservice teachers, practicing beginning teachers, and faculty affiliated
with the CalTeach and teacher education programs at each of the six SMTRI campuses. For this analysis, we used data collected from CalTeach undergraduate students and alumni.

Participants

There were different sets of participants for the survey and interview data collected. For the survey portion of the study, we collected data from undergraduate students enrolled in at least one of the CalTeach courses targeted for investigation during the 2017–2018 academic year. The following year, in 2018–2019, we collected survey data from a subset of these undergraduates who had since graduated and who were then considered CalTeach alumni. A total of 468 undergraduates participated in the first survey, and 76 of these undergraduates participated as alumni in the second survey. For the interview portion of the study, we collected data from CalTeach alumni who were enrolled as preservice teachers in TEPs at the six SMTRI UC campuses. These preservice teachers came from three different cohorts completing their credentials from 2016 to 2019. A total of 104 CalTeach alumni participated as preservice teachers in these interviews. We note that the alumni who were interviewed were separate from the alumni who completed the survey. Demographic information about the survey and interview participants is shown in TABLES 1 and 2.
### TABLE 1
Demographic Information for CalTeach Undergraduate and CalTeach Undergraduate Alumni Survey Participants

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Number of CalTeach Undergraduate Survey Participants (n = 468)</th>
<th>Number of CalTeach Alumni Survey Participants (n = 76)</th>
</tr>
</thead>
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<tr>
<td><strong>Focus</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math focus</td>
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<td>37</td>
</tr>
<tr>
<td>Science focus</td>
<td>202</td>
<td>38</td>
</tr>
<tr>
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<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Campus</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Campus 1</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>Campus 2</td>
<td>230</td>
<td>24</td>
</tr>
<tr>
<td>Campus 3</td>
<td>49</td>
<td>6</td>
</tr>
<tr>
<td>Campus 4</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Campus 5</td>
<td>127</td>
<td>21</td>
</tr>
<tr>
<td>Campus 6</td>
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<td>7</td>
</tr>
<tr>
<td>Unknown</td>
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<td>0</td>
</tr>
<tr>
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<td></td>
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<tr>
<td>Female</td>
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<td>53</td>
</tr>
<tr>
<td>Male</td>
<td>152</td>
<td>21</td>
</tr>
<tr>
<td>Other</td>
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<td>1</td>
</tr>
<tr>
<td>Declined to state</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Racial/Ethnic Background</strong></td>
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<td></td>
</tr>
<tr>
<td>Asian/Asian American</td>
<td>148</td>
<td>28</td>
</tr>
<tr>
<td>Black/African American</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Hispanic/Latinx</td>
<td>131</td>
<td>13</td>
</tr>
<tr>
<td>Multiracial/multiethnic</td>
<td>62</td>
<td>15</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>White/European American</td>
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<td>18</td>
</tr>
<tr>
<td>Declined to state</td>
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<td>1</td>
</tr>
<tr>
<td><strong>Languages</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First language other than or in addition to English</td>
<td>190</td>
<td>22</td>
</tr>
<tr>
<td>First language English</td>
<td>268</td>
<td>52</td>
</tr>
<tr>
<td>Declined to state</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>
### TABLE 2

**Demographic Information for Preservice Teacher Interview Participants (Former CalTeach Undergraduates)**

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Number of Participants (n = 104)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Credential</strong></td>
<td></td>
</tr>
<tr>
<td>Math</td>
<td>51</td>
</tr>
<tr>
<td>Science</td>
<td>53</td>
</tr>
<tr>
<td><strong>Campus</strong></td>
<td></td>
</tr>
<tr>
<td>Campus 1</td>
<td>32</td>
</tr>
<tr>
<td>Campus 2</td>
<td>15</td>
</tr>
<tr>
<td>Campus 3</td>
<td>7</td>
</tr>
<tr>
<td>Campus 4</td>
<td>7</td>
</tr>
<tr>
<td>Campus 5</td>
<td>21</td>
</tr>
<tr>
<td>Campus 6</td>
<td>22</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>62</td>
</tr>
<tr>
<td>Male</td>
<td>40</td>
</tr>
<tr>
<td>Declined to state</td>
<td>2</td>
</tr>
<tr>
<td><strong>Racial/Ethnic Background</strong></td>
<td></td>
</tr>
<tr>
<td>Asian/Asian American</td>
<td>25</td>
</tr>
<tr>
<td>Hispanic/Latinx</td>
<td>21</td>
</tr>
<tr>
<td>Multiracial/multiethnic</td>
<td>12</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>1</td>
</tr>
<tr>
<td>White/European American</td>
<td>40</td>
</tr>
<tr>
<td>Declined to state</td>
<td>2</td>
</tr>
<tr>
<td><strong>Languages</strong></td>
<td></td>
</tr>
<tr>
<td>First language other than or in addition to English</td>
<td>33</td>
</tr>
<tr>
<td>First language English</td>
<td>70</td>
</tr>
<tr>
<td>Declined to state</td>
<td>1</td>
</tr>
</tbody>
</table>
Data Collection

Survey Data

To investigate how participating in a STEM teacher recruitment program influenced both undergraduates’ decisions to pursue or not pursue teaching and their self-reported understanding of teaching, we distributed a survey across the six SMTRI UC campuses to CalTeach undergraduates in the 2017–2018 academic year. To balance the differing sizes of the CalTeach programs across campuses with the solicitation of data from undergraduates with a range of experiences in CalTeach and with the need to ensure an acceptable survey response rate, each campus targeted a different number of CalTeach courses. Out of a total of 1,057 undergraduates who attended these targeted CalTeach courses, 468 completed the survey; our overall survey response rate was 44%. A total number of 1,659 undergraduates participated in the CalTeach program across the six SMTRI campuses during the 2017–2018 academic year. We then administered a follow-up survey in the spring (April-June) of 2019 to all respondents of the undergraduate survey who had graduated by the end of the 2017–2018 academic year. Seventy-six of these 151 CalTeach alumni responded to the follow-up survey; the response rate to this second survey was 50%. Both surveys were administered online, securely via Qualtrics.

Both the undergraduate and alumni surveys included open- and closed-ended items. Items were constructed using the guidelines, such as question-stem wording and scale length, provided in Dillman et al. (2009). The undergraduate survey included items about the following topics: (1) participants’ experiences with CalTeach (e.g., courses taken, nature of field placements, participation in other CalTeach activities); (2) their self-reported understanding of the teaching and learning of mathematics or science; (3) the impact of CalTeach on their career plans, skill development, and learning; and (4) their demographic information. The alumni survey included items about (1) participants’ current career path or plans and (2) the impact of CalTeach on their career plans and
interests. The undergraduate and alumni surveys are included as Appendices A and B. Note that, at the time of administration, the term English language learners was used instead of multilingual learners.

**Interview Data**

To better understand how a STEM teacher recruitment program helped prepare credential candidates for teaching, we collected and analyzed interview data from preservice secondary science and mathematics teachers who had participated in CalTeach as undergraduates but who were now enrolled in TEPs at the six SMTRI UC campuses. Preservice teacher participants were interviewed toward the beginning and end of their TEPs (i.e., initial and follow-up interviews) using a semi-structured protocol (Brenner, 2006). We note that as part of the larger SMTRI study, we interviewed both preservice teachers who had participated in CalTeach as undergraduates and preservice teachers who had not participated in CalTeach. However, for this analysis, we focused on interviews from preservice teachers who had participated in CalTeach as undergraduates. In the initial interview, we asked preservice teachers who had participated in CalTeach the following question: How did CalTeach help prepare you for teaching? The responses to this question were the focus of our analysis. Although 116 preservice teachers in our sample participated in CalTeach as undergraduates, because of variations in implementation of the semi-structured interview protocol, only 104 of them responded to the targeted question. We therefore collected interview data from the following numbers of preservice teachers who had participated in CalTeach as undergraduates: 33 in 2016–2017, 31 in 2017–2018, and 40 in 2018–2019. These 104 participants constituted 58% of the total 180 preservice teachers who participated in the larger SMTRI study from these six campuses over 3 years—and 25% of all 419 preservice science and mathematics teachers enrolled in the credential programs at these campuses during that period. Interviews lasted approximately 1 hour and were audio recorded and transcribed.
Impacts of an Undergraduate STEM Teacher Recruitment and Preparation Program on Prospective Teachers’ Aspirations and Understanding

Data Analysis

Survey Analysis

To answer our first research question, we quantitatively and qualitatively analyzed items from both the undergraduate and alumni surveys. For the undergraduate survey, we began by quantitatively analyzing items pertaining to the impact of CalTeach on participants’ career plans. We calculated percentages of responses for a subset of closed-ended items from this first survey. We compared participants’ decision to pursue or not pursue teaching by the number of education courses completed. Additionally, we conducted a chi-square test of independence in order to determine if there were any significant associations between the career plans of participants and five key variables of interest: participants’ self-identified content discipline, gender, ethnicity, first language, and number of education courses taken. The chi-square test was interpreted with a Bonferroni correction to account for multiple comparisons. A power analysis for the chi-square test was conducted as well to determine the size of the sample necessary with a significance level of 0.05, the appropriate degrees of freedom and a power level of 0.8. For the alumni survey, we analyzed items pertaining to participants’ current career path and the impact of CalTeach on their career plans and interests. Again, we calculated percentages of responses for a subset of closed-ended items from this second survey.

Across both surveys, we also qualitatively analyzed open-ended items about CalTeach’s impact on career choices using an iterative process of inductive coding (Huckin, 2004; Kvale, 2009). To begin, for each open-ended response, the first author of this chapter applied descriptive codes—words or short phrases that describe the topic of the text segment (Saldaña, 2016). These descriptive codes were determined from the data (i.e., were not a priori codes) and were refined over time. After the first round of coding was completed, the descriptive codes were reviewed for similarity and frequency and subsequently collapsed into fewer, more discrete codes. The first author then recoded the data using the final
set of descriptive codes (see Findings section for the final set), and the three coauthors checked the coding for accuracy; discrepancies were resolved through collective discussion.

To answer our second research question about CalTeach undergraduate and alumni self-reported understanding of science or mathematics teaching, we quantitatively analyzed additional survey items. More specifically, we calculated percentages of responses for a subset of Likert-scale items from both the undergraduate and alumni surveys.

**Interview Analysis**

To answer our third research question, we qualitatively analyzed the interview transcript data from preservice teachers who had participated in CalTeach as undergraduates. We identified responses to the relevant interview question: How did CalTeach help prepare you for teaching? The team of four authors then coded these responses using the set of descriptive codes developed from the survey analysis as a provisional list to start the coding process (Saldaña, 2016). We iteratively refined this coding scheme by adding or removing codes. After this first round of coding was completed, we focused on the two most frequent codes (field experiences and coursework) and inductively developed subcodes to describe these topics in more detail, with 17 subcodes for field experiences and 14 subcodes for coursework. Again, researchers discussed and resolved discrepancies in codes as a collective. In the Findings, we present the most common subcodes for both field experiences and coursework. Our purpose in conducting this qualitative interview analysis was to delve more deeply into how the complex phenomenon of teacher recruitment prepared former CalTeach participants for teaching.
Findings

Our findings are organized by our three research questions. In the first Findings section, we examine how a STEM teacher recruitment program influenced participants’ decisions to pursue or not to pursue teaching. In the second section, we discuss how teacher recruitment shaped participants’ self-reported understanding of science and mathematics teaching, including their understanding of reform-based instruction and multilingual learners. In the third, we delve more deeply into the ways participants’ CalTeach courses and field experiences influenced both their decision to pursue teaching and their understanding of science and mathematics teaching.

Undergraduates’ and Alumni’s Decisions to Pursue Teaching

We analyzed items from both the undergraduate and alumni surveys to better understand how a STEM teacher recruitment program influenced respondents’ decisions to pursue or not pursue teaching as a career. We begin with findings from the undergraduate survey. As mentioned, a total of 468 CalTeach undergraduates completed the survey. From our analysis of closed-ended items, we found that 50% of survey respondents planned to pursue teaching as a career, 37% were unsure about pursuing teaching, and 13% did not plan to pursue teaching. We also found variation in undergraduates’ responses by the number of education courses taken: As one might expect, the percentage of undergraduates who stated they would not pursue teaching or who stated they were unsure about teaching as a career decreased as the number of education courses completed increased (see Table 3). Further, of the 234 respondents who planned to pursue a teaching career, approximately 63% intended to teach at the secondary level, 23% at the postsecondary level, and 11% at the elementary level. The remaining 4% were undecided.
We next explored participants’ responses about pursuing or not pursuing teaching using a chi-square analysis. (Participants who were unsure about teaching as a career were excluded here.) TABLE 4 presents the raw data that were used for these comparisons. We found that the association between teacher career choice and content discipline ($\chi^2 (1, n = 295) = .03, p > .05$) was not significant. Similarly, the associations between teacher career choice and gender ($\chi^2 (1, n = 294) = 0, p > .05$) as well as ethnicity ($\chi^2 (3, n = 285) = 1.97, p > .05$) were not significant. However, there might be a relationship between teacher career choice and first language ($\chi^2 (1, n = 293) = 5.90, p = .015$). Although the relationship was not significant while considering our Bonferroni correction value of .01, our analysis suggests that teacher career choice and first language might
be dependent on one another, with participants whose first language was English being more likely to pursue teaching as a career. This initial analysis suggests the importance of further exploring how teacher career choice might be influenced by an individual’s first language. Lastly, there was a significant relationship between teacher career choice and the number of undergraduate education courses that a participant completed ($\chi^2 (2, n = 295) = 30.74, p < .001$). This result suggests that participants who decided to take more education courses were more likely to pursue teaching as a career choice.

### TABLE 4

*Raw Data Used for Chi-Square Comparisons*

<table>
<thead>
<tr>
<th></th>
<th>Teaching</th>
</tr>
</thead>
<tbody>
<tr>
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<td><strong>Discipline</strong></td>
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<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>299</td>
</tr>
</tbody>
</table>

Note. Total samples for the individual variables vary, as some participants were not included in every analysis.
We also qualitatively analyzed written responses to an open-ended survey item that asked respondents who planned to pursue teaching \((n = 234)\) how participating in a STEM teacher recruitment program influenced their decision. We remind readers that, because the question was open-ended, participants listed one to several ways they were influenced by CalTeach to pursue teaching. Because the question was broad, there was substantial variability in the responses given. Moreover, individual participants might have identified additional ways they were impacted by CalTeach if directly probed. **Table 5** shows the qualitative codes with corresponding descriptions, example quotes from participants, and percentage of responses. Of the 234 respondents who planned to pursue teaching as a career, 41% reported that participating in CalTeach reinforced or strengthened their decision. Many of these respondents commented that they were already interested in teaching before CalTeach but participating in CalTeach solidified their interest in and desire to pursue teaching. The field experience component of the CalTeach program was a notable influence on respondents, as 31% commented that field experiences were helpful in shaping their decision to pursue teaching or that participating in CalTeach gave them insight into the realities of what a teaching career was like. In addition, respondents commented that CalTeach provided them with teaching tools or methods (6%), increased confidence or a sense of preparation to teach (5%), a pathway toward teaching (5%), or a sense of the power of teaching to make a difference (5%).
TABLE 5

Qualitative Coding of Undergraduates’ Open-Ended Responses on How CalTeach Influenced Their Decisions to Pursue Teaching

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Example Responses</th>
<th>Percent</th>
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</table>
| **Solidified**              | Participant mentioned that CalTeach helped solidify, reinforce, confirm, strengthen, or increase their desire to pursue teaching as a career. | “Participating in CalTeach has made me more certain that I want to pursue a career as a teacher.”  
“In a way it solidified what I already knew. I had an inkling that I wanted to go into teaching, now I really know.” | 41      |
| **Field experience/insight**| Participant mentioned the classroom-based field experiences as valuable or mentioned gaining insight on what a teaching career entails. | “It exposed me to what it’s really like to be in the classroom.”  
“CalTeach has shown me what it’s like to be a teacher by showing me their point of view. As a result, it has showed how the teaching life is, and is an example of how life as a teacher is going to be.” | 31      |
| **No response**             | Participant left response field blank.                                      | Not applicable.                                                                                             | 10      |
| **Tools or methods**        | Participant mentioned learning tools or teaching methods through CalTeach.   | “It has given me tools for when I begin to teach.”  
“It has opened my eyes to new methods.”                                                                 | 6       |
| **Confidence or sense of preparation** | Participant mentioned gaining confidence or an increased sense of preparation to teach from CalTeach. | “It has increased [my] confidence in my potential efficacy as a teacher.”  
“Participating in CalTeach has strengthened my confidence in becoming a future science teacher.” | 5       |

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### Impacts of an Undergraduate STEM Teacher Recruitment and Preparation Program on Prospective Teachers' Aspirations and Understanding

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<th>Code</th>
<th>Description</th>
<th>Example Responses</th>
<th>Percent</th>
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</table>
| Power of teaching | Participant mentioned gaining a sense of the power of teaching to make a difference or the rewarding nature of teaching. | “Made me see all the things teaching has to offer and how rewarding it is.”
  “Teaching was never part of my career plan, but taking this course has made me realize the importance of equity in science education. The lack of representation of students of color in STEM majors at 4-year institutions is due in part because of the lack of support in math and science courses at the secondary level.” | 5       |
| Pathway to teaching | Participant mentioned that CalTeach provided them with help or resources to apply to credential programs or pursue teaching. | “Helped me prepare and pass required tests and gain professional experience through professional development activities both within CalTeach and in outside professional settings.”
  “CalTeach was a huge factor in deciding to apply to the credential program. I came to them looking for more information and they helped me along every step of the way.” | 5       |
| Clarify levels | Participant mentioned that CalTeach helped them clarify what grade levels they would like to teach. | “It made me certain that I want to teach secondary because I currently help out kinder.”
  “It has increased my desire to teach at a secondary level rather than community college.” | 4       |
| General positive | Participant mentioned that CalTeach was a positive experience or gave a general statement about its influence on their career decision. | “I think my experience was a positive one and I hope to impact students’ lives positively.”
  “Very influential.” | 4       |
| No influence | Participant mentioned that CalTeach did not influence their decision to pursue teaching. | “Hasn’t influenced my decision very much.”
  “Neither made me want to do it more or want to do it less.” | 3       |

*Note.* Percentages were calculated as the number of responses that included each code out of the total number of respondents who indicated they planned to pursue teaching as a career (*n* = 234). Percentages do not sum to 100% because one to multiple codes could be included for each response.
Similarly, we qualitatively analyzed written responses to an open-ended survey item that asked undergraduate respondents who did not plan to pursue teaching \((n=61)\) how participating in a STEM teacher recruitment program influenced their decision. **TABLE 6** shows the qualitative codes with corresponding descriptions, examples of participant responses, and percentage of responses. Of the 61 respondents who did not plan to pursue teaching as a career, 38% reported that participating in CalTeach helped them realize that a career in teaching was not aligned with their strengths or interests. However, 33% reported that participating in CalTeach did not influence their career decision—they already knew they did not want a teaching career and participating in CalTeach did not change that. Although these 61 respondents did not plan to pursue a teaching career, 16% noted that participating in CalTeach was still an enjoyable and informative experience, and 10% noted that their CalTeach experiences would be applicable to their intended careers.

**TABLE 6**

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<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Example Responses</th>
<th>Percent</th>
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</table>
| Not aligned with strengths or interests | Participant mentioned that CalTeach helped them realize teaching was not aligned with their strengths or interests. | “I entered the program in hopes that it would help me decide if I wanted to pursue teaching. Being in a classroom helped me realize that I did not want to be doing that for the rest of my life.”  
“I’m too nice, I can’t discipline children.” | 38      |
| No influence                  | Participant mentioned that CalTeach did not influence their decision not to pursue teaching; they already did not want a career in teaching. | “It hasn’t really influenced my decision not to teach as a career.”  
“My career plans are to work in an animal clinic or hospital. I decided to pursue this career because animals are my main area of interest. CalTeach has not influenced my decision at all.” | 33      |
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<th>Code</th>
<th>Description</th>
<th>Example Responses</th>
<th>Percent</th>
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<tbody>
<tr>
<td>Enjoyable/informative</td>
<td>Participant mentioned that the CalTeach experience was enjoyable or informative.</td>
<td>“It hasn’t changed my thought, but I got a good picture of how the school system is here in U.S. because I haven’t experienced K–12 here.” “CalTeach has given me the opportunity to work with students in a different capacity. Though it hasn’t swayed my decision one way or another, it has given me the chance to think about what my life would be like if I did decide to pursue teaching.”</td>
<td>16</td>
</tr>
<tr>
<td>Applicable to other careers</td>
<td>Participant mentioned that experiences gained through CalTeach could be applicable to other careers or their future.</td>
<td>“Although I think knowing how to effectively teach others is important, I would not like to pursue it as my career. However, I am not averse to working as a tutor and using what I have learned in everyday life.” “I plan on going to medical school and be a family doctor. I believe that as a doctor I can still teach my patients about their health and the importance of maintaining a healthy lifestyle.”</td>
<td>10</td>
</tr>
<tr>
<td>No response</td>
<td>Participant left response field blank.</td>
<td>Not applicable.</td>
<td>8</td>
</tr>
<tr>
<td>Negatives of teaching</td>
<td>Participant mentioned negative aspects of a teaching career, such as low pay or low respect.</td>
<td>“Engineering is the career path that I will be pursuing. Teachers are not paid enough, [and there is] little flexibility or ability to be in control other than what you teach your class. Building and designing the next revolutionary thing and making a company out of it while making a significant amount of money is way more appealing.” “I wanna be in a field that makes good money.”</td>
<td>7</td>
</tr>
</tbody>
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Note. Percentages were calculated as the number of responses that included each code out of the total number of respondents who indicated they did not plan to pursue teaching as a career (n = 61). Percentages do not sum to 100% because one to multiple codes could be included for each response.
Further, we conducted similar analyses of the alumni survey. As mentioned, 76 CalTeach alumni responded to this follow-up survey. Of these alumni respondents, 68% ($n = 52$) indicated that they were pursuing or planning to pursue teaching as a career, while 32% ($n = 24$) were not pursuing or planning to pursue teaching as a career. Indeed, 34% of alumni respondents—approximately half of those who indicated they were pursuing or planning to pursue teaching—were either currently enrolled in or had already completed a teacher credential program. These same 76 participants had expressed similar responses about pursuing a career in teaching to those of undergraduates the previous year, if those who were unsure and those who were not planning to pursue teaching are put together: At that time, 65% ($n = 49$) were planning to pursue teaching; 25%, or $n = 19$, were unsure; and 9%, or $n = 7$, were not planning to pursue teaching. One respondent’s earlier decision, or 1%, was unknown.

As with the undergraduate survey, we qualitatively analyzed written responses to an open-ended survey item that asked alumni respondents how participating in a STEM teacher recruitment program influenced their decision to pursue or not pursue teaching as a career. As shown in TABLE 7, similar to the results of the undergraduate survey, 54% of the 52 alumni respondents who were pursuing or planning to pursue a teaching career indicated that CalTeach solidified their decision to pursue teaching, and 31% noted the field experiences as being valuable. As shown in TABLE 8, of those who indicated they were not pursuing teaching as a career, 21% of the 24 alumni indicated that CalTeach helped them realize that teaching was not aligned with their strengths or interests. In addition, 38% of respondents who indicated they were not pursuing teaching as a career noted that CalTeach increased their overall interest in teaching or helped them consider teaching as something to pursue in the future; 29% noted the field experiences as helpful; and 21% indicated CalTeach helped them pursue other careers in education, such as a clinical instructor in medicine, an educational policy maker, or an educational researcher.
**TABLE 7**
*Qualitative Coding of Alumni’s Open-Ended Responses on How CalTeach Influenced Their Decisions to Pursue Teaching*

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<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Example Responses</th>
<th>Percent</th>
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</table>
| Solidified              | Participant mentioned that CalTeach helped solidify, reinforce, confirm, strengthen, or increase their desire to pursue teaching as a career. | “I had such a great experience with them that it made me want to pursue teaching.”  
“CalTeach solidified my decision to pursue teaching; I was unsure/mildly curious before taking my first CalTeach course.” | 54      |
| Field experience/insight| Participant mentioned the classroom-based field experiences as valuable or mentioned gaining insight on what a teaching career entails. | “It helped show me what teaching encompasses as a whole and that there are many things teachers consider all the time.”  
“The internship gave me insights into teaching and teachers’ work behind each lesson.” | 31      |
| Pathway to teaching     | Participant mentioned that CalTeach provided them with help or resources to apply to credential programs or pursue teaching. | “I also was able to take CSET prep classes offered through SMI which helped me to pass the exams in a timely manner. Finally, I was matched with a peer mentor who helped me on my teaching journey.”  
“I knew I wanted to be a teacher before enrolling in CalTeach courses. However, I was happy about the services CalTeach provided to let me explore this further, as well as the CSET waivers.” | 8       |
| Tools or methods        | Participant mentioned learning tools or teaching methods through CalTeach. | “I got to learn lesson planning, creating assessments, classroom organization.”  
“It changed the way I thought about teaching mathematics.” | 8       |

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<th>Code</th>
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<th>Example Responses</th>
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| Confidence or sense of preparation | Participant mentioned gaining confidence or an increased sense of preparation to teach from CalTeach. | “It helped me pursue a career related to education because it gave me confidence in the skills needed to teach. Teaching is a daunting task and I wouldn’t think I’d be able to do it if it wasn’t for the preparation CalTeach showed me.”  
“It gave me experience in the classroom which really showed me that I could handle working in a classroom with young students. Before the CalTeach program, I didn’t have confidence that I could manage a classroom. Now I know I do.” | 6       |
| Clarify levels             | Participant mentioned that CalTeach helped them clarify what grade levels they would like to teach. | “Working with various age groups helped me decide what grade level I would be most interested in teaching. CalTeach also helped me discover what material I was most interested in teaching.”  
“I’ve always thought I wanted to teach chemistry at a CC, but CalTeach made me realize how much I love teaching in a high school setting. I now plan to get a single subject credential in science and teach chemistry at the high school level.” | 4       |
| General positive           | Participant mentioned that CalTeach was a positive experience or gave a general statement about its influence on their career decision. | “It was a fun and engaging experience.”  
“A lot.”                                                                                                                                   | 4       |
| No response                | Participant left response field blank.                                        | Not applicable.                                                                                                                                                                                                   | 4       |

Note. Percentages were calculated as the number of responses that included each code out of the total number of respondents who indicated they were pursuing or planned to pursue teaching as a career (n = 52). Percentages do not sum to 100% because one to multiple codes could be included for each response.
TABLE 8

Qualitative Coding of Alumni’s Open-Ended Responses on How CalTeach Influenced Their Decisions Not to Pursue Teaching

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<th>Description</th>
<th>Example Responses</th>
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| Increased interest/consider in future | Participant mentioned that CalTeach increased their interest in teaching or that they may consider teaching in the future. | “My in-class experience through the program helped me realize that I am not quite ready to become a teacher. I am inspired, though, to hopefully revisit the idea of being a teacher later in life when I have the capacity to fully commit to an entire classroom full of students.”  
“I seriously considered teaching, and my experience at CalTeach definitely enhanced my desire to teach. However, during that same quarter, I received an acceptance to medical school and went with that career path instead.” | 38      |
| Field experience/insight           | Participant mentioned the classroom-based field experiences as valuable or mentioned gaining insight on what a teaching career entails. | “I thought the part where we had to go intern at an elementary school was very rewarding and made me understand the teaching system.”  
“CalTeach gave me experience in the classroom and I know that it made me a better tutor, and those experiences helped me understand what it was really like to be a teacher in a public school. The reason I am not teaching is because I felt my passion lies with the non-profit org that I currently work with. I think that CalTeach prepared me to make that decision because it gave me a realistic picture of what it would look like to be a teacher.” | 29      |
| Not aligned with strengths or interests | Participant mentioned that CalTeach helped them realize teaching was not aligned with their strengths or interests. | “It made me realize that I was not as passionate about teaching as my fellow classmates.”  
“It confirmed my decision to not participate in teaching. I don’t have the skills needed to be a great teacher and the courses helped me learn that.” | 21      |

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Impacts of an Undergraduate STEM Teacher Recruitment and Preparation Program on Prospective Teachers’ Aspirations and Understanding

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| Other career in Education     | Participant mentioned that CalTeach helped them pursue a career in education other than teaching. | “CalTeach did not influence me to become a teacher, but it did influence me to pursue an academic career in education research. I hope to one day be working within the NeuroEd initiative at Stanford.”  
“Made me consider becoming a teacher much more seriously than I would have without participating, but more so interested me in education policy making, and getting involved in education on an institutional level.” | 21      |
| No influence                  | Participant mentioned that CalTeach did not influence their decision not to pursue teaching; they already did not want a career in teaching. | “It did not influence me at all.”  
“It’s a great program that really showcases the career of a teacher. However, it was not enough for me to change career plans as I always wanted to practice medicine.” | 8       |

Note. Percentages were calculated as the number of responses that included each code out of the total number of respondents who indicated they were not pursuing or planning to pursue teaching as a career (n = 24). Percentages do not sum to 100% because one to multiple codes could be included for each response.

To summarize, we found that participating in a STEM teacher recruitment program could solidify undergraduates’ decisions to pursue teaching as career. In particular, we found that the field experiences—opportunities that gave insight into what a teaching career was like—were influential in shaping undergraduates’ decisions to pursue teaching. We also found that participating in CalTeach could help undergraduates realize that teaching was not aligned with their strengths or interests, and thus, that a teaching career was not for them. We consider this just as valuable as confirming a desire to teach; we discuss this point further in our Discussion and Implications sections below.
Undergraduates’ and Alumni’s Understanding of Science or Mathematics Teaching

To examine how a STEM teacher recruitment program impacted respondents’ self-reported understanding of science and mathematics teaching, we analyzed a subset of Likert-scale items from the undergraduate and alumni surveys. Both surveys asked respondents to indicate how much they agreed or disagreed with the following four statements: (1) I am more informed about education issues in my community from participating in CalTeach. (2) I am more aware of the Next Generation Science Standards from participating in CalTeach. (3) I am more aware of the Common Core State Standards in Mathematics from participating in CalTeach. (4) I have a greater understanding of teaching English language learners from participating in CalTeach. The level of agreement with these statements was indicated using the following 5-point scale: strongly agree, agree, neutral, disagree, and strongly disagree.

**FIGURE 1**

*Percentage of Undergraduate Respondents Who Agreed/Disagreed With Statements About How CalTeach Impacted Their Understanding of Science and Mathematics Teaching*
As shown in **FIGURE 1**, for the undergraduate CalTeach respondents, we found that over 70% agreed or strongly agreed that they were more informed about educational issues in their communities, more aware of the NGSS, and more aware of the CCSS-M from participating in CalTeach. However, only 58% agreed or strongly agreed that they had a greater understanding of multilingual learners (again, referred to as English language learners at the time of the survey) from participating in CalTeach.

**FIGURE 2**

**Percentage of Alumni Respondents Who Agreed/Disagreed With Statements About How CalTeach Impacted Understanding of Science and Mathematics Teaching**

As shown in **FIGURE 2**, we found a similar pattern of responses in the alumni survey: Over 80% agreed or strongly agreed that they were more informed about educational issues in their communities, more aware of the NGSS, and more aware of the CCSS-M from participating in CalTeach. Slightly less agreed or strongly agreed that they had a greater understanding of multilingual learners. We note that, in the alumni survey, we added the following two items to this question set: (1) My awareness
of K–12 education political/social issues increased from participating in CalTeach. (2) I have a greater appreciation of K–12 teachers from participating in CalTeach. As also shown in Figure 2, most respondents agreed or strongly agreed that they had an increased awareness of K–12 education political and social issues from participating in the teacher recruitment program, and respondents overwhelmingly gained a greater appreciation of K–12 teachers, with 88% strongly agreeing with that statement (see again Whang-Sayson et al., 2017, for related findings).

Overall, although these self-reported items are limited, we found that respondents noted gaining more knowledge of educational issues and standards from participating in CalTeach. Fewer respondents reported gaining an understanding of multilingual learners, which is consistent with findings from a separate analysis of SMTRI data (see Moon et al., 2021).

Preservice Teachers’ Preparation for Teaching

To further examine how STEM teacher recruitment programs contribute to teacher preparation, we analyzed interview data from CalTeach alumni who, at the time of the interviews, were enrolled in TEPs at the six participating SMTRI campuses. Since these alumni were enrolled in TEPs, they were actively pursuing teaching as a career. We used interview data from these preservice teachers to provide us with richer descriptions than the survey data—to gain better insight into how CalTeach helped prepare these preservice teachers for secondary science or mathematics teaching and how STEM teacher recruitment programs can effectively prepare future teachers.

We analyzed preservice teacher participants’ responses to the following interview question: How did CalTeach help prepare you for teaching? Unsurprisingly, in approximately 90% of the interview responses, participants discussed how the field experience and/or coursework components of the CalTeach program contributed to their preparation. Through further examination of what participants discussed related to these two components, we found that participants discussed a wide
variety of ways that the field experiences and/or courses impacted their decision to teach and their self-reported understanding of science or mathematics teaching. Here, we present the themes most commonly discussed by preservice teacher participants.

Regarding field experiences, participants most commonly discussed the following four themes: gaining exposure to different types of classes, grade levels, and educational contexts; gaining experience working with students; gaining a teacher’s perspective of classrooms; and gaining opportunities to practice teaching or to apply theory and methods. Participants also commonly discussed the role of field experiences in solidifying their decisions to pursue teaching as a career.

To elaborate, 22 preservice teacher participants highlighted how they were exposed to different types of classes, grade levels, and/or educational contexts through their CalTeach field placements. For example, one participant noted, “I got to see elementary, middle, and high school, which was really exciting.” Another participant stated:

> Being four or five years removed from being in a high school environment, it was good to see some high schools. I think we went to middle schools and elementary schools as well. So, it had been a long time since I’d been in there. And it was really enlightening to see what was going on and new things. . . . I never went to a Montessori school, but I got to see a Montessori school. So it’s like, “Oh wow, I didn’t even know that these things existed.” [I] saw bilingual schools and got a good run of the gamut of all the different types of classrooms there were, so that was really, really important.

This participant was exposed to both a variety of grade levels and a variety of school contexts through their CalTeach experiences. As noted in the Study Context, CalTeach’s foundational course sequence is accompanied by field experiences of increasing teaching responsibility at different schools and grade levels, including elementary, middle, and
high school classrooms. Participants noted the importance of this variety of field placements offered through the recruitment program.

A second common theme in preservice teacher participant responses about the field experience component of CalTeach was the opportunity to work with students. Twenty participants discussed the value of working with students through their field placements. For example, one preservice teacher noted the CalTeach field experience was an opportunity to work with multiple students in a classroom setting as opposed to working with students one-on-one in tutoring contexts:

*I'd worked with students one-on-one, but never in a classroom, so that was really interesting. So with the CalTeach course, you work with really small groups, so [there are] like five or six students that you work with, which kind of helped me work with more than one person. And then that totally escalates when you’re in a classroom with like 35 students.*

Another participant described how their interactions with students improved as they progressed through a CalTeach field experience:

*I had [to] do a lot of hours at [school name] with [teacher name] and then I realized that it was really hard for me to try to talk to high schoolers. It was just something new to me. I thought I was being weird and everything. But I think coming back now [into a teacher education program], I think having experience in CalTeach really allowed me to get past that phase and just dive into teaching and thinking about what I’m doing. And talking to the students didn’t seem as much of a big deal or a scary thing to do.*

As these examples illustrate, the field experiences were valuable introductory opportunities to interact and work with students in a classroom setting.
Preservice teacher participants also commonly discussed how CalTeach field experiences allowed them to gain a teacher’s perspective of classrooms. Seventeen participants commented on seeing classrooms from beyond a student’s perspective and witnessing the behind-the-scenes work of teaching. For example, one participant said:

*I remember the first time I went into my [course name] placement and it was the first time where I was in a room where I was like on the teacher’s side looking at the class versus on the student’s side looking at a class. And I remember that being a really cool, interesting experience for me and it was exciting that that could be my future.*

Similarly, another participant stated:

*Getting to actually be in the classrooms and seeing what kinds of activities [teachers] do and actually what all goes into teaching [was helpful]. I felt like it prepared me a lot because, as a student in high school, you don’t really see all the behind-the-scenes work that gets put into running a classroom. I think that experience of being in the class and seeing what goes on was really helpful to my decision to pursue teaching, or kind of helped me as a teacher as well as [in] the program I’m doing right now.*

In short, participants noted the value of seeing classrooms from a teacher’s perspective as a CalTeach undergraduate, often for the first time.

A fourth common theme from preservice teacher participants’ discussions of field experiences was the opportunities to practice teaching or to apply theory and methods covered in their CalTeach coursework. Fourteen preservice teacher participants discussed this theme. As one participant described:

*I think the most valuable learning experiences that I’ve gotten through CalTeach have just [been] me actually getting to step*
inside a classroom. Trial by fire, I guess. Learning what works and what doesn’t work, slowly in my field placements, slowly getting more and more responsibility. The classes themselves are also really great, but as with any classes, they’re always on the theoretical side, so it’s nice to get part theory and then part trying it out.

Similarly, another preservice teacher participant said, “We would talk about math problems in the [CalTeach] class, and then some of the techniques that we would talk about, we were then able to practice it when we were doing the hours in the high school.” Participants were able to practice or apply what they learned in CalTeach coursework in their field placement classrooms.

Finally, similar to our findings from the survey data, many preservice teacher participants mentioned that CalTeach helped solidify their decision to pursue a teaching career. Indeed, 20 of the 21 preservice teachers who spoke of this specifically mentioned the field experience component as playing a role in solidifying their decision to pursue teaching. For example, as one participant explained:

It made me really seriously consider it [teaching] as an option, because I had that practical experience, where I actually got to work in classrooms and kind of see science instruction. I mostly just took it [CalTeach] out of interest, but then it really just kind of increased my interest in the profession and in the area.

Another preservice teacher participant said, “Being in the classroom just inspired me again to want to become a teacher.” Experiences in real classrooms helped participants make the decision to pursue teaching as a career.

Regarding the coursework component of CalTeach, preservice teacher participants most commonly discussed themes of learning about teaching methods or learning about theory. Twenty-two participants
discussed learning about teaching methods. They spoke of learning about teaching methods in general, or about specific methods and skills for teaching, such as facilitating discussions or lesson planning. For example, one preservice teacher participant commented generally on learning teaching methods through coursework and practicing those methods in the field placements:

I thought that coming into CalTeach I was going to learn more like theoretical perspectives. But no, they actually teach the different methods, and that’s what I really like about CalTeach. That different methods are talked about during class, and then they give you the opportunity to actually go in the classroom and use those methods.

Another participant, when speaking of their CalTeach courses, said:

The types of assignments we did in there, like practicing writing a lesson plan, learning how to implement technology in the classroom with all the new resources that they have nowadays, and different strategies for using manipulatives and everything was really helpful because my experience in math as a student was very traditional, very direct instruction. There wasn’t a lot of Common-Core-based lessons or inquiry-based lessons or anything like that.

This preservice mathematics teacher highlighted specific teaching methods and skills they learned through CalTeach coursework, such as planning lessons, implementing technology, and using manipulatives, and how these methods and skills contrasted with their own experiences as a mathematics student.

In addition, 13 preservice participants discussed learning about theories of teaching and learning in their CalTeach coursework. For example, when asked how CalTeach helped prepare them for teaching, one preservice teacher replied, “One [way] is with theory. We’ve learned a lot of theory of pedagogy through our different courses.” Another preservice teacher
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commented, “[CalTeach] really sequenced nicely into showing me what being in a class is like every day, and then also an introduction to education theory.” A third preservice teacher similarly noted how CalTeach featured fieldwork in classrooms along with theory in coursework. They explained:

CalTeach also teaches you a lot of the theory. It’s not just like, “Oh, this is how we do it,” and then you never actually get to do it. It’s also not just like, “Oh, go watch other people do it,” and then you never really learn what their thought process is. You get kind of both.

Beyond the value of field experiences, then, preservice teacher participants noted the value of learning teaching methods and theory through their CalTeach coursework.

Although less common than the themes of teaching methods and theory, two additional themes related to their coursework were discussed by some preservice participants: learning about standards (the NGSS and/or CCSS-M) or learning about issues of equity. Nine preservice teacher participants commented on learning about current standards. For example, one participant described how their CalTeach program “had a quarter-long seminar on Common Core, so I got to learn the ins and outs of Common Core and how it’s being implemented in the classroom and what that means for teachers and students.” Another participant noted how learning about the NGSS through CalTeach gave them an advantage in their TEP. They said, “I was exposed to NGSS for the first time through CalTeach, which was really helpful because I’m a good step ahead of a lot of my [TEP] cohort with regard to NGSS simply because I had that experience.”

Similarly, eight preservice teacher participants commented on learning about issues of equity in CalTeach courses. For example, one preservice teacher noted:

I really enjoyed my pedagogy classes, where we discussed race and socioeconomic status and underprivileged students, and
how we can better serve them. I felt that that was very thought provoking and it helped me realize how much inequity there is in the world, and it made me want to really bridge that gap.

Another preservice teacher commented:

[CalTeach] also showed me a lot about the different inequities in education and how to make a dent in helping with the inequities in the schools and the classrooms that we’re in. Also, just learning about the history of how the education system worked, which is pretty interesting too. It just led me to begin questioning the system that we have in education.

For these undergraduates, CalTeach coursework was an important opportunity to learn about issues of equity in education and ways they might begin to address educational inequities in their own teaching.

Discussion

Pursuing Teaching as a Career

In this study, we examined how an undergraduate STEM teacher recruitment and preparation program influenced participants’ decisions to pursue or not pursue a career in teaching. From our analysis of the undergraduate survey, we found that half of the undergraduate respondents did indeed plan to pursue teaching as a career. (Of the remaining undergraduates surveyed, 13% did not plan to teach and 37% were undecided.) From our qualitative analysis of open-ended items in both the undergraduate and alumni surveys, we found that CalTeach helped undergraduates who were interested in pursuing teaching as a career to solidify their decision to do so. As Swanson and Coddington (2016) found that participating in a STEM teacher recruitment program helped undergraduates develop stronger teacher identities, we found
such participation strengthened or confirmed some participants’
decisions to pursue a teaching career. Examining the (mis)connections
between teacher identity development and decisions to pursue (or not
pursue) teaching resulting from teacher recruitment programs is an
interesting avenue for future research.

We also found that the field experience component of the STEM
teacher recruitment program was particularly influential in helping
participants decide to pursue teaching. Our findings from both the
survey and interview data suggest that a variety of field experiences in
K–12 classrooms were impactful in helping undergraduates solidify their
decision to pursue teaching. More specifically, participants in our study
noted these field placements in actual K–12 classrooms were important
for gaining exposure to various types of grade levels and school contexts,
working with students in classrooms, gaining a teacher’s perspective of
classrooms, and gaining opportunities to practice teaching. Whereas
Morrell and Salomone (2017) and Worsham et al. (2014) found that field
experiences in informal science education contexts were unsuccessful
in recruiting STEM majors to teaching, we found the K–12 school-based
field experiences associated with the CalT each recruitment program to
be an important factor in solidifying participants’ decisions to pursue
teaching. As discussed under Study Context above, the CalT each program
is intentionally designed to include field experiences in a variety of K–12
schools and grade levels in conjunction with university-based coursework.

Further, from both the undergraduate and alumni surveys, we found that
the STEM teacher recruitment program helped deepen participants’
understanding of and appreciation for teaching. A number of participants
realized that a career in teaching was not aligned with their strengths
or interests. We consider this just as valuable as confirming a desire to
teach, as beginning STEM teachers often leave the profession after just
a few years in classrooms (Fuller & Pendola, 2019; Ingersoll et al., 2014).
In addition, a large number of CalTeach alumni—both those who intended
to pursue teaching and those who did not—agreed that their awareness
of K–12 education political and social issues and their appreciation of K–12 teachers increased as a result of participating in CalTeach (see again Whang-Sayson et al., 2017). Both of these sets of findings are important, as they suggest undergraduate STEM teacher recruitment programs have effects beyond recruiting beginning teachers—that they can improve the retention of beginning teachers and the public support of these teachers as well.

**Self-Reported Understanding of Science or Mathematics Teaching**

We also examined how the STEM teacher recruitment program impacted participants’ self-reported understanding of science or mathematics teaching. From our analysis of the survey data, we found that participants believed they gained more knowledge of the NGSS and CCSS-M from participating in CalTeach. Similarly, our findings from the interview analysis indicated that the teacher recruitment program, particularly its coursework, helped familiarize participants with current standards and thus helped prepare them for TEPs. Indeed, although CalTeach coursework was rarely brought up in the survey data, we found that those who went on to enroll in TEPs did consider the recruitment program’s coursework—in addition to their field experiences—influential to their preparation for teaching.

However, our survey analysis indicated that the recruitment program had less of an impact on undergraduates’ understanding of teaching multilingual learners, which is consistent with findings from a separate analysis of SMTRI preservice teacher participants (see Moon et al., 2021). In response to the increasing numbers of multilingual learners in science and mathematics classrooms, teacher education programs have begun to focus more intently on preparing their preservice teachers to effectively teach these disciplines and organize their science and mathematics content and language instruction around a comprehensive multilingual learner framework (Heineke & Giatsou, 2020; Lyon et al.,
Research is needed to determine how recruitment programs can more closely attend to multilingual learner instruction through field experiences and coursework.

On a related note, a small number of preservice teacher participants shared that they learned about equity issues in their CalTeach courses. Because we did not probe these responses, we did not determine how these participants’ understanding of equity intersected (or did not intersect) with their understanding of teaching to the standards and/or teaching multilingual learners. Further, few studies we used to inform our research on STEM teacher recruitment examined prospective teachers’ learning about science or mathematics teaching through an equity lens. As such, research is needed to explore both how recruitment program participants understand teaching toward equity more specifically, and given our survey findings about multilingual learner instruction, how participants understand the relationship between equitable instruction and instruction for multilingual learners.

Finally, our qualitative analyses of data from the open-ended survey items and interviews yielded categories regarding the influence of STEM teacher recruitment on aspirations and preparation for teaching that can be used in future studies of STEM teacher recruitment programs. While other studies have tracked participant decisions to pursue teaching (e.g., Morrell & Salomone, 2017; Worsham et al., 2014), our study provides categories for future studies to examine how and why recruitment programs influence participants’ decisions to pursue teaching, such as solidifying their aspirations to teach, discovering that teaching is not aligned with their strengths or interests, gaining a sense of the power of teaching, or being exposed to specific teaching tools and methods.
Limitations

We identified several avenues of future research in our Discussion section; our study’s limitations suggest additional research directions as well. One limitation of our study was our survey response rate: Only 44% of CalTeach undergraduates and 50% of CalTeach alumni invited to complete a survey did so. As such, we do not know in what ways the substantial number of those who declined to complete the surveys were similar to or different from those who decided to participate. As a second limitation, indeed because we collected most of our data from surveys, we did not have the opportunity to probe participants’ responses to questions. In general, we were unable to determine whether individual participants would have identified additional ways CalTeach influenced them if probed. More specifically, we were unable to explore why a number of undergraduates completed CalTeach courses when they had already decided to pursue a career other than teaching. As a third limitation, while we explored the responses of both undergraduates who were planning to pursue teaching and those who were not planning to pursue teaching, we did not analyze the responses of undergraduates who expressed uncertainty; how recruitment programs can better appeal to and persuade undergraduates who are undecided about teaching is important to consider. As a final limitation, from our power analysis, we determined that our current sample size for our chi-square analysis was smaller than the ideal size. However, for pragmatic purposes, our current sample was deemed appropriate for the claims we made. To repeat, these limitations serve as suggestions for future research on STEM teacher recruitment—from larger sample sizes to the inclusion of more interviews to deeper analysis of participants who express uncertainty about their career path.
Implications

Luft et al. (2011) called for STEM teacher recruitment programs that are strategic and comprehensive. In our Discussion and Limitations sections above, we discussed several directions for future research on recruitment to help meet these goals. Here, we focus on three possible implications to aid other STEM teacher recruitment programs in becoming more strategic and comprehensive.

One implication expands on points made in our Discussion section: It provides a stronger argument for the formation of STEM teacher recruitment programs in the first place. STEM teacher recruitment programs can help undergraduates solidify their decisions to pursue or not to pursue teaching. Whether undergraduates decide to pursue or to not pursue teaching, either outcome is valuable, especially considering issues of teacher retention and the high number of STEM teachers who leave the profession within the first 5 years of teaching (Fuller & Pendola, 2019; Ingersoll et al., 2014). As we found in our study, many undergraduates affirmed their desire for a teaching career after participating in CalTeach. We also found a substantial number of undergraduates realized after participating in the CalTeach recruitment program that a career in teaching did not align with their personal strengths and interests; we argue that it is valuable to learn this early on, before even entering the profession. Further, we found that both those who were planning to pursue teaching and those who were not increased their appreciation for teachers as a result of their participation in the recruitment program. These findings argue for the importance of STEM teacher recruitment programs, demonstrating the potential these programs have in strengthening prospective teachers’ commitment to teaching, promoting teacher retention, and increasing the perceived value of teachers by the public.
Beyond strengthening the argument for STEM teacher recruitment programs, our study yields insights into effective components of these programs. Indeed, a second implication is that STEM teacher recruitment programs should carefully consider their inclusion and structure of field experiences. As we found, the field experience component of CalTeach was notable for participants’ decisions to pursue teaching and their preparation for teaching. The strategic format of offering multiple field placements in a variety of K–12 schools and grade levels in conjunction with university-based coursework was particularly impactful. This field experience format allowed participants opportunities to be exposed to a variety of classroom contexts and to gain experience working with students, a teacher’s perspective of classrooms, and the ability to practice teaching or apply theory and methods. Other recruitment programs should consider this structure for their field experience component. The additional field experiences in K–12 classrooms afforded by STEM teacher recruitment programs can have long-term impacts on STEM teacher retention. As Ingersoll et al. (2014) found, science and mathematics teachers with more practice teaching, observations of teaching, and feedback on their own teaching were less likely to leave the teaching profession after the first year.

Our study also yields insights into areas that need improvement in STEM teacher recruitment programs like CalTeach. A third implication, then, is that recruitment programs need to consider how to better integrate instruction on the standards with instruction for culturally and linguistically diverse students. As we found, more participants reported an increased awareness of current standards than an increased understanding of teaching multilingual learners. Yet, teaching to the standards requires attention to language and literacy so that all students can excel in science and mathematics sense-making and learning (Bunch, 2013). As such, STEM teacher recruitment programs should view instruction about current standards as opportunities for instruction about language, literacy, and supporting multilingual learners as well.
Conclusion

Taken together, our findings from survey and interview data indicate that participation in a STEM teacher recruitment program is impactful. A substantial number of prospective and preservice teacher participants found their recruitment experiences useful both in deciding to pursue teaching and in understanding how to teach science or mathematics in reform-based ways. They emphasized that the recruitment program’s field experiences and, to a lesser extent, its coursework were instrumental in doing so. The recruitment program also helped other participants determine that teaching was not a good fit for them. Both sets of findings are important in promoting beginning STEM teacher retention: They add to the existing teacher education literature that has found field experiences and coursework in teacher preparation helpful in retaining beginning STEM teachers (Cochran-Smith et al., 2011; Fuller & Pendola, 2019; Ingersoll et al., 2014). Said another way, the experiences and understandings prospective teachers gain from participation in a recruitment program can help them build the strong foundation they need to excel in the teacher preparation phase of the learning-to-teach continuum and beyond. Going forward, to ensure the foundation built includes a clear commitment to equity and diversity, STEM teacher recruitment programs should attend more closely to how field experiences and coursework can deepen prospective teachers’ understanding of reform-based instruction for culturally and linguistically diverse students, including multilingual learners (see again Bunch, 2013).
Acknowledgments

We would like to thank the PI, co-PIs, and collaborators of the SMTRI project.

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Sherry Seethaler,
UNIVERSITY OF CALIFORNIA, SAN DIEGO
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Ingersoll, R., Merrill, L., & May, H. (2014). *What are the effects of teacher education and preparation on beginning teacher attrition? CPRE Research Reports.* [https://repository.upenn.edu/cpre_researchreports/78](https://repository.upenn.edu/cpre_researchreports/78)


Impacts of an Undergraduate STEM Teacher Recruitment and Preparation Program on Prospective Teachers’ Aspirations and Understanding


Appendix A: 
CalTeach Undergraduate Survey

Introduction
The survey is divided into 4 parts. It should take less than 30 minutes to complete. You may stop the survey at any time and return to it later by clicking on the link.

[For UNIVERSITY 4 students only]

1. Are you an undergraduate science or mathematics major?
   □ Yes
   □ No  
   [If no, skip to question 39.]

Section 1: CalTeach Program Information
This first section asks about your CalTeach Program.

2. What CalTeach activities are you or have you been involved with?  
   (Select all that apply.)
   □ Courses (e.g., STEM education courses, education courses)
   □ Research experiences
   □ Summer trainings or summer internships
   □ Workshops/seminars
   □ Career counseling
   □ Other (please explain):
3. Which of the following courses have you taken or are currently taking? (Select all that apply.)

[For UNIVERSITY 1 Students]
- UGIS 82—K–8 Teaching and Inquiry-Based Lesson Design in the Science and Mathematics Classroom
- EDUC 130—Knowing and Learning in Mathematics and Science
- EDUC 131—Classroom Interactions in Science and Mathematics: A Focus on Equity and Urban Schools
- UGIS 187—Project-Based Instruction
- HIST 138, 180 or 182—History of Science
- UGIS 188/189—Research Methods for Science and Math K–12 Teachers

[For UNIVERSITY 2 Students]
- EDU/GEL 81—MAST I: Learning in Science and Mathematics
- EDU/GEL 181—MAST II: Teaching in Science and Mathematics
- EDU/GEL 183—MAST III: Teaching High School Mathematics and Science
- GEL 185 A—Conceptual Integrated Science: The Physical World
- GEL 185 B—Conceptual Integrated Science: Earth System and Environmental Science
- GEL 186—Learning Assistant Program

[For UNIVERSITY 3 Students]
- EDUC 003—Imagining Teaching: Science/Mathematics Emphasis
- EDUC 004—Looking in Classrooms: Science/Mathematics Emphasis
- NASC 192—STEM Education Seminar
- EDUC 109—Education in a Diverse Society
- EDUC 110—Learning Theory and Psychology in Education
- EDUC 116—The Exceptional Child
- EDUC 174—Reading and Writing in the Content Areas
- EDUC 175 (formerly 177A)—Language Development in the Content Areas
- CaT3 Summer Institute
Impacts of an Undergraduate STEM Teacher Recruitment and Preparation Program on Prospective Teachers’ Aspirations and Understanding

[For UNIVERSITY 4 Students]
- MATH 87—Teaching Math: The Challenge
- CHEM 87—Teaching Science: The Challenge
- MATH 95/EDS 30—Introduction to Teaching Mathematics
- CHEM 96/EDS 31—Introduction to Teaching Science
- EDS 39—Practicum in Mathematics and Science Teaching/Learning
- MATH 121A/EDS 121A—Foundations of Teaching and Learning Mathematics I
- MATH 121B/EDS 121B—Foundations of Teaching and Learning Mathematics II
- CHEM 187/EDS 122—Foundations of Teaching and Learning Science
- CHEM 188/EDS 123—Capstone Seminar in Science Education
- EDS 129A—Teaching and Learning: Secondary
- EDS 129B—Teaching and Learning: Secondary
- EDS 129C—Teaching and Learning: Secondary

[For UNIVERSITY 5 Students]
- ED 128—CalTeach, Elementary Mathematics Education
- ED 129—CalTeach, Elementary Science Education
- ED 130—CalTeach, Secondary Mathematics Education
- ED 131—CalTeach, Secondary Science Education
- CHEM 102—Teaching Chemistry at the High School/Junior High Level
- CHEM 193—Internship in Chemistry: SciTrek
- EEMB 182—Communicating Ocean Science
- EEMB 189/ENV S 191—Nature and Science Education Practicum
- ENV S 127B—Advanced Environmental Education and Practicum
- ENV S 166FP/ANTH 166FP/GEOG 171FP—Small-Scale Food Production
- MATH 181B/ED 135—Advanced Problem Solving in Mathematical, Historical and Pedagogical Contexts
- PHYS 260J—Physics Outreach
[For UNIVERSITY 6 Students]

☐ EDUC 50B—CaT1 Math
☐ EDUC 50C—CaT1 Science
☐ EDUC 100A—CaT2 Combo
☐ EDUC 100B—CaT2 Math
☐ EDUC 100C—CaT2 Science
☐ EDUC 185L—CaT3 Combo
☐ EDUC 185B—Introduction to Mathematics Education
☐ EDUC 185C—Introduction to Teaching Science
☐ EDUC 197A—CaT Special Project
☐ EDUC 197B—CaT Special Project
☐ EDUC 197C—CaT Special Project
☐ PBS 101—Learning Assistant Pedagogy

4. List any other education courses you have taken or are currently taking.

5. List each of your CalTeach field/practicum/internship placements and the type of school for each placement (e.g., charter school, middle school, high school).

6. What types of activities have you done during field/practicum/internship placements? (Select all that apply.)
   - Observed teachers and students in classroom(s)
   - Taught entire lesson(s)
   - Taught part of lesson(s)
   - Helped students during class
   - Helped students during lunch or after school
   - Attended inservice professional development with classroom teacher
   - None of the above
   - Other (please explain):
Section 2: The Teaching and Learning of Mathematics or Science

The following questions are about the teaching and learning of mathematics or science.

7. Which discipline do you feel most prepared to answer questions about? (Select one.)
   - □ Mathematics teaching and learning
   - □ Science teaching and learning

[ITEMS FOR MATHEMATICS]

8. Please mark the option that best describes how much you agree or disagree with each of the following statements about secondary (grades 6–12) students and student learning.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>To understand mathematics concepts, secondary students need real, concrete, hands-on experiences.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Students master and retain mathematics concepts most effectively when reading, writing, and talking are used in support of mathematics learning.</td>
<td></td>
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</tr>
<tr>
<td>Mathematics is learned best when it is connected to students’ everyday lives.</td>
<td></td>
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</tr>
<tr>
<td>All students have some background knowledge in mathematics.</td>
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<tr>
<td>Reaching the correct solution is more important than making sense of problems and persevering in solving them.</td>
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</tr>
<tr>
<td>Excelling in mathematics requires special abilities that only some people possess.</td>
<td></td>
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</tr>
<tr>
<td>English language learners need to be able to read and write proficiently in English before being taught mathematics.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
9. Please mark the option that best describes how much you agree or disagree with each of the following statements about effective secondary (grades 6–12) mathematics teaching.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listening and responding to student ideas about mathematics should be a focus in most mathematics lessons.</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Student discussions should be used sparingly, as they often lead to confusion and misunderstanding of mathematics concepts.</td>
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<td>☐</td>
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<tr>
<td>Common Core mathematics practices should be taught separately from mathematics content.</td>
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<tr>
<td>It is better to cover more mathematics topics than to teach fewer topics in more depth.</td>
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<tr>
<td>Mathematics teachers should communicate the lesson’s learning goal(s) to students.</td>
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<tr>
<td>Connecting mathematics instruction to students’ culture and communities will distract them from actually learning mathematics content.</td>
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<tr>
<td>Mathematics teachers are to address students’ language development as well as their content understanding in mathematics lessons.</td>
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<tr>
<td>Mathematics teachers are responsible for teaching students both how to read and produce mathematics texts.</td>
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</tbody>
</table>
10. Please mark the option that best describes how important you think it is for secondary (grades 6–12) mathematics teachers to do the following:

<table>
<thead>
<tr>
<th></th>
<th>Very Important</th>
<th>Important</th>
<th>Neutral</th>
<th>Not Important</th>
<th>Very Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide students with language supports (e.g., graphic organizers, sentence frames).</td>
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<td>☐</td>
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</tr>
<tr>
<td>Involve students in developing and using mathematical models.</td>
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</tr>
<tr>
<td>Discourage students from critiquing their peers’ mathematical reasoning.</td>
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</tr>
<tr>
<td>Engage students in sustained discussions about mathematics topics.</td>
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<tr>
<td>Help students understand how mathematics is used in their everyday life.</td>
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</tr>
<tr>
<td>Elicit students’ prior knowledge about mathematics concepts.</td>
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<tr>
<td>Involve students in reflecting on what they have learned during the lesson.</td>
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<tr>
<td>Teach mathematics as objective and culture free.</td>
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<tr>
<td>Use multiple modalities (e.g., reading, writing, listening, and speaking) while teaching and assessing students.</td>
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</tr>
<tr>
<td>Frame instruction around a big idea or puzzling phenomenon.</td>
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<td>☐</td>
</tr>
</tbody>
</table>
11. Please mark the option that best describes how much you agree or disagree with each of the following statements about how well prepared you feel to teach mathematics.

I feel well prepared to . . .

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
<tbody>
<tr>
<td>implement Common Core State Standards for Mathematics.</td>
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<tr>
<td>teach an advanced mathematics course (e.g., honors, advanced placement).</td>
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<tr>
<td>integrate language and literacy in my mathematics teaching.</td>
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<tr>
<td>make mathematics relevant to my students.</td>
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<tr>
<td>involve students in constructing and critiquing mathematical arguments.</td>
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</tr>
<tr>
<td>teach mathematics to English language learners.</td>
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<tr>
<td>find out about my students’ lives outside of school.</td>
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</tbody>
</table>
## ITEMS FOR SCIENCE

12. Please mark the option that best describes how much you agree or disagree with each of the following statements about secondary (grades 6–12) students and student learning.

<table>
<thead>
<tr>
<th>Statement</th>
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<td>Science is learned best when it is connected to students’ everyday lives.</td>
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<td>All students have some background knowledge in science.</td>
<td>☐</td>
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</tr>
<tr>
<td>Following investigation procedures is more important than asking testable questions and constructing explanations of phenomena.</td>
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<tr>
<td>Excelling in science requires special abilities that only some people possess.</td>
<td>☐</td>
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</tbody>
</table>
13. Please mark the option that best describes how much you agree or disagree with each of the following statements about effective secondary (grades 6–12) science teaching.

<table>
<thead>
<tr>
<th>Statement</th>
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<tr>
<td>Science and engineering practices should be taught separately from content.</td>
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<tr>
<td>It is better to cover more science topics than to teach fewer topics in more depth.</td>
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<tr>
<td>Science teachers should communicate the lesson's learning goal(s) to students.</td>
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<tr>
<td>Connecting science instruction to students' culture and communities will distract them from actually learning science content.</td>
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<tr>
<td>Science teachers are to address students' language development as well as their content understanding in science lessons.</td>
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<tr>
<td>Science teachers are responsible for teaching students both how to read and how to produce science texts.</td>
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</tbody>
</table>
14. Please mark the option that best describes how important you think it is for secondary (grades 6–12) science teachers to do the following:

<table>
<thead>
<tr>
<th></th>
<th>Very Important</th>
<th>Important</th>
<th>Neutral</th>
<th>Not Important</th>
<th>Very Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide students with language supports (e.g., graphic organizers, sentence frames).</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Involve students in developing and using scientific models.</td>
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<tr>
<td>Discourage students from critiquing their peers’ scientific reasoning.</td>
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<td>☐</td>
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<tr>
<td>Engage students in sustained discussions about science topics.</td>
<td>☐</td>
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<tr>
<td>Help students understand how science is used in their everyday life.</td>
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<tr>
<td>Elicit students’ prior knowledge about science concepts.</td>
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<tr>
<td>Involve students in reflecting on what they have learned during the lesson.</td>
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</tr>
<tr>
<td>Teach science as objective and culture free.</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Use multiple modalities (e.g., reading, writing, listening, and speaking) while teaching and assessing students.</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Frame instruction around a big idea or puzzling phenomenon.</td>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
15. Please mark the option that best describes how much you agree or disagree with how well prepared you feel to teach science.

I feel well prepared to . . .

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>implement the Next Generation Science Standards.</td>
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<tr>
<td>teach an advanced science course (e.g., honors, advanced placement).</td>
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<tr>
<td>integrate language and literacy in my science teaching.</td>
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<tr>
<td>make science relevant to my students.</td>
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<tr>
<td>involve students in constructing and critiquing scientific arguments.</td>
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<tr>
<td>teach science to English language learners.</td>
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<tr>
<td>find out about my students’ lives outside of school.</td>
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</tbody>
</table>
Section 3: Impact of CalTeach Program

This set of questions asks about CalTeach’s impact on your career plans, skill development, and learning.

16. Do you plan to pursue teaching as a career?
   □ Yes
   □ No
   □ Unsure

17. [If yes to 16] What grade levels do you hope to teach?
   □ Elementary
   □ Secondary
   □ Higher education (postsecondary)
   □ Other: ____________

18. [If yes to 16] How has participating in CalTeach influenced your decision to pursue teaching as a career?

19. [If no to 16] What are your career plans instead of teaching? What are some reasons why you decided to pursue this career rather than teaching?

20. [If no to 16] How has participating in CalTeach influenced your decision not to pursue teaching as a career?

21. If you do not pursue teaching as a career, how likely are you to be involved with other educational activities (e.g., outreach, museum education)?
   □ Very likely
   □ Somewhat likely
   □ Neutral
   □ Somewhat unlikely
   □ Very unlikely

22. Have you applied or do you plan to apply to a teacher credential program?
   □ Yes
   □ No
   □ Unsure
23. [If yes to 22] To which teacher credential program(s) have you applied or do you plan to apply?

24. Have you applied or do you plan to apply to programs that offer an alternative route to teaching (e.g., Teach for America)?
   - □ Yes
   - □ No
   - □ Unsure

25. [If yes to 24] To which alternative programs have you applied or do you plan to apply?

26. Please mark the option that best describes how much you agree or disagree with each of the following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am more informed about education issues in my community from participating in CalTeach.</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I am more likely to stick with my major because of participating in CalTeach.</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I am more aware of the Next Generation Science Standards from participating in CalTeach.</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>I am more aware of the Common Core State Standards for Mathematics from participating in CalTeach.</td>
<td>□</td>
<td>□</td>
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<tr>
<td>I have a greater understanding of teaching English language learners from participating in CalTeach.</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

27. Has participating in CalTeach changed the way you learn in your other STEM classes? If so, how?
Section 4: Demographic Information

This final set of questions asks about your academic preparation and personal background.

28. What is your undergraduate major(s)?

29. What is your undergraduate minor(s), if any?

30. Are you a community college transfer student?
   □ Yes
   □ No

31. What year are you at the university? What quarter/semester and year will you graduate?

32. Using the visual above, how would you best describe your socioeconomic status growing up? (Select one.)
   □ Lower class
   □ Working class
   □ Lower middle class
   □ Upper middle class
   □ Upper class (e.g., CEOs, politicians)
33. How would you best describe the community where you completed most of your secondary (grades 6–12) schooling? (Select one.)
   - Urban/city
   - Suburban
   - Town
   - Rural
   - Other (please specify):

34. How would you best describe the population of the community in which you completed most of your secondary (grades 6–12) schooling? (Select one.)
   - Varied cultural and racial backgrounds
   - Predominantly people of color
   - Predominantly people who are White/European American

35. How would you best describe the population of students in the classes you took for most of your secondary (grades 6-12) schooling? (Select one.)
   - Students of varied cultural and racial backgrounds
   - Predominantly students of color
   - Predominantly White/European American students

36. What is your gender?
   - Male
   - Female
   - Other (please specify): ________________________________

37. What is your racial/ethnic background? (Check all that apply.)
   - Asian/Asian American
   - Black/African American
   - Hispanic or Latina/o
   - Native American/American Indian or Alaskan Native
   - Pacific Islander
   - White/European American
   - Multiracial (please specify): ________________________________
   - Other (please specify): ________________________________

38. What is your first language? ________________________________
39. Do you speak a language other than English?
   - No
   - Yes

   [If yes, please list the language(s) below and your proficiency level (e.g., beginning, intermediate, advanced, fluent).]

40. This survey has been distributed in other CalTeach classes. Do you remember taking this survey before? If yes, in what class(es)?
   - No
   - Yes __________________________

41. Please discuss anything else you would like to share about your experiences in CalTeach (MAST or SMI).

42. What is your permanent email address? (so we may contact you in the future for a follow-up survey)

43. [Only for UNIVERSITY 4 students who chose “no” for question 1.]

<table>
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<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>To understand concepts, secondary students need real, concrete, hands-on experiences.</td>
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<tr>
<td>Students master and retain concepts most effectively when reading, writing, and talking are used in support of learning.</td>
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<td>Listening and responding to student ideas should be a key focus in most lessons.</td>
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<tr>
<td>Student discussions should be used sparingly, as they often lead to confusion and misunderstanding of concepts.</td>
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<tr>
<td>It is better to cover more topics than to teach fewer topics in more depth.</td>
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<tr>
<td>Teachers should communicate the lesson’s learning goal(s) to students.</td>
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</table>
### Impacts of an Undergraduate STEM Teacher Recruitment and Preparation Program on Prospective Teachers’ Aspirations and Understanding

<table>
<thead>
<tr>
<th>Statement</th>
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<th>Agree</th>
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<th>Disagree</th>
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<td>Teachers should involve students in reflecting on what they have learned during the lesson.</td>
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<td>Teachers should use multiple modalities (e.g., reading, writing, listening, and speaking) while teaching and assessing students.</td>
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Appendix B: CalTeach Alumni Survey

Section 1: Career Path
The following questions ask about your current career path/plans.

1. Are you currently teaching, pursuing teaching as a career or planning to pursue teaching as a career?
   - [ ] Yes
   - [ ] No
   [If no to question 1, skip to 8.]

2. Are you currently enrolled in a teacher credential program?
   - [ ] Yes
   - [ ] No
   [If yes to 2] What credential program are you enrolled in (what institution or program)?

3. Do you have a teaching credential, or have you completed a teacher credential program?
   - [ ] Yes
   - [ ] No
   [If yes to 3] Where did you complete your credential program (what institution or program)?

4. Did you complete or are you enrolled in an alternative teaching certification program (e.g., Teach for America, AmeriCorps)?
   - [ ] Yes
   - [ ] No
   [If yes to 4] What alternative certification program did you complete/are you enrolled in?

5. Are you currently teaching in a private school without a credential or certification?
   - [ ] Yes
   - [ ] No
6. Which of the following best describes your current teaching situation? *(Pick one.)*
   - [ ] I am teaching in a K–12 school.
   - [ ] I am teaching in a K–12 school and my teaching is associated with a teacher preparation program.
   - [ ] I am a student teacher or intern teacher.
   - [ ] I am teaching but not in a K–12 school *(please explain):*

   _____________________________

   [ ] I am not teaching, but I work in education *(please explain):*

   _____________________________

   [ ] I am not teaching or working in education.

   *If a or b for 6* Where are you currently teaching?
   - Name of school(s): ________________________________
   - City, state, country: ________________________________
   - What grade levels and/or subjects are you teaching?
   ________________________________

7. Do you think you will be teaching in *(rate each one):*

<table>
<thead>
<tr>
<th></th>
<th>Likely</th>
<th>Unlikely</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year?</td>
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<td>2 years?</td>
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<tr>
<td>5 years?</td>
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<tr>
<td>10 years?</td>
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</table>

8. *If no to question 1* What is your current career path?
Section 2: Impact of CalTeach Program

The following questions ask about CalTeach’s impact on your career plans and interests.

9. In which CalTeach program did you participate?
   - [ ] UC Berkeley
   - [ ] UC Davis (MAST program)
   - [ ] UC Riverside (SMI program)
   - [ ] UC San Diego
   - [ ] UC Santa Barbara (mathematics or science education minor)
   - [ ] UC Santa Cruz

10. How did participating in CalTeach influence your decision to pursue or not to pursue teaching as a career?

11. Did participating in CalTeach help inform and shape your career plans?
   - [ ] Yes
   - [ ] No
12. Please mark the option that best describes how much you agree or disagree with each of the following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Somewhat Agree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am more informed about education issues in my community from participating in CalTeach.</td>
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<tr>
<td>My awareness of K–12 education political/social issues increased from participating in CalTeach.</td>
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<tr>
<td>I have a greater appreciation of K–12 teachers from participating in CalTeach.</td>
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</tr>
<tr>
<td>I am more aware of the Common Core State Standards for Mathematics from participating in CalTeach.</td>
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</tr>
<tr>
<td>I am more aware of the Next Generation Science Standards from participating in CalTeach.</td>
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</tr>
<tr>
<td>I have a greater understanding of teaching English language learners from participating in CalTeach.</td>
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</tbody>
</table>

13. [If no to question 1] Please mark the option that best describes how much you agree or disagree with each of the following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Somewhat Agree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am more likely to volunteer in a school from participating in CalTeach.</td>
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<tr>
<td>I am more likely to participate in an education outreach program from participating in CalTeach.</td>
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</tr>
<tr>
<td>I am more likely to encourage education outreach in the workplace from participating in CalTeach.</td>
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CHAPTER 3

Opportunity Openers for Preservice Science Teachers Experiencing the “Two-Worlds Pitfall”
Opportunity Openers for Preservice Science Teachers Experiencing the “Two-Worlds Pitfall”

Caroline Long, University of Washington, Seattle
Soo-Yean Shim, Seoul National University, Seoul, South Korea
Mark Windschitl, University of Washington, Seattle
Karin Lohwasser, University of California, Santa Barbara

NSF DUE-1758264, 1852960

Preservice teachers were able to find meaningful opportunities to learn, even with mentors whose practices did not reflect the university’s vision of effective and equitable science instruction. Novices’ professional agency, coupled with structural supports and mentors’ openness, allowed them to find ways to bridge gaps between university and placement practices.
ABSTRACT

The clinical experience of preservice teachers can provide rich opportunities for them to learn about the work of teaching, but for many novices the opportunities are more limited because their host classroom does not reflect the type of instruction that they learn in their university coursework. Without these opportunities, preservice teachers (PSTs) may not get to apply, experiment with, and internalize the research-based teaching practices they are trained with. To address this challenge, this chapter looks at how the teacher education program, novice’s professional agency, and mentor openness can work together to open up new learning opportunities for teacher candidates facing the “two-worlds pitfall.” We interviewed and surveyed 63 teacher candidates throughout their clinical placement. Based on their reports, we coded the placement for its congruence with the PST’s university coursework. For candidates in low congruence placements, we analyzed their learning opportunities over time and the role of the three factors (university structures, PST agency, and mentor openness) in creating those opportunities. We use the story of three preservice teachers to illustrate how the factors can work in isolation but can also work together to create more frequent and more meaningful opportunities to learn how to teach with effective and equitable practices. Teacher education programs, teacher candidates, and mentor teachers all have a role to play in preparing teachers who are ready to work in high-need classrooms. As such, we have recommendations for how all three groups can create opportunities to learn about teaching during the clinical placement, even when the host classroom and the university are not fully aligned.
Introduction

The clinical experience of preservice teachers (PSTs1) has been called the “holy grail of teacher education,” preparing future teachers through opportunities to plan and teach with the guidance of an experienced educator, and giving them the chance to try out teaching practices on their own (Darling-Hammond, 2014).

However, the clinical experience has also been described as a time of lost opportunities due to lack of modeling, limited feedback from mentors, and few chances to try out what is learned in coursework (Anderson & Stillman, 2010; Valencia et al., 2009). Clearly there is a gap between the potential of the clinical experience and the reality of what teacher candidates actually experience.

Within one cohort of science PSTs, teacher candidates encounter a wide range of teaching practices and views of students. Some novices work with mentors who enact effective and equitable science teaching that foregrounds students’ diverse ideas, practices, and ways of thinking, reflecting the teaching practices that are espoused by the TEP. Meanwhile, other PSTs in the same program may experience environments contrary to the vision of their university training, where students are positioned as receivers and reproducers of established knowledge. In classrooms like the latter, many teacher candidates struggle with incongruence between the two worlds—their university coursework and their experiences in the field. Scholars have named this problem the “two-worlds pitfall” (Anagnostopoulos et al., 2007; Braaten, 2019; Feiman-Nemser & Buchmann, 1985; Grossman et al., 2011). In these low congruence

1 For the purpose of this paper, we use the terms preservice teacher (PST), teacher candidate, and novice interchangeably.
classrooms, teacher candidates tend to have limited opportunities to plan and teach compared to their counterparts in more aligned classrooms (Windschitl et al., 2020, 2021). The clinical experience should provide PSTs with opportunities to grow as effective educators; however, in low congruence placements, many PSTs become frustrated by contradictory messages about high-quality teaching, inconsistent expectations about their work, and barriers they encounter while trying to enact teaching practices endorsed by the university.

Many PSTs find themselves in low congruence classrooms facing additional challenges and pressures, but these circumstances do not preclude productive learning opportunities in the field. Unfortunately, little is known about how such opportunities arise. In a previous study we identified factors that open up opportunities for PSTs to learn about teaching during clinical placement: structural supports from teacher education programs (TEPs), PSTs’ agency to influence their situations, and mentor teachers’ openness to PST experimentation (Windschitl et al., 2021). In this chapter we focus on PSTs in low congruence classrooms to understand their struggles and, more importantly, explore how these factors work together to create and enhance learning opportunities in those environments. Specifically, we asked:

*How do structural factors, PST agency, and mentor openness work together to open up PSTs’ opportunities to learn in low congruence classrooms?*

By studying opportunities in low congruence placements, we hope to identify ways to support PSTs’ learning, regardless of their placement’s alignment with the university. In this chapter, we share stories of three teacher candidates who were each in different low congruence placements to illustrate how the factors worked together and created opportunities in their different contexts.
Conceptual Framework

PSTs’ Opportunities to Learn About Teaching
We are interested in PSTs’ opportunities in the field that build toward independent and effective teaching. Opportunities to learn are defined as the affordances of a setting for changing learners’ participation in communities of practice that engage in the collective process of learning (Greeno & Gresalfi, 2008). We especially focus on three kinds of opportunities for PSTs to shift their participation in teaching: 1) opportunities for active and purposeful planning, teaching, and assessing; 2) opportunities to get to know students; and 3) opportunities to reflect on the work of teaching. These three categories reflect the practical, relational, and reflective work of teaching.

Opportunities for Planning, Teaching, and Assessing
For teacher candidates, participating in planning, teaching, and assessing in a real classroom provides a chance to apply and experiment with different teaching practices, strategies, and theories. In these opportunities, PSTs can take up a variety of roles, ranging from passive and peripheral, where the PST primarily observes the work of the mentor, to active and central, where the PST takes the lead directing classroom learning. TABLE 1 lists examples of opportunities to learn across planning, teaching, and assessment (Windschitl et al., 2020, 2021). In an idealized trajectory, PSTs’ role in shaping classroom activity progressively advances from peripheral to central as they gain more insights from their experiences, their mentor, and their interactions with students (Cochran-Smith et al., 2015; Lave & Wenger, 1991). Simultaneously, the mentor’s role moves from that of calibrator toward that of coach (Lipton-Wellman, 2013). We conceptualize learning as shifts in participation over time, and so when the PST tried out new, more significant roles in the classroom, we classified this as opening up learning opportunities.
The opportunities above reflect how PSTs’ *level of involvement* in the classroom can shift over time. Changes in the *type* of instruction that PSTs enact can also reflect new opportunities to learn. For example, PSTs in a low congruence placement may regularly be able to lead lessons, but if the type of teaching shifts from lectures that focus on knowledge transfer to a series of lessons that support student sensemaking, it reflects a new type of opportunity to learn because the novice’s participation in *effective and equitable science teaching* changed. The types of instruction that we used to signal meaningful opportunities were based on widely cited consensus documents in science education (NRC, 2012, 2007; NASEM, 2019) and consisted of four major themes (see Windschitl et al., 2020, for more information). First, lessons are connected across a unit and contextualized in complex phenomena that

### TABLE 1

*Examples of Opportunities to Learn About Planning, Teaching, and Assessing*

| Planning | • Observing the mentor plan  
|          | • Tweaking the mentor’s plans without changing the intellectual work of students  
|          | • Substantively co-planning with the mentor to create or re-design lessons  
|          | • Taking the lead in planning a whole lesson or lesson segment  
|          | • Taking the lead in planning a lesson series or unit  
| Teaching | • Observing the mentor teach  
|          | • Observing the mentor teach a class and then teaching a similar lesson or segment of the lesson to a subsequent class period  
|          | • Chipping in and checking in with students during a lesson the mentor teaches  
|          | • Substantively co-teaching, sharing responsibility for leading the class, supporting learning in small groups, and/or enabling differentiation  
|          | • Taking the lead in teaching a lesson or segment of the lesson  
| Assessing | • Making minor modifications to assessment items  
|          | • Substantively modifying assessment items  
|          | • Designing assessment items  
|          | • Grading student work  
|          | • Providing feedback  
|          | • Analyzing student thinking  
|          | • Using assessments to modify instruction  

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embody “big science ideas.” Second, classroom activities are oriented around supporting students’ sensemaking of science ideas through rich discourse opportunities that leverage students’ interests. Third, students engage in purposeful self-directed disciplinary work to construct and revise their ideas and explanations of phenomena. Finally, there are diverse assessment practices for gauging students’ developing ideas and ongoing thinking, and teachers provide feedback and modify instruction to help students reflect on and develop their understanding. Enacting this type of classroom activity during the clinical placement represents an opportunity for PSTs to learn because they become better prepared to implement it in their own future classrooms. In low congruence classrooms, this type of teaching is not the norm, and so understanding when and how PSTs try it out in those contexts is critical to supporting novices experiencing the two-worlds pitfall.

Opportunities for Getting to Know Students

To engage in equitable and effective teaching also requires relational work as teachers get to know their students and school community (Moll et al., 1992; Grossman et al., 2009; National Board for Professional Teaching Standards, 2014). This knowledge informs and affects novices’ attempts at planning and teaching during the clinical experience and equips them to attend to students’ ideas and identities in their own future classroom (McLaughlin & Calabrese Barton, 2013). Getting to know students can take many forms. For instance, PSTs can learn about students as individuals from the very beginning of the placement, starting with memorizing student names. The learning process can continue as PSTs talk with students about their lives and experiences, attend after-school events, and create ongoing opportunities for students to share. Likewise, novices can better understand students as learners by reading student files (such as Individualized Education Program or 504 documents), talking to faculty, or using surveys and conversations to gather students’ perspectives on their learning and participation. To understand the community that students come from, teacher candidates
can take intentional steps to explore the neighborhood, talk to others in and outside the school who have a deeper understanding of the context, and participate in community events. Ultimately, a range of opportunities to get to know students and their community are necessary in order for PSTs to learn how to effectively support students. As such, it is important that we better understand how these opportunities come about for teacher candidates.

**Opportunities for Studying the Work of Teaching**

The teaching profession requires ongoing learning, noticing, and reflecting, and so novices’ opportunities to study the work of teaching are key to developing novices’ interpretive power and professional vision as they make sense of classroom activity and students’ ideas (McDonald, 2016; Rosebery et al., 2015). The clinical placement provides unique ways to study teaching because PSTs share a classroom with an experienced professional. This presents opportunities to thoughtfully observe, receive feedback, or co-think about plans, classroom practice, and student ideas. For instance, a PST observing a lesson could intentionally examine the teaching moves made by the mentor and note how and which students responded. As PSTs become more involved in the classroom, they may shift toward reflecting on their own practice during debriefs with the mentor. Although studies of mentor feedback often report lackluster experiences, there is consensus that it has the potential to shape PSTs’ ways of thinking about teaching and learning (Valencia, 2009; Anderson & Stillman, 2010; Hoffman et al., 2015). Opportunities to practice a reflective stance, with or without the mentor, prepare teacher candidates for the ongoing reflection and attunement to student ideas that is necessary for equitable and effective teaching.
Factors That Create and Enhance Opportunities to Learn

Based on our previous work, we selected three factors that can create and enhance opportunities for PSTs to learn about and try effective and equitable instruction in the field placement: Structural factors including university assignments and credentialing requirements, PSTs’ agency, and mentors’ openness to PSTs’ experimentation. FIGURE 1 illustrates the factors and the potential interconnectedness among them. Before we dive into PSTs’ stories, we briefly explain what we mean by these terms.

Note. Revised from Windschitl et al., 2021.
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**TEP Structural Factors That Promote Opportunities**

As part of their practice-based teacher education, the university’s TEP has a major role in the frequency and type of work that PSTs do during the clinical placement. Candidates in low congruence placements may face challenges and frustrations when they encounter the two-worlds pitfall, but university requirements and supports can help them recognize and bridge this divide. TEP influences are made visible in required assignments, performance assessments like the educative Teacher Performance Assessment (edTPA), and, in the case of our study, optional resources that promote opportunities to learn.

University assignments can provide new opportunities for PSTs because they identify specific, required roles for the novice and set expectations for the type of teaching that should be attempted. For many PSTs in low congruence placements, assignments were the primary source of opportunities to take the lead in teaching or planning (Windschitl et al., 2020). Assignments can act as boundary objects that support dyad conversations about the differences that exist between the two worlds (Braaten, 2019) and can be entry points for PSTs to try out methods learned in university coursework, especially when assignments accommodate a variety of field placement contexts (Hebard, 2016; Canipe & Gunckel, 2019). Similarly, required observations by university supervisors and the accompanying debrief conversations can lead to opportunities for the PST to take on a new role or try a new strategy (Borko & Mayfield, 1995).

Like course assignments, credentialing requirements such as edTPA can create unique opportunities for PSTs to take on new classroom roles, try out different practices, and reflect on their teaching. The high-stakes requirements explicitly name the type of planning, teaching, and assessing that the novice should include, and candidates must provide evidence that they meet the criteria (SCALE, 2018). The edTPA (along with similar performance assessments) has been recognized as a learning tool for PSTs. The experience of completing the edTPA and its
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reflections has been found to increase PSTs’ understanding of their own instructional practices, the importance of knowing their students, and the connection between teaching, planning, and assessment (Chung, 2008; Paugh et al., 2018; Darling-Hammond, 2014). Additionally, the edTPA creates protected space for PSTs to try out new practices, especially for those facing the two-worlds pitfall (Lohwasser et al., 2021). Regardless of the type of classroom PSTs are in, TEP expectations and requirements shape the roles and work novices take up during the clinical placement and can create unique opportunities.

**PSTs’ Agency to Create Opportunities**

Even when PSTs find themselves in classrooms where teaching practices don’t look like what they learned in their university coursework, they can take action by requesting chances to try something new, engaging with students in a different way, or asking questions about mentors’ plans. Attending to PSTs’ agency—intentional efforts to influence circumstances or “make a difference”—helps us understand how novices learn in situations where they must constantly negotiate their authority to try out new roles and teaching strategies (Hokkä et al., 2017). Because agency can encompass any actions a PST may endeavor to take (or not take), we focused on instances of professional agency, in which PSTs influence, make choices about, and take stances on their work and work-related identities (Eteläpelto et al., 2013). PSTs’ professional agency takes many forms, including trying out new ways of doing things, asking the mentor for support, or making suggestions for revising existing practices. Professional agency may also challenge the status quo through requesting justification of mentor decisions, pushing back on informal curriculum policies, or questioning what others define as possible in classrooms (Fenwick & Somerville, 2006). (See APPENDIX, TABLE A for more detail on different forms of agency as well as nonexamples).

As both novices to the profession and guests in the mentor teacher’s classroom, PSTs experience a twofold power asymmetry that makes it challenging to act with agency in field placements. While there are studies
showing instances of PSTs enacting agency to make their pedagogy more student-centered, critically conscious, and challenging than that of their mentors or department peers (e.g., Braaten & Sheth, 2017; Larkin, 2020; Milner, 2010; Windschitl et al., 2021). PSTs’ choices often are complicated by pressures to conform to expectations and require taking calculated risks (e.g., Edwards, 2007; Soslau et al., 2019). These challenges are particularly significant in low congruence classrooms.

In a previous study, we found that even though PSTs experiencing the two-worlds divide had a similar frequency of agentic acts compared to their peers in high-congruence placements, the enactments were qualitatively different (Windschitl et al., 2021). For example, the ways PSTs extended normative classroom practices varied greatly if the mentor primarily relied on lecture-based instruction compared to whole-class sensemaking discussions. To support future PSTs in navigating these complex tensions and creating meaningful opportunities, we need to better understand real-world examples of the agentic activities that novices engage in, especially in classrooms where opportunities to try out high quality practices are more limited and are counter to the classroom culture.

**Mentors’ Openness That Fosters Opportunities**

Even though mentor teachers in low congruence classrooms do not regularly demonstrate aspects of effective and equitable instruction for their PSTs, there are ways they can create and extend productive opportunities for novices to learn. Mentors’ openness to teacher candidates’ expansion of roles in the classroom can effectively facilitate opportunities to try out ambitious instruction (Kang, 2021; Windschitl et al., 2021). Mentor teachers who are supportive of PSTs’ experimentation encourage them to make decisions about what they want to try out, implement those decisions, and reflect on them, even if they are different from the mentors’ usual ways of teaching (Kang, 2021).

Mentor teachers’ willingness to expand their own practices also plays an important role in creating opportunities for PSTs (Edwards, 2005;
LaBoskey & Richert, 2002). Mentors who position themselves as learners of principles and practices advocated by university programs and acknowledge teacher candidates’ strengths often try to learn from their novice partners by not only encouraging them to try out new things but also incorporating those as part of their classroom routines (Hoffman et al., 2015). With mentors’ openness and willingness to learn, classrooms become a better place for novices to experiment with and improve their instruction.

While independent studies have looked at the roles of these three factors—TEP structural factors, PST agency, and mentors’ openness—there is scant literature on how they work together in the real world. Because these elements rarely operate independently, we chose to look closely at cases that illustrate the relationships between them.

Methods

Context of the Larger Study and Participants
Using a mixed-method multi-case approach (Creswell, 2012), we collected both survey and interview data from a total of 50 preservice secondary science teachers from four different teacher education programs at research universities in the western and northwestern United States. These graduate-level programs lasted between 13 and 15 months and used the edTPA, or a comparable requirement, to assess readiness to teach (SCALE, 2018). Each of the programs included extensive coursework, observations, and student teaching that predominantly took place in high-need school districts in urban, rural, and suburban schools. Methods and assessment classes were designed around the Ambitious Science Teaching framework (Windschitl et al., 2018; Stroupe et al., 2020), drawing from the recommendations in widely cited consensus documents, with a focus on student sensemaking and equity in science teaching (NRC, 2012, 2007; NASEM, 2019).
For candidates in this study, the field placement is concurrent with some or all of their coursework at the university. Assignments were similar across the TEPs and included increasingly longer and more independent experiences of planning and teaching. For example, at University 2, PSTs were initially required to plan, record, and reflect on a lesson that included a whole-class sensemaking conversation. A few months later these PSTs were asked to teach a “mini-unit” of instruction that included eliciting students’ initial ideas about a phenomenon through modeling, another whole-class sensemaking conversation, and eventually students’ revision of the models. Assignments at other universities were comparable, with PSTs creating lesson plans using either original material or adapting plans from their mentor and teaching the lessons to at least one class period for increasing lengths during the year. Other assignments across universities included giving exit tickets, interviewing students, and talking to other faculty and staff in the building. All PSTs in the study also completed credentialing requirements, with the three focal participants completing the edTPA. For these requirements, they implemented a multi-day learning segment that reflects the cycle of planning, teaching, and assessment with a focus on students’ learning needs (SCALE, 2018).

As part of this study, we regularly sent all candidates and their mentors additional resources during the clinical experience. These resources suggested activities for the PST and mentor to do together and were designed to support their work as partners. At the beginning of the year the dyads received trajectories that outlined their work across the categories of planning, teaching, assessment, and getting to know the students, school, and community. Other resources included a “Professional Roommate Conversation” that provided questions to discuss with each other at the start of the year and “Feedback Index Cards” that scaffolded lesson debriefs. Throughout the placement the dyads also received regular email newsletters that highlighted mentoring practices and recommended how dyads should work together at that point in their trajectory. Prompts included “PSTs, visit other classrooms if feasible to see how multiple teachers set up norms and routines” and
“Mentors, make the thinking behind an upcoming lesson explicit to your PST.” (For more information about mentoring practices, trajectories, and resources, visit our website: mentorteachers.org.) Unlike the assignments of edTPA, these materials were neither high stakes nor required, but the dyads were encouraged by their professors and the researchers to try out materials and recommendations.

Data Collection

Participants responded to nine online surveys during their clinical placement, which began at the start of the school year and lasted 6 to 9 months. Data collection occurred during the 2018–2019 school year and during in-person instruction for the 2019–2020 school year. Questions focused on novices’ participation in the work of teaching over time (e.g., observing planning, co-planning, or taking the lead in planning). At four points during the clinical placement, we also conducted 1-hour semi-structured interviews with each participant. We used their survey responses and a standard set of questions to learn more about their opportunities in the placement, how opportunities were initiated, and the mentor’s typical practice. (Sample survey and interview questions are provided in the APPENDIX.)

Identifying Low Congruence Placements

To define and measure congruence between the vision of science teaching emphasized in PSTs’ university coursework and their host teachers’ instruction, we focused on the four dimensions of effective and equitable science instruction that we introduced in the conceptual framework. The four dimensions are: 1) contextualization and connectedness of lessons, 2) opportunities for students to make sense of science ideas, 3) opportunities for students to engage in purposeful and self-directed disciplinary work, and 4) the use of diverse assessment practices. TABLE B (APPENDIX) shows criteria used to characterize the congruence of a science classroom (see Windschitl et al., 2020, for more information).
We used PSTs’ descriptions of their mentor’s typical practice and classroom culture to code each placement across the four dimensions (aggregate scores ranged from 4 to 20). For this chapter we focus on PSTs in lower congruence classrooms, where the prevailing norms and practices scored between 4 and 12, the lower half of potential scores. These classrooms mostly scored 1–3 for each category in the rubric, and so lessons or units were usually not grounded in real-world contexts or organically connected, activities were mostly focused on low cognitive-demand objectives, and students had little opportunity to make sense of science concepts based on their own ideas and experiences. Additionally, students did not have substantial chances to engage in disciplinary work, and the classroom assessments mostly focused on reproducing information and vocabulary.

Data Analysis

For this study we used a constant comparative approach (Glaser & Strauss, 1967) to examine PSTs’ opportunities to learn in low congruence placements. For each PST we coded the role of the three factors in their opportunities to learn. Next, we identified three cases that represent the larger sample and illustrate different relationships between the factors and the type of teaching practices introduced. (See TABLE 2 for a summary of the three PSTs’ placements and primary opportunity openers.) For these three cases, we identified events where the PST reported a new opportunity to learn about teaching (i.e., new classroom role, new opportunity to practice effective and equitable teaching, new opportunity to get to know students, and new opportunities to study the work of teaching). Next, we coded for which factor(s) prompted the opportunity: TEP structural factors, PST agency, or mentor openness.
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TABLE 2
Information About Placements and Primary Opportunity Openers for the Preservice Teachers

<table>
<thead>
<tr>
<th>Name</th>
<th>University</th>
<th>High Needs Placement</th>
<th>Primary Opportunity Opener(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joseph</td>
<td>University 1</td>
<td>No</td>
<td>Structural factors</td>
</tr>
<tr>
<td>Yichen</td>
<td>University 2</td>
<td>Yes</td>
<td>Structural factors, PST agency</td>
</tr>
<tr>
<td>Emily</td>
<td>University 1</td>
<td>Yes</td>
<td>Structural factors, PST agency, mentor openness</td>
</tr>
</tbody>
</table>


Findings: How Do the Factors Work Together to Create Opportunities?

To illustrate the different ways that agency, structural factors, and mentor openness can work together to support learning opportunities, we have selected three cases that take place in low congruence classrooms. First, we introduce Joseph, whose university assignments and the edTPA (what we call structural factors) provided him with opportunities to try out ambitious science teaching in his placement. Next, we highlight Yichen, who also used assignments to try out new things and took an agentic role to go beyond what was required by the university. Finally, we look at the experiences of Emily, who, unlike the other two cases, had a mentor who was open to instructional experimentation with the PST. These cases represent a range of ways PSTs could get extended opportunities in their low congruence placements and show the value of a mentor who welcomed experimentation, the potential of TEP resources and assignments, and the ways the PST can act to support and advocate for their own learning needs in the clinical placement.
Joseph’s Story: University Assignments and the edTPA Creating Opportunities to Learn

Joseph’s placement was a relatively small high school (less than 1,000 students) located in an affluent area in California, with a reputation of high parent involvement. Joseph was a graduate of the school and a former student of his mentor teacher, Brad. Brad taught 10th-grade chemistry and had a highly organized routine for his lessons. His typical 90-minute lesson started with greeting the class and reviewing the agenda for the day. Then he used a prerecorded video of himself to give students instructions about how to engage in the lab of the day. Examples of labs included students working in pairs to determine the concentration of solutions using titrations or making 3D models of certain molecules using kits.

While students had chances to manipulate materials and collect data, they rarely had opportunities to collectively make sense of what their observations meant or what arguments or explanations they could generate or support with data. After collecting data in the lab, students had 10–15 minutes of individual work time to document what they had observed and learned from the lab. Brad and Joseph circulated around the class to monitor students and ask them questions about their data and interpretation. Assessments were composed of students’ individual documentation and a performance grade for the lab. The class engaged in this highly organized routine for most of the lessons, but connections across labs or lessons were rarely made explicit for students.

**Adhering to the Mentor’s Routines**

Joseph at first reported getting along with Brad because he “knew him already,” but as time went on, Joseph found it more difficult to work with him. In his second interview, Joseph said that he believed that his mentor was smart, but reported, “It’s often difficult to access the mechanics of how he’s thinking, why he thinks that way.” Joseph said that he did not want to push on that because it could be uncomfortable, and so the mentor’s professional reasoning remained hidden. Additionally, Brad
was not open to letting Joseph try out strategies from the university, especially when they were different from his own typical ways of teaching. Joseph reported that this was partly due to the high parent involvement in the school community:

\[
\text{My mentor teacher was reluctant to let me fail, I think because he was worried about parents emailing the school . . . I get that, but I think that also can limit how much I can experiment and try new things because he was always worried about that angle.}
\]

Joseph’s opportunities to plan instruction did not go beyond tweaking Brad’s lesson plans, with the exception of assignments. He did play some substantial roles in co-teaching—mostly circulating to students’ lab groups. However, his teaching was bound strictly by Brad’s plans. Joseph asked individual students routine questions, such as “What do you see?” or “What do you think it means?” but did not have substantial chances to support collective sensemaking or creation of arguments and explanations. The only time that Joseph could go beyond this routine or Brad’s boundaries was when he had to work on his university assignments or during the edTPA.

**University Requirements Creating Spaces for Joseph to Engage in the Work of Teaching**

University assignments and edTPA enabled Joseph to advocate for opportunities to try out things that were “very different” from normal without confronting his mentor’s resistance or challenging the status quo himself. Joseph said that the university assignments, especially the ones that asked him to plan and teach lesson segments or whole lessons that aligned with the edTPA criteria, were “really very valuable” for him:

\[
\text{We did a series of assignments in our methods class that was like a lesson sequence. It’s kind of like the edTPA. . . . That was good because my mentor teacher was often very resistant to doing weird things that were different. So instead of that being,}
\]
“I’m asking if I can do this,” it’s more like, “I need to do this for my program.”

Assignments were critical opportunity openers for Joseph because he felt constrained by boundaries set by Brad but felt uncomfortable pushing for opportunities by himself.

The university assignments provided two new kinds of opportunities for Joseph. First, he could engage in the work of planning and teaching more substantially with Brad. Before the assignments, Joseph did not have chances to engage in planning lessons with his mentor, but he reported that “because of those two assignments, yeah, I got to plan with him much more extensively. Because we actually had to find a time to sit down and look through this and see if it was going to work.”

Second, the assignments gave Joseph opportunities to try out teaching that was more aligned with university and edTPA expectations. For example, one of the assignments from his university methods course required him to engage students in collective sensemaking. This led Joseph and Brad to plan for and facilitate a whole-class discussion, which was not typical in Brad’s lessons. Brad usually had his students work in small groups and engage in small-group discussions; however, “there was never any class discussion,” according to Joseph’s reports. Joseph’s assignments also required him to contextualize lessons with real-world phenomena, and this made Joseph and Brad come up with and use new ideas. For example, when the class talked about chemical potential energy, Joseph asked students to think about and explain how their cell phones’ batteries work.

The edTPA created similar opportunities for Joseph to take significant roles in planning and teaching and apply edTPA-aligned principles to his instruction. Planning for the edTPA was the only opportunity that Joseph had to take the lead in planning whole lessons (compared to activity-level planning) throughout his placement. Prior to this, most of Joseph’s planning focused on tweaking Brad’s lesson plans, but during the edTPA,
he made substantial changes to his mentor’s plans and made several lessons from scratch. Joseph reported that his edTPA lessons were significantly different from Brad’s in several ways. For example, Joseph incorporated more real-world phenomena into his lessons:

“We had learned a lot in our methods class about how important it was to make the stuff we teach relevant to students. . . . But that was something that my mentor did not always do, or he didn’t find it super important. And so, it was nice to see some rewards for that when I did it for my edTPA, because I think it did help with engagement.”

During the edTPA, Joseph could incorporate more of what he had learned in the university courses into his lessons and see students’ responses. In addition to incorporating phenomena relevant to students’ lives, Joseph reported that he used what he learned from his course on supporting English language learners to facilitate students’ collective sensemaking of science ideas and promote students’ use of scientific language in his lessons. Examples of strategies he tried were “pulling words apart” (“like the morphology of the words”) and explaining meanings for each part of the words that students might not know.

Although university assignments enabled Joseph to circumvent his mentor’s resistance to change in order to enact what he had learned, he faced challenges because his students were not used to these “new ways” of teaching. For example, when Joseph attempted to facilitate a whole-class discussion, the experience was new to students, and many were hesitant to share their ideas and opinions. Because Joseph did not have many more chances to take the lead in planning and teaching after this experience, he could not try out different strategies or seek ways to improve.
Summary and Challenges: Required Opportunities in a Low Congruence Placement

At first it seemed there was no room for university practices in Joseph’s placement; however, the structural factors—assignments from the TEP and the edTPA—opened up unique opportunities for Joseph to take more significant roles in planning and teaching and try out new strategies. Unfortunately, these opportunities did not extend beyond the required assignments. Consequently, Joseph only periodically had chances to plan and teach, and he encountered some significant challenges because the experiences were “so new” to students. Next, we explore the case of another PST, Yichen, who had very similar TEP assignments and requirements, but paired them with her own agency to disrupt the status quo in her classroom and create additional learning opportunities.

Yichen’s Story: Using Structural Factors to Create and Enhance Opportunities

Before entering her teacher preparation program, Yichen taught eighth-grade physics in China for one year. During this study, Yichen was a teacher candidate in a physics classroom at a large public high-need school. Yichen was placed with Rob, a first-time mentor with 10 years of teaching experience. Rob described his mentoring philosophy as very hands off, “basically monitor, monitor, then walk away.”

Based on Yichen’s descriptions, Rob’s classroom was identified as a low congruence classroom, scoring a 7 on the rubric. Each unit of instruction concluded with a project that focused primarily on engineering design and problem-solving (e.g., building a trebuchet), but otherwise the units followed the textbook, and most lessons were not explicitly connected to the project. Lessons were “about lecture and students self-learning” with the teacher explaining terms and students doing practice problems and worksheets. Students teamed up to complete unit projects, do whiteboard problems, and share their thinking with a partner, but not for the purpose of collaborative sensemaking or engaging with scientific practices. Rob’s way of doing things varied greatly from Yichen’s university training.
Initiating Opportunities to Learn From the Sideline

Yichen’s participation in the classroom was affected not only by the differences she saw between the two worlds but also by how her mentor involved her in the classroom. One month into the placement, Yichen’s mentor had still not introduced her to the students, which was “really bothering” her as a new and unrecognized member of the classroom. When Yichen and her TEP coach brought this up to Rob, he suggested that she instead walk around and identify herself to the student groups. Rob failed to use his authority in the classroom to ease Yichen’s transition, indirectly communicating to Yichen her responsibility to take charge of her opportunities to learn. Yichen shared, “He should introduce me to the students, but it seems he maybe has his way of doing things.”

Although Yichen wanted the mentor to explain her role to students, her effort to know and be known by students was one of many instances in which she used her professional agency to create opportunities to learn about teaching. Yichen memorized the seating chart and recorded what students hoped to do in the future when they shared it with the class. When Rob never explained her role to the class, she visited each group to introduce herself and get to know students. This act of professional agency prepared Yichen and the students for what she hoped would grow into a more involved classroom role.

For two months, Yichen’s opportunities to participate in lesson planning or teaching were very limited. She could not observe any planning because as her mentor explained, “I don’t plan. I already have my plan. I basically use what I have used last year.” For this reason, Yichen was limited to reviewing Rob’s PowerPoints and observing his teaching. This form of “co-planning” does not give PSTs insight into the mentor’s decision-making process that preceded the slides, and so Yichen used her mentor’s prep period to ask questions about his planning and teaching choices. She describes, “What I do during the debrief is just ask questions, why did my mentor teacher do that at that moment, and also, what he’s going to do with the situation that I observed.” Over time
Yichen’s self-advocacy and requests for information led to Rob voluntarily sharing his thinking as he made changes to lessons:

And like right now, for example, this week, whenever he changes his plan, he comes to me, “Hey I changed this plan because I noticed that they’re doing this, a little bit left behind, so I want to get them all together.” So, he started without me asking.

Although Yichen did not yet have input in the planning process, her questioning allowed her to access Rob’s professional vision, and provided new opportunities to learn.

Similarly, Yichen’s role in teaching was limited to observation, but she used her professional agency to make the most of any opportunity to learn. During class, Yichen took strategic observations, looked for ways to participate, and shared her observations with the mentor. Yichen also intentionally noticed how students’ thinking shifted over time and the role of the teacher’s questioning in that progression. This format of observation was recommended by resources Yichen received from the university but implemented in her own way to make the most of her limited role in teaching.

Yichen also expanded her classroom role during lessons by circulating in the classroom whenever students worked in groups. In one lesson students moved between stations, and she decided to position herself where students were struggling to progress. At this post she provided guiding questions to help them make sense of the work. Recounting this experience, Yichen described takeaways that she would continue to use in her teaching:

They were really frustrated when they don’t know why they’re doing this. “What’s the point?” I overheard someone saying. . . . I really realized that the student has to know why they’re doing that. The objective goal has to be really clear for that lesson.
This type of interaction with students went beyond learning about students to include learning how to support student learning as a teacher. Even though she was not fully positioned as a teacher, Yichen acted with agency to become more involved in the classroom, support students’ engagement with science, and create opportunities for her own learning about planning and teaching.

**Increasing Her Role Through University Recommendations and Requirements**

As the placement progressed, Yichen used assignments and resources from the research project to prompt an increasing role in the classroom. For one of her earliest assignments, Yichen was asked to have students complete an exit slip. She explained the assignment to her mentor, but she encountered some challenges during implementation. To her dismay, on the day of the activity, her mentor proctored the exit ticket himself, sideling Yichen. This left her frustrated:

> I was like, “Oh, no. What should I do? OK, I have nothing to do.”
> This is not how I should lead an activity because he’s basically leading the whole thing . . . all I can do is collect the exit slips. So, I struggle from that night, and then the other day, I was like, “OK, I have to do this. I have to have this one-on-one conversation.”

After this disappointment, Yichen brought up her concerns with Rob so that it wouldn’t happen again. During the conversation, Yichen explained why she needed the chance to try things herself:

> I understand that I’m a novice teacher, and he’s a really experienced teacher, and there’s a moment that he can help to jump in, and teachers interrupt, and I totally understand, but I really need that struggle moment. . . . And we talked it through, and he’s understanding.

Through this conversation with her mentor, Yichen advocated for her own learning and well-being. Although the assignment did not have
the intended outcome, it led to a conversation that supported future opportunities to try things out her own way.

Following this incident, Yichen used assignments and project resources to advocate for opportunities to try out her own style of teaching. Yichen shared, “I never mention it’s from the newsletter. I just tell him, ‘Oh, this is what we’re going to do next. This is what my program expects me to do.’” Having the supplemental resources as an outside authority supported Yichen to ask for additional opportunities to learn, including co-planning and taking the lead teaching some of the lessons. Although her mentor’s typical planning did not always align with the type of teaching she was learning about in her methods course, co-planning led to conversations about scaffolding lessons, making explicit connections for students, and anticipating students’ prior knowledge. Additionally, opportunities to take the lead in teaching led to new types of learning that are not possible while only observing another teacher:

There’s a lot of things I learned, and things that I’m still learning about pacing, timing myself, and also how to respond to students’ reaction to the question, and also how to deal with something that is not within your expectation. . . . And you get to know students better and know how they will react to a particular activity.

Instead of waiting for an invitation to participate, Yichen used her own professional agency in combination with university structures to move off the sidelines and onto the playing field.

**Shifting Classroom Norms by Extending Assignments and edTPA**

During the first semester, Yichen had two major assignments that required her to plan and teach lessons using the framework and strategies from her university methods course. The assignments were “a good reason to start to teach in the class” and created a justification for altering the status quo in the lower congruence classroom. She reported, “I will talk to my mentor teacher, ‘This is my assignment. This is my requirement. I have to do it. I have to use what I learn in our program.’”
To perform well on her assignments, Yichen had to make some changes to her role and the type of teaching that occurred, and she did not shy away from dramatically shifting the classroom practices when she had the opportunity. She introduced new talk norms and scaffolds for classroom discourse and incorporated modeling into the classroom for the first time. She provided sentence stems for scientific talk, framed divergent ideas as normal, and encouraged students to “agree and disagree and make comments on each other.” Additionally, for one of the assignments Yichen extended the length of teaching and planning beyond the 3-day requirement. Here she made her first moves to shift the classroom culture to help students engage in sensemaking, use evidence, and share their thinking even if it was different from that of their peers.

The second semester of the placement brought new requirements to fulfill—those from the edTPA. During the unit immediately before the edTPA, Yichen was primarily only able to tweak her mentor’s plans by adding pictures and videos to his slides. She taught the lessons, but only after seeing her mentor teach the lesson first period. Based on her observations she would make some adjustments to instruction, but she was largely held to his plans. Due to its high-stakes nature, the edTPA dramatically shifted Yichen’s role in planning and teaching. Yichen and Rob agreed that she should plan and teach the entire unit, rather than just the three to five lessons required. This larger segment of time allowed her to experiment with unit planning and gave her more flexibility in the segment she would use for edTPA.

Because the mentor’s typical lessons from the textbook would not meet the standards of edTPA, Yichen made all her materials from scratch and used this new and broader role to experiment in ways that were different from her mentor’s typical practice. She incorporated a local anchoring phenomenon, modeling, and new forms of classroom discourse. Likewise, assessments were totally new for students: “This was the first time they had to write a theory in their own way. And they actually got to explain why the evidence supports their claim, so it’s a new thing for them.” In
this expanded role, Yichen created plans that applied strategies she was learning in her university courses to elevate students’ funds of knowledge as a resource and position students as sensemakers.

These were not small changes from her mentor’s routine, so Yichen not only had to prepare new plans but also had to 1) convince her mentor that the changes were worthwhile and 2) prepare students for the different norms they would encounter. Yichen’s ambitious plans brought up some concerns for Rob, who was unsure that students would be able to succeed with this different type of science work. She described, “So, my mentor teacher actually worried about, it’s too new to them, and whether they can take it or not. But I still want to give it a shot and say, ‘We’ll see how students do.’”

Despite her mentor’s hesitation, Yichen stuck with her plans and, as in the fall, prepared students for the new types of work. Yichen expressed, “It took some time to prepare them to get ready for my new style of teaching that they are totally new with.” She incorporated extra supports like sentence-starters, dedicated an entire lesson to resetting classroom talk norms, and included additional framing to help students adjust: “Sometimes I need to stop and explain why we’re doing something, because they probably don’t understand and are not used to why they’re doing this . . . they’re so used to writing down what the teacher wants them to write.” The edTPA prompted a sustained opportunity to try out teaching practices that were aligned with what she was learning at the university. Without the extended time, Yichen would not have been able to practice planning an entire unit, framing talk norms, seeing and responding to students’ thinking, and supporting students in enacting the practices of scientific modeling and argumentation.

After the completion of edTPA, Rob was convinced that Yichen’s methods of planning and teaching were working for the students, and he allowed her to continue taking the lead: “After the edTPA, he felt like, ‘Yes, the students actually can know what they need to do, and they can do it. So, you can just do your planning.’” Yichen used this time to continue
experimenting with the ambitious methods she was learning at the university, but with “more flexibility to adjust my lessons.” Without the constraints of edTPA, Yichen described an increased ability to focus on responding to students’ ideas as she continued to incorporate student modeling, consensus-building conversations, and scientific talk in argumentation. Rob was so pleased with Yichen’s teaching that he asked for her unit materials at the end of the placement so that he could try some of it himself the next year.

**Summary and Challenges: Expanding Opportunities in a Low Congruence Placement**

Despite being in a low congruence placement, Yichen was able to practice the work of getting to know students, planning, teaching, and assessing. Yichen’s acts of agency and her strategic use of resources and requirements from the university opened up increasingly significant opportunities to practice effective and equitable teaching. At the beginning of her placement, she focused on getting to know students in whatever ways she could and advocated for additional insight into Rob’s planning. Later she used assignments and edTPA to create space for her own teaching. Finally, her mentor became open to her experimentation and let her take on ongoing teaching responsibility outside the requirements.

The misalignment between her university coursework and her mentor’s practices did not prevent meaningful learning, but it did mean that she encountered additional challenges. First, planning lessons that were different from classroom norms meant working solo:

> I have to start everything from scratch, so I struggle. I struggled a lot. Sometimes, I would have to plan my lesson until midnight or 1:00 or 2:00. . . . Sometimes, I’m not really confident that I did it right, but I just do it the way that I learned.

Planning without the mentor’s help meant time demands, risk, and uncertainty for Yichen. This was compounded by the limited feedback she received on her teaching. Because her instruction was so different,
Rob’s advice was limited or nonexistent. Instead, Yichen had to interpret feedback from students and independently reflect to figure out how to adjust her teaching. Unlike her peers in high congruence placements, Yichen did not have access to expertise and professional vision that aligned with the type of teacher she hoped to become.

Not only was Yichen working solo, but she had to frequently convince her mentor and her students that what she was trying was worthwhile. She reflected, “It would be helpful if my mentor teacher actually knew something about AST—Ambitious Science Teaching. Then we won’t have as much confusion about it like, ‘Why are we doing this?’ and that would be good.” Although the university requirements gave Yichen grounds for why she was doing something and her mentor did not prevent her from trying things out, there was an additional challenge to get students acclimated to the work and an added pressure to show the value to the teacher.

Without a doubt, Yichen’s experience was shaped by being in a low congruence classroom. However, it is also clear that her agency and TEP structures opened up meaningful opportunities for expanding both her role in the classroom and the types of practices that occurred. Next, we move on to the story of Emily, whose mentor was open to her trying out things in the classroom and willing to learn about practices aligned with Next Generation Science Standards (NGSS). The mentor teacher’s openness, in harmony with Emily’s agency and structural supports, created rich opportunities for Emily to practice and grow.
Emily’s Story: A Mentor’s Openness
Opening Up Opportunities

Emily was placed in an 11th- and 12th-grade physics classroom with a mentor who had 36 years of teaching experience. Emily described her mentor, Jenny, as being very busy with many roles, including being a department chair, helping with professional development at school, and teaching robotics.

Based on Emily’s descriptions, the mentor’s classroom was identified as a low congruence classroom, but Emily described the mentor as “trying really hard to implement more NGSS practices.” Emily said, “She said it’s hard for her just because she’s been teaching for so long, and she’s kind of stuck in her habits.” For example, the mentor tried to incorporate real-world phenomena into her instruction, but the phenomena were mostly used as hooks for engaging students, rather than being used as anchors for connecting ideas across lessons. Students worked in small groups to solve problems on worksheets almost every day, but there were always correct results, which were reviewed to make sure each student had the right answer. Students sometimes engaged in labs with predetermined procedures, but they did not have substantial chances to make sense of their observations. Assessments were mostly composed of multiple-choice questions, asking students to choose “the right answer.”

Making Contributions by Invitation and by Enacting Agency

From early on, Jenny regarded Emily as a thought partner and invited her contribution to planning and reflection. For example, she sometimes asked Emily for feedback on her own teaching:

> Sometimes, she’ll be like, “How do you think that went? I don’t think it went that well. Why do you think that is?” . . .
> And together, we brainstormed a way to adjust that, hopefully making it better for the students’ learning.

The mentor often shared the reasoning behind her pedagogical choices with Emily. For example, during instruction, the mentor sometimes called
Emily over to the side and explained her decisions. For example, “Take a look at the worksheet. This is what I put together. This is why I framed these questions this way.” Other times, Emily prompted Jenny to clarify or justify her thinking. For example, Emily said, “I’m like, ‘How did you go about choosing to do that?’ . . . So, it’s kind of just getting at the root of why she’s making certain decisions.” Both Jenny’s openness and Emily’s agency worked together to create opportunities to learn about planning.

Jenny often shared her desire to learn about NGSS and improve her instruction toward that end. One focus was developing real-world phenomena that connect science ideas across lessons and she often asked for Emily’s input. For example, they modified a unit to investigate satellites launched to improve Wi-Fi connectivity. Additionally, Jenny openly expressed interest in redesigning several of her units:

She said that she’s ready to scrap almost her entire curriculum for the second semester and start from scratch because she feels like, “I’ve been teaching for 36 years and I’m getting tired of doing the same thing every year. And I want to do more NGSS, so while I have someone else, this is the best time to try it.”

Through these invitations to be a thought partner, Emily gained insight into her mentor’s vision of teaching and was given opportunities to influence the type of teaching that occurred, though it was largely guided by the mentor’s interests and requests.

Even though Jenny was open to Emily’s input on planning, she was hesitant to ask her mentor for a larger role in planning and teaching. One way that Emily tried to influence lessons was by modifying assessments. Emily advocated for significant changes and redesigned several classroom assessments to give students the opportunity to show what they know. In her first interview, she described changing questions from multiple-choice to written explanations so she could “hear [their] thinking behind it.” This opportunity was sought out by Emily and considered a victory, where Emily engaged with her mentor’s interest in shifting her practice.
Opportunity Openers for Preservice Science Teachers
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*Working Together to Plan and Implement NGSS-Based Instruction*

It was university assignments that created opportunities for Emily to take the lead in planning and teaching, instead of only working within the mentor’s comfort zone. Jenny’s desire to improve her instruction toward NGSS encouraged Emily to continue to try out and work on practices aligned with expectations from the university and the edTPA that were oftentimes different from her mentor’s normal ways of teaching. As Emily and her mentor tried out more of these practices, the classroom culture shifted toward encouraging students to share their ideas and engage in processes of sensemaking:

After we had done a couple units that were very much student-inquiry focused, and we followed the 5E storyline of NGSS… students were having more fun with it. And even if we didn’t reach the same depth that we normally did, at least they were kind of constructing it themselves, and they were having a better time doing it and growing confidence in the classroom.

Positive student responses expanded the mentor’s openness to trying out more NGSS-aligned practices. Emily said, “I think she’s a bigger fan of NGSS since she’s been able to see it more practically in her classroom… and more willing to implement it next year when I’m gone.” As classroom practices shifted, Emily and her mentor co-constructed opportunities for both themselves and students to grow.
Summary and Challenges: Co-creating Opportunities in a Low Congruence Placement

Early in the placement, Emily’s mentor invited her to be a thought partner in the work of planning. Emily also sought out additional ways to shift her mentor’s assessment practices. Through assignments, new opportunities opened up for Emily to more fully try out practices from the university that she and her mentor continued to explore and experiment with during the placement.

Incongruencies between the placement and the university still presented challenges that Emily had to navigate. Even though Jenny invited Emily’s input and was open to her suggestions, she was still hesitant to permit radical changes. Emily reflected on this challenge, saying, “For me, it’s kind of trying to inch my way in until she’s more comfortable.” In the beginning she had to pick and choose what opportunities to pursue, and when: “Now that I see how well it’s going with my mentor, it would have been awesome to be doing it earlier. But it’s almost like one thing at a time, right?” Because of the incongruent classroom norms, Emily had a constant challenge to balance what was required from the university and her mentor’s view:

That methods class, I feel like we focus a lot on “never ask questions that have a correct answer.” And then, balancing that with my mentor’s view of like, “You don’t want them walking away with any misconceptions.” . . . So, I think it’s been interesting for me to negotiate those two vastly different perspectives on what students are supposed to be doing in the classroom and finding a happy medium.

Emily’s mentor was open to changing her practice, but this did not eliminate the differences between her way of doing things and the practices of the university.

Like Joseph and Yichen, Emily was able to find meaningful opportunities, even in a field placement that illustrated the two-worlds pitfall. The
mentor teacher’s openness, coupled with agency and structural support, allowed her to find ways to bridge the gap between university and placement practices. We wrap up these three stories with Emily’s advice for other preservice teachers: “It would be, don’t be afraid to speak your mind. Let them know your ideas, advocate for yourself if you want to try something new in the classroom.”

Limitations

This study relied solely on PSTs’ descriptions of their own experiences and field placements. This might limit how full or accurate our pictures of their clinical experience were. For instance, some parts of their experiences might not have come up in interviews and logs, or PSTs may have over- or understated their own agency during the placement. However, this method highlights the PSTs’ perspectives and what was important to them—perspectives that are not always prioritized in the power imbalance they encounter with their mentor teacher and the university. Deeper understandings of their experiences could be gained by additional data sources such as classroom observations or mentor interviews.

Implications

Because the field placement is an integral part of teacher preparation, it is critical to understand how TEPs, teacher candidates, and mentor teachers can open up opportunities to learn, especially in low congruence placements. Although this chapter focused on low congruence placements, the lessons learned can support PSTs’ preparation across a range of clinical placement experiences. Based on the experiences of the three teacher candidates above and the others we interviewed, we have developed the following recommendations:
Opportunity Openers for Preservice Science Teachers
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Teacher education programs and teacher educators:
- Seek out mentor teachers who support the university’s vision of science teaching and are open to and encourage PST experimentation.
- Provide assignments that create opportunities for PSTs to try out reform-based practices in their placement.
- Share clear expectations of novices’ roles in the classroom and the type of teaching they should be doing.
- Communicate to mentor teachers the high-stakes nature of credentialing requirements to protect space for the candidate to take the lead.
- Encourage teacher candidates’ agency in the placement, providing examples of ways they can navigate the power imbalance in the dyad.

Preservice teachers:
- Early in the placement, initiate explicit conversations with your mentor about your goals, feedback preferences, communication methods, and style for planning.
- Capitalize on university assignments to expand your role in the classroom, extend the duration of your responsibilities, and try new practices that are beneficial for students but not common in your placement.
- Regularly ask mentor teachers to share their thinking, let them know what you would like feedback on, and request opportunities to modify materials or try new things.
- Seek out opportunities to engage with students and other faculty and staff.

Mentor teachers:
- Be aware of the power dynamic in your relationship and open up conversations for the teacher candidate to make requests, try new things, and experiment.
- Publicly position the PST as a teaching partner in your classroom.
- Ask the teacher candidate what they are learning about in their coursework, what new practices they would like to try out, and what they would like feedback on.
• When they try new things with students, allow the novice to have extra time and multiple attempts.
• Visit our website (mentorteachers.org) to learn more about mentoring practices.

Conclusion

Ideally, all PSTs would be placed in high congruence classrooms where the practices align with the vision of the university. However, the training PSTs receive is constantly advancing (Davis et al., 2019; Stroupe et al., 2020), and so many PSTs spend their field experience in a classroom that is not completely aligned with their future-facing university coursework. Many PSTs spend their field experiences in a classroom where students’ participation in sensemaking and disciplinary practices are limited, lessons are not connected or contextualized, and assessments fail to reflect students’ diverse ideas.

Fortunately, PSTs can still find opportunities to learn in low congruence classrooms. Assignments, credentialing requirements, and other resources provided by the university can create protected space for PSTs to have specified roles in the classroom and use practices from the university. While facing a two-worlds divide, PSTs can also create opportunities to learn when they exercise their agency to make requests of the mentor, try out different ways to teach science, and shift norms in the classroom. Finally, even if a mentor’s practice does not align with the university’s vision, their openness to the novice’s experimentation and willingness to learn things themselves can support critical opportunities for the candidate. These factors—TEP structures, PST agency, and mentor openness—can shape PSTs’ experiences in the field placement and open up longer, deeper, and more meaningful opportunities to learn about effective and equitable teaching.
References


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Opportunity Openers for Preservice Science Teachers
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Appendix

TABLE A
Different Forms of Agency

<table>
<thead>
<tr>
<th>Form of Agency</th>
<th>Description</th>
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| **Self-advocacy**                                  | • Requests of PST to design something, enact something, participate in new way, take up new role.  
                                          | • Requests for feedback or for a particular kind of opportunity to learn something new.  
                                          | • Sitting someone down for a conversation, including actions that support the well-being of the novice.  
                                          | • Advocating on behalf of students or fellow teacher candidates. | |
| **Elaborating on, extending, or adding to a normative practice or classroom norm** | • Making adaptations to or trying out new strategies for a purpose related to student learning, equity, participation, well-being, developing classroom community, etc.  
                                          | • Modifications to any aspect of the work of planning or teaching to solve a problem or experiment with how students respond.  
                                          | • Trying out assessments unlike what is typically done in the classroom. | |
| **Engaging with others**                           | • Students: Interacting with students in a new way or to get to know them as individuals or as learners (in or outside the classroom, at extracurricular events, etc.)  
                                          | • Faculty, staff, or admin (other than the mentor): Observing and/or debriefing with other teachers, consulting with staff, asking for input or info from administrators, other adults in school.  
                                          | • Parents: Engaging via email, phone, parent nights, other meetings.  
                                          | • Fellow PSTs: Communicating for information, advice, comparisons of ideas, emotional support, etc.  
                                          | • Community: Visiting local shops, eating in the area, talking with community members with the purpose of learning. | |
| **Studying situation for a purpose**               | • Observing or recording students, analyzing student work, observing an educator with a purpose without being asked to do so, other similar situations.  
                                          | • Documenting and analyzing elements of one’s own practice. | |
| **Making suggestions and/or providing or asking for justifications or clarifications** | • Asking CTs or others in authority why things are done a particular way or are a part of normal practice (or not a part of practice).  
                                          | • Offering the CT a suggestion (no matter if it is taken up or not) to make substantive instructional changes.  
                                          | • Offering a rationale for a stance or practice that may not be common or normative in that classroom. |
### Opportunity Openers for Preservice Science Teachers  
**Experiencing the “Two-Worlds Pitfall”**

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<tr>
<th>Form of Agency</th>
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<tr>
<td><strong>Resisting norms or authority</strong></td>
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  • Making choices of lesson design or other practice contrary to the perceived culture, practice, or expectations.  
  • Stopping something the PST feels is unhelpful for student learning, participation, or well-being. |
| **Nonexamples** |  
  • Lacks intention to learn something relevant to their role as an educator, or to effect change they expressed as meaningful to them or to students.  
  • Responding to what someone else asked them to try out in the classroom.  
  • Taking up practices or other aspects of the work of teaching that emulated their classroom’s norms or prevailing practices.  
  • Only described the actions they felt they should take, but not following through. |
### TABLE B

**Congruence Rubric**

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<thead>
<tr>
<th>Criterion</th>
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<th>3</th>
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<tbody>
<tr>
<td><strong>A</strong> Contextualization and connectedness of lessons</td>
<td>• Lessons or units not grounded in real-world contexts (not connected to phenomena).</td>
<td>• Inclusion of interests or experiences as hooks for lessons.</td>
<td>• Content is made relevant to student experiences or interests.</td>
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<td>• Lessons represent isolated bodies of knowledge, information, skills (do not build upon one another).</td>
<td>• Use of overarching phenomena for some units or small segments of units.</td>
<td>• Lessons anchored in the press to explain complex phenomena.</td>
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<tr>
<td></td>
<td>• Inclusion of interests or experiences as hooks for lessons.</td>
<td>• Knowledge built across some lessons, but little effort across unit to construct big ideas.</td>
<td>• Learning and activity reflect “big ideas” in science, are connected and cumulative across unit.</td>
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<tr>
<td><strong>B</strong> Students’ equitable opportunities to make sense of science ideas</td>
<td>• Activities focused on lower cognitive-demand objectives: memorization, procedures, vocabulary, and answering closed questions.</td>
<td>• Occasional challenging activities in which students actively participate in achieving goals, solving problems, or representing ideas. (Indicators: sharing ideas, small-group activity to solve problems or represent ideas.)</td>
<td>• Regular challenging activities in which students actively participate in achieving goals, solving problems, or representing ideas.</td>
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<td></td>
<td>• Little or no opportunity for students to reflect on what was learned.</td>
<td>• Some classroom talk devoted to students’ ideas or experiences relative to the science.</td>
<td>• Small- or whole-group discourse built into lessons, aimed at unpacking students’ ideas or experiences generated by activity.</td>
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<td></td>
<td>• Strict pacing of lessons, regardless of students’ state of interest, need, or confusion.</td>
<td>• Students take part in occasional reflection on what was learned.</td>
<td>• Sensemaking support available: differentiation or scaffolding to support all students’ participation.</td>
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<tr>
<td></td>
<td></td>
<td>• Occasional modification of curriculum to address students’ interests or needs.</td>
<td>• Curriculum modified to address students’ challenges in understanding or opportunities to build on their interests.</td>
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## Criterion C: Students’ engagement in disciplinary work

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| C | • Students’ work unrelated to disciplinary activity (e.g., copy and paste models or lab procedures; rigid color-coding). | • Occasional activity that includes scientific practices, but used in isolation.  
• Teacher provides some structured opportunities for students to make choices during disciplinary work (e.g., choosing how data is presented, changing a variable, or identifying trends from larger data sets; conversations about error). | • Students coordinate the use of multiple scientific practices (including modeling, argumentation, or explanation) to construct knowledge.  
• Students decide the specifics in how to take up this work (e.g., answering their own questions). |

## Criterion D: Classroom assessment practices

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| D | • No formative assessment, and quizzes and tests are only used for evaluative purposes.  
• Assessments focus on reproduction of textbook information, vocabulary, procedures, etc. | • Formative assessment used (exit slips, diagnostic conversations, rough draft explanations), but limited feedback given to students or feedback not used to modify instruction.  
• Summative assessments occasionally focus on challenging intellectual work or performances. | • Formative assessment used regularly. Feedback helps students reflect on responses; used to modify instruction.  
• Summative assessments focus on challenging intellectual work or performances.  
• Students offered support and options to show what they know. |
Sample Survey Questions:

**Your opportunities to learn—about students and their communities**

1. What opportunities did you have to learn about my students and/or their community, and how often? (click on all that apply: e.g., interacting with my students to know more about their interests, backgrounds they have from outside the classroom, attending an after-school event, analyzing my students’ work, etc.)

2. Please describe an example of an insight you gained about your students or community during this logging period that might become important in the work of teaching, and how you gained it.

**Your opportunities to learn—about planning for instruction**

3. Observing other professionals: How often have you had the chance to . . . (e.g., observe how individual lessons are modified to take advantage of students’ experiences or interests, etc.)

4. For the opportunities below (e.g., Observing, Tweaking, Substantive co-planning, Taking the lead, Other, etc.)
   a. Which opportunities did you have for planning lessons? Units?
   b. Which describes most of your opportunities for planning lessons? Units?

5. How often did your mentor provide you with feedback on planning lessons? Units?
   a. Please describe a type of feedback on planning lessons OR units that was especially useful for you, and why.

**Your opportunities to learn—about teaching**

6. I’ve observed teaching by educators other than my mentor in my school placement . . . (select frequency and describe the occasions)

7. For the opportunities below (e.g., Observing, Chipping/Checking in, Observing and repeating, Substantive co-teaching, Taking the lead, other, etc.)
   a. Which did you have for teaching?
   b. Which characterizes most of your opportunities for teaching?
8. During this logging period, I’ve had a chance to try out these parts of teaching: (click on all that apply: e.g., giving instructions for an activity, asking students to fill out exit tickets, engaging students in whole class sensemaking talk, etc.)

9. How often did you and your mentor debrief your attempts at instruction?
   a. Please describe a type of feedback on teaching that was especially useful for you, and why.

Your opportunities to learn—about assessment

10. I developed assessment items or assessments that measure students’ . . . (select frequency: e.g., conceptual understanding of science ideas, ability to engage in a science practice or skill in service of solving a larger problem, etc.)

11. I’ve had a chance to look at students’ work, written responses, or tests/quizzes to . . . (select frequency: e.g., give grades, modify instruction, etc.)

12. What other opportunities have you had with assessment during this logging period (if applicable)?

Your opportunities to learn—use of project resources

13. For the resources listed below from the newsletter or project website, please select whether you looked at and/or used the resource and in what way(s) during this logging period. (Select how it was used and its helpfulness.)

14. For interactions between you and your mentor around project resources . . .
   a. Who initiated, what did you do together, and how often did they occur?

Your opportunities to learn—general

15. I was able to implement ideas from my university courses . . . (click on all that apply: e.g., in the design of a lesson, when teaching, etc.)

16. On a scale of 1–7, how capable do you feel currently in the following areas? (e.g., planning lessons, teaching, getting to know students as learners, etc.)
Sample Interview Questions:

1. Field context: brief description of typical lesson in placement classroom, including opportunities for students to participate in disciplinary practices, engage in sensemaking talk, etc.

2. Opportunities to learn about students, their parents, and the students’ community.

3. Planning for instruction: examples of experiences with lesson planning selected on log (e.g., tweaking, substantive co-planning); involvement in unit planning; opportunities to receive feedback on planning.

4. Teaching: examples of experiences selected on log (e.g., observing and repeating, taking the lead); opportunities to debrief with mentor.

5. Assessment: examples of experiences selected on log (e.g., developing items to measure conceptual understanding, looking at student work to identify trends); what students are asked to do/share via assessments.

6. Brief description of changes in how you are using the newsletter, website, or specific resources at this point in your placement; how you and your mentor use these together.

7. Why you selected the resources you did as most valuable; what resources would be helpful.

8. Is there something else that stood out as a learning opportunity in your placement since the beginning of the school year? Something we’ve not asked about?
CHAPTER 4

Impacts of the STEM Teacher and Researcher (STAR) Program on Teachers, Students, and Classrooms
Michael Perez, three-time STAR fellow in 2015, 2016 and 2017 at the Santa Rosa Island Research Station [Image credit: Zach Green, Zach Green Films]
Impacts of the STEM Teacher and Researcher (STAR) Program on Teachers, Students, and Classrooms

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Collaborative: NSF DUE-1660839, 1836335, 1660810, 1660777, 1660715, 1660658

Our findings demonstrate the value of engaging preservice educators in structured and supported research experiences to increase their productive mind-sets about themselves as participants in STEM, as well as to support their STEM-related classroom practices.
ABSTRACT

For over a decade, the STEM Teacher and Researcher (STAR) Program has been supported by the National Science Foundation (NSF) Robert Noyce Teacher Scholarship Program along with other funders to provide paid summer research experiences for preservice and early-career science and mathematics teachers at national laboratories and other research facilities. Research into teacher research experiences (TREs) often includes self-report data from program participants, with few studies looking at impacts on students or longer-term impacts. We present results from a set of three Noyce Track 4 Research studies regarding the impact of the STAR Program on teacher effectiveness and productive mind-set. The first study compared eight STAR and non-STAR classrooms and found measurable differences both in how teachers describe their classroom practices and in how students perceive these practices and their own interests and skills, specifically in STEM career awareness, perception of the value of STEM learning, and student perseverance. The second study investigated the impact of STAR teachers on student achievement and found that there were no measurable differences in student achievement on high-stakes state assessments between students of nine STAR teachers and students of other teachers in their five respective districts. The third study found that infusing explicit instruction on productive mind-sets has a positive impact on preservice teachers’ own mind-sets and the strategies that they plan to use with their students. Ongoing work involves investigating the impact of the STAR Program on teacher retention, comparing long-term retention rates of STAR and non-STAR teachers in the state of California. Our work demonstrates the value of supported research experiences for future STEM teachers and illustrates some of the complexity of assessing the impact for students.
Introduction

For decades, the model of providing mentored research opportunities during both summer and academic months has been used to prepare the future STEM workforce. The NSF has maintained a robust Research Experience for Undergraduates (REU) Program since 1987 and has also maintained a Research Experience for Teachers (RET) Program for roughly the same duration of time. Applying these models to preservice or aspiring teachers is a more recent but equally compelling approach to preparing students to learn about STEM and STEM careers.

Teacher Research Experiences (TREs), which include NSF-funded REU projects for pre-service teachers and RET projects, come in many forms. In this chapter, we focus primarily on the STEM Teacher and Researcher (STAR) Program as a model of mentored summer research for preservice STEM teachers. The STAR Program includes mentored research along with a weekly professional development education workshop and a closing conference in which participants present their research to a community of scientists, STEM educators, and teacher-researchers. The STAR Program has been funded by the NSF Robert Noyce Teacher Scholarship Program for over a decade to place preservice Noyce Scholars into 9-week summer research experiences in laboratories, primarily across the western U.S. Any Noyce Scholar, along with preservice STEM teachers from any California State University campus, can participate in STAR for up to 3 consecutive years, which can include up to 2 years of inservice participation. Robust program evaluation has been conducted since the inception of the STAR Program. More recently, we have leveraged
15 years of alumni into a set of follow-up studies of STAR teachers and have added sets of comparison teachers who have not participated in this TRE program to increase the validity of our findings.

Background

The STAR Program has conducted rigorous evaluation since its inception. Here we report on a set of three studies, funded by two Noyce Track 4 Research awards, that have been conducted to investigate the impact of the STAR Program. These studies include two comparative research studies of the impacts of the STAR experience on perceived outcomes among students and student achievement scores as measures of teacher effectiveness (DUE 1660839, 1660810, 1660777, 1660715, and 1660658). A third study investigated changes in productive mind-sets among STAR Fellows across their summer research and support workshops (DUE 1836335). These studies have been conducted through collaborations of faculty from the California State University system, University of Colorado, University of Arizona, Baruch College, CUNY, and researchers from the American Institutes for Research. These studies, including the research questions and data sources, will be described following the literature review and overview of the STAR Program.

Teacher Research Experiences

Assessment of TREs has been conducted for over 20 years (Westerlund et al., 2002). Research on TREs illustrates many positive outcomes for teachers completing these programs. Such benefits include improved self-efficacy, enhanced understandings of the nature of science and inquiry, better science content knowledge, refined or extended teaching practices, and greater knowledge of science practices (Evans & Crippen, 2020; Feldman & Ozalp, 2009; MacFadden et al., 2020; Southerland et al., 2016). However, research has also documented challenges in identifying
effective research mentor-research mentee matches, as well as issues of collaborations between teachers and scientists, as scientists can downplay or undervalue teacher expertise (Shanahan & Bechtel, 2020). Teachers may also be initially intimidated by scientists’ expertise in a given field when first joining a research project (Shanahan & Bechtel, 2020). Further, studies of teacher conceptual gains in TREs show mixed results (Feldman et al., 2013; Luera & Murray, 2016; Westerlund et al., 2002). As such, despite potentially positive TRE outcomes, there is still much to be learned about TRE design features that ensure mutually beneficial outcomes for scientists and teachers.

Beyond outcomes directly self-reported by TRE participants, there is a dearth of research illustrating how TREs translate into classroom practices and, in particular, how students of these teachers are impacted. Previous studies of TREs have predominantly relied on teacher accounts of student experiences and have not included students’ perspectives. Further, there has been limited insight not only into student perceptions but also into student conceptual learning as a result of having a teacher with a TRE. Two studies with firsthand accounts from engineering TRE participants found that their students showed increased subject awareness and increased interest in pursuing an engineering career (Autenrieth et al., 2018; Reynolds et al., 2013). Studies on conceptual learning of students of TRE teachers showed increased pre-/post-content knowledge (Ragusa & Juarez, 2017; Yang et al., 2020). One study has shown that students of TRE teachers outperform students of non-TRE teachers in the New York Regents exam (Silverstein et al., 2009).

Overall, the existing literature illustrates the relative infancy of research into TRE programs. Many programs are still determining effective design features of the TRE for intended outcomes. Furthermore, limited studies of TRE program alumni effectively investigate how TREs translate into STEM classrooms, from teacher and student perspectives. Only one study has included comparison teachers when assessing student conceptual learning for TRE teachers (Silverstein et al., 2009). Hence, there is still much to learn about the impact of TREs.
Productive Mind-Sets

U.S. cultural assumptions about STEM ability are sometimes rooted in innate, talent-based views. These views encompass beliefs that some people are “STEM people” and some are not, and that these abilities are conferred at birth (Williams & King, 1980). Holding this “fixed view” of intelligence has been shown to lower motivation, undermine performance, and disrupt learning, especially when learners are faced with challenging content (Dweck & Leggett, 1988; Dweck & Yeager, 2019; Grant & Dweck, 2003; Mangels et al., 2006; Yeager & Dweck, 2012). Furthermore, recent research has established a strong connection between the extent that a field is imbued with a culture of talent and the lack of representation of female and Black students in that domain (Leslie et al., 2015). The alternative to this view—a “growth mind-set”—eschews these talent-based foundations for success and instead embraces the idea that intelligence can be developed over time through hard work, perseverance, and productive effort (Dweck & Leggett, 1988). In learning settings, all benefit when students are focused on improving, rather than proving, their ability, motivation, performance, and learning (Yeager et al., 2019). Further, research has shown that intentionally and explicitly teaching students about the malleability of intelligence—that is, that neurological and biological changes happen in the brain in response to novel, challenging content—not only boosts students’ test scores, but also increases student achievement across the board in mathematics (Aronson, Fried, & Good, 2002; Good, Aronson, & Inzlicht, 2003).

Mind-sets about intelligence do not exist in a vacuum. Rather, the learning culture that students experience can affect their own beliefs and perspectives (see Bielock, 2010), and teachers’ own fixed or growth mind-sets can impact the culture of talent in their STEM classroom. For example, teachers’ mind-sets affect their pedagogical practices (Anderman et al., 2001) in ways that align with those beliefs, such as highlighting achievement of students rather than their growth and development. In addition, teachers with a fixed mind-set have been shown to be more likely to implement a performance approach rather
than a learning approach in their classrooms, to lower expectations for struggling students, and to blame students for their own struggles (Rattan et al., 2012) rather than focus on improving pedagogy (Gooyabadi & Good, 2016). Students not only accurately discern their teachers’ mind-sets through these differentiated pedagogical approaches but respond with reduced motivation, interest, investment in the class (Rattan et al., 2012) and grades (Canning et al., 2019) when teachers hold fixed rather than growth mind-sets. Thus, promoting growth, rather than fixed, mind-sets is important for all students. This approach is particularly important for prospective STEM teachers who will impact the mind-set of their future students (Dweck, 2016).

Promoting growth mind-sets is particularly critical within STEM domains whose culture of talent not only undermines students’ foundations for success but also amplifies harmful messages that only some people truly belong in the domain (Good, Rattan, & Dweck, 2012). Sense of belonging is a fundamental human motive (Baumeister & Leary, 1995), and as such, can affect important outcomes such as physical and mental health. Feelings of belonging to an academic domain are critical (Steele, 1997), especially for learning. High academic belonging not only reflects feelings of being inside a discipline or learning community rather than on the fringes of it (Good, Rattan, & Dweck, 2012) but also predicts a suite of important variables related to learning success, such as anxiety, confidence, utility value, and intrinsic motivation.

The foundations upon which students base their feelings of belonging can also be important to consider. For example, do students feel like valued members of the STEM community because of their own efforts and engagement, or does belongingness depend on their achievement? Emerging research (Good et al., 2015) has shown the importance of fostering effort-based belonging (growth mind-set) over achievement-based belonging (fixed mind-set) for STEM outcomes. Specifically, students whose belonging is contingent on effort (rather than achievement) not only engage more with their learning task but also
are less vulnerable to both cultural stereotypes, suggesting that some people have more ability than others in STEM and to talent-based messages in their learning environment (Good et al., 2015). This is especially important for underrepresented groups in STEM. Often, teachers employ “comfort strategies” when a student does not do well to help them feel better, instead of encouraging them to try productive approaches (involving more or different kinds of effort) to succeed, aligning with a fixed mind-set for some of their students (Gooyabadi & Good, 2016). Thus, developing a hardy effort-based sense of belonging is also important for both STEM students and teachers, and especially for teachers who work with high-need students. As discipline-based education research in all STEM domains has amply illustrated, the learning of STEM inevitably involves conceptual and problem-solving struggle through engagement with tasks of high cognitive demand. If this struggle is interpreted by the student (or worse, by the teacher) as evidence that the student has reached immutable limits of their innate STEM intelligence, then the response to this struggle will be profoundly different than the response of those who recognize that everything worth learning is difficult and requires effortful practice. Normalizing productive struggle, therefore, is an important orientation for future STEM teachers. It is important to note that in recent years, misunderstandings about fixed and growth mind-sets in educational contexts have served to place the blame that properly belongs to systems on individual students (see, for instance, Good & Regnier, 2016).

Conceptual Framework: Studying TREs
Understanding the value of research experiences for undergraduate students and teachers continues to be an active area of research (Krim et al., 2019). The Collaborative Around Research Experiences for Teachers (CARET) is a group of stakeholders from U.S. research programs from across the country that has come together to discuss systematic ways to assess TREs, undergraduate research experiences, and course-based undergraduate research experiences in science courses. As part of
Impacts of the STEM Teacher and Researcher (STAR)
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this work, the group reviewed 307 empirical papers studying research experiences and developed a research-based model for studying research experiences (Krim et al., 2019). The CARET model conceptualizes a relationship among TRE communities of practice, professional learning communities, and outcomes for teachers and their students. The CARET model lays out the potential impacts of TREs to involve teachers’ STEM research experience, knowledge, practices, awareness, attitudes, and perceptions, which in turn results in changes to classroom practices. Those practices, if enacted, are predicted to result in changes in student outcomes. In addition to the CARET framework, we draw upon a model of third-generation activity theory (Engeström, 2015; Wade-Jaimes, Cohen, & Calandra, 2019) to conceptualize interactions between TREs and classrooms, as teachers make decisions about what can be implemented in the classroom from their research experiences. Taken together, this conceptual framework helps drive the direction of data collected and an analysis framework to understand the complexity of not only how research experiences may be implemented but also barriers to implementation in classrooms.

Context for Research: STAR Program

The STAR Program is a national initiative headquartered at California Polytechnic State University, in San Luis Obispo, California. It provides immersive 8- to 10-week summer research experiences to prospective STEM teachers from any California State University campus or any Noyce Program in the nation. Noyce students must start their first STAR placement when they are participating in either a Track 1 or a Track 2 Noyce Program. To be eligible to participate in STAR, a student needs to be at least in their junior year, but not have begun teaching in their own classroom, by the beginning of the year in which they participate for the first time. Participants may return for two additional summers until they complete the second year in which they are the teacher of record.

Since its inception in 2007, STAR has served 590 aspiring and early-career participants in 820 research placements at more than 40
cooperating research settings including national labs funded by NSF, the National Aeronautics and Space Administration, the Department of Energy, the Department of Defense, the National Oceanic and Atmospheric Administration, and the United States Geologic Survey, as well as university laboratories and research and development settings. Successful STAR applicants have come from all 22 California State University (CSU) campuses with teacher education programs and 88 Noyce projects throughout the United States. STAR Fellows have impacted more than 200,000 pre-college students in their own classrooms. STAR Fellows have aspired to pursue teaching (or are in their first or second year of teaching) STEM subjects at the middle and high school levels (90%) as well as the elementary school level (10%).

The STAR experience has the following components, which together form the backbone of the STAR model:

1. A 9-week paid research experience with a mentor chosen by a lab site coordinator. Occasionally, with the mutual agreement of the STAR Fellow and their mentor, STAR extends the appointment for a tenth paid week. Similarly, the experience may be shortened by a week (with a concomitant reduction in the stipend) to accommodate a Fellow’s need to assume their professional teaching responsibilities at an early-start school district.

2. A concurrent weekly 3–5-hour STEM Education Workshop, organized around geographically close face-to-face placements (pre-COVID-19) or in remote cohorts that include STAR Fellows with varying experience in STEM teaching (during COVID-19).

3. A 2-day closing research conference, which until 2018 was a STAR-specific conference. Starting in 2019, the STAR closing conference has been held in conjunction with several other TRE programs, with substantial support from the M. J. Murdock Charitable Trust through its Partners in Science National Conference.
Both the research experience and the closing conference are similar to other TRE programs. Key to the research is that participants work in STEM research labs, are mentored by active science researchers, and do independent research that contributes to the overall research program for that lab. At the closing conference, STAR Fellows come together to present their summer research findings (through poster presentations and/or oral presentations) and to network.

A central feature of the STAR TRE model, the STAR STEM Education Workshop, provides crucial support that helps Fellows translate the research placement into productive K–12 classroom practice. With specially designed experiences that bridge the laboratory with the classroom, STAR Fellows are encouraged to develop lessons and opportunities for pre-college students that will engage them in authentic science and engineering or mathematical practices, which is a major goal of the Next Generation Science Standards and the Common Core Standards in Mathematics for all students. Originally, the workshop involved two deliverables: a research poster (as an enduring, authentic disciplinary product) and a lesson plan that reflected, if not the research focus of the STAR Fellow, at least the practices of the laboratory. In addition, topics of reflection in the workshop included Nature of Science considerations, a focus on the plethora of STEM careers open to students, and professional advice about job-seeking in school systems. Since 2018, STAR has deemphasized the second deliverable, moving it from individual lesson plans to lesson plans developed by a group of STAR Fellows, and introduced an explicit focus on productive mind-sets.

Although a primary goal of STAR is for teachers to create authentic, scientific research experiences in their own classrooms, the STAR leadership reflected that a precursor to succeeding in this goal is the development of STAR Fellows’ dual identities as teacher-researchers. That is, it is necessary to recognize the need to provide experiences for STAR participants that will help them build resilient identities not just as STEM teachers but also as STEM researchers. Consequently, the
program turned to the literature in social psychology, described above, to identify key psychosocial variables that research has shown to be predictive of STEM outcomes, such as identification with STEM domains. The program leadership chose to focus on mind-sets about the nature of STEM intelligence (Dweck, 2013) and mind-sets about who truly belongs in STEM (see Good et al., 2012).

It is the intention of the program that explicitly discussing these mind-sets—beliefs about intelligence (e.g., fixed and growth mind-sets) as well as belonging—not only can help STAR Fellows understand that productive struggle is part of the process of research but also can aid in retaining STEM teacher-researchers. Each weekly, 3–5-hour educational workshop session includes opportunities to develop Fellows’ deep understanding of growth mind-set and belonging. For example, Fellows work on a challenging mathematics problem that necessitates productive struggle and then discuss their responses to that struggle. Fellows also discuss their work in their research lab and focus on the shared experience of struggling within the content and process of doing research. These conversations are intended to normalize their experiences of challenge and help establish the universality of feeling confused or unsure in science. Research has shown that when hard work and struggle are conveyed as normal processes of academic work, feelings of belonging are boosted (Smith et al., 2012).
Investigations

Motivated to better understand the impact of the STAR Program on current Fellows and on alumni as teachers, a group of researchers designed and implemented three research studies to explore the impact of STAR on teachers’ classroom practices, potential impacts on student achievement, and the impact of newer innovations in the weekly workshops on Fellows’ mind-sets and feelings of belongingness. The first two studies are of classrooms of alumni who participated in STAR between 2007 and 2018 and are active science or mathematics teachers. Both studies employ a matched design and include student data. The third study, of active STAR participants, was carried out to understand how changes related to infusing a productive mind-set would impact the participants’ own mind-sets and feelings of belongingness in STEM.

Study 1: Classroom Practices and Teacher Effectiveness

The purpose of this study was to determine the impact of a STAR research experience on teachers’ classroom practices as a way to investigate teacher effectiveness. Data were collected from teachers and their students from classrooms of STAR teachers and, for comparison, of non-STAR teachers. The overall study was guided by the following research questions:

1. Student Perceptions—Compared to students of non-STAR teachers, how do students of STAR teachers differ in their perceptions of STEM classroom practices, engagement, perseverance, STEM career awareness, and the value of learning STEM subjects?

2. Classroom Practices—Compared to other teachers in their schools and/or districts, how do STAR teachers talk about classroom practices and student learning?
Methods for Investigating Classroom Practices and Teacher Effectiveness

This study collected data from teachers and students in 16 classrooms, eight STAR and eight non-STAR. The non-STAR comparison teachers were selected because they taught related subjects in the same school or district as the STAR teachers. Data included student perceptions as well as teachers’ narratives. Students’ perceptions were gathered through surveys and included constructs related to their teachers’ classroom practices, and student engagement, as well as questions on their own STEM career awareness, perception of value of learning STEM subjects, and student perseverance. The study employed a quasi-experimental, matched design to examine differences in these constructs between the study sample of classrooms of STAR alumni and non-STAR matched comparison groups. The survey was administered to students during both the beginning and the end of the 2018–2019 academic year. The survey was based on existing and validated scales (Hayes et. al., 2016; TIMMS 2007 Assessment Frameworks, 2007; Friday Institute for Educational Innovation, 2012; University of Chicago, 2017) with modifications.

During the pre-administration of the survey, a total of 817 students (405 students taught by eight STAR teachers and 412 students taught by eight non-STAR teachers) were asked to rate their prior STEM learning experiences; during the post-administration, students were asked to rate their experience with their current STEM teacher. The overall response rate was 63% (67% for students of STAR teachers and 60% for students of comparison teachers). A matched comparison analysis was conducted amongst student survey respondents. This kind of matching ensures that we compare students who are as similar as possible across observable characteristics (that is, characteristics we can measure, such as baseline scores for the measures on the pre-survey, and background characteristics such as gender, race/ethnicity, grade level, highest educational attainment anticipated, an indicator of having been taught by the same teacher in the prior year, and class subject). Accounting for students who did not fully complete the survey and the
propensity matching resulted in a total of 392 students taught by a STAR teacher matched with 184 students taught by non-STAR teachers. TABLE 1 below gives some of the demographics of the sample of students used for the comparison.

### TABLE 1

*Example Student Demographics Used for Student Matching*

<table>
<thead>
<tr>
<th>Student Characteristics</th>
<th>Students of TRE Teachers</th>
<th>Matched Comparison</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>50.5%</td>
<td>52.6%</td>
<td>51.2%</td>
</tr>
<tr>
<td>Non-White</td>
<td>64.0%</td>
<td>67.9%</td>
<td>65.3%</td>
</tr>
<tr>
<td>Taught by Teacher Previously</td>
<td>13.5%</td>
<td>8.7%</td>
<td>12.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Students of TRE Teachers</th>
<th>Matched Comparison</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math</td>
<td>7.4%</td>
<td>7.4%</td>
<td>7.4%</td>
</tr>
<tr>
<td>STEM</td>
<td>6.4%</td>
<td>0.0%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Science</td>
<td>86.2%</td>
<td>92.6%</td>
<td>88.3%</td>
</tr>
</tbody>
</table>

| Number of Students | 392                     | 184                | 576   |
| Number of Teachers | 8                       | 8                  | 16    |
| Number of Schools | 7                       | 6                  | 8     |

A weighted linear regression was used to estimate the relationship between the teacher’s TRE status and student perceptions for each construct. Additionally, subgroup analyses investigated both high-need status (based on school-level data) and Noyce status of each teacher.

Phone interviews were conducted with each teacher to obtain teacher narratives about their classroom practices. These interviews were recorded, transcribed, and coded by a team of three researchers. An initial codebook was developed before coding based on the constructs of the student survey. An initial coding of transcripts led to the addition of codes related to both student constructs and emergent themes. Each transcript was coded by at least two researchers. Inter-rater reliability was 0.85. All transcripts were coded with the final codebook and emergent themes were analyzed with attention to STAR and non-STAR teachers.
**Classroom Practices Findings**

Below we summarize the key findings of the study. More detail about analyses, full results, and findings can be found in Keller et al. (2022).

In comparing student survey responses between STAR teachers and comparison teachers, statistically significant findings were obtained in the domains of student perseverance ($p < .01$) as well as STEM career awareness and perception of values of learning STEM subjects ($p < .05$). **TABLE 2** below summarizes these differences. The regression coefficients can be found in Keller et al. (2022). Students of STAR teachers reported stronger gains in STEM career awareness, value of learning STEM subjects, and student perseverance.

**TABLE 2**

*Student Survey Main Model Regression Summary of Result*

<table>
<thead>
<tr>
<th>Student Survey Construct</th>
<th>n</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom practices</td>
<td>576</td>
<td>Negative</td>
</tr>
<tr>
<td>Student engagement</td>
<td>576</td>
<td>Positive</td>
</tr>
<tr>
<td>STEM career awareness</td>
<td>574</td>
<td>Positive*</td>
</tr>
<tr>
<td>Value of learning STEM subjects</td>
<td>573</td>
<td>Positive*</td>
</tr>
<tr>
<td>Student perseverance</td>
<td>574</td>
<td>Positive**</td>
</tr>
</tbody>
</table>

*Note.* Each row represents a separate regression. Coefficients are statistically significant at the * 5% and ** 1% levels.

Subgroup analysis revealed that the STEM career awareness increase for students of STAR teachers was consistent in non-high-need settings regardless of Noyce status. The same was true for non-Noyce teachers. Students of STAR teachers reported stronger gains in perceptions of the value of learning STEM in aggregate and for non-Noyce teachers. Students of STAR alumni had stronger gains in student perseverance in aggregate, for teachers in high-need schools and for non-Noyce teachers. Lastly, an analysis of students in high-need schools revealed stronger frequency of self-reported classroom practices for non-STAR teachers.
TABLE 3 below summarizes the regression coefficients for the subgroup analysis. All of the coefficients were positive except the one for classroom practices in the high-need subgroup analysis (noted in the table).

**TABLE 3**

*Summary of Findings From Subgroup Analysis of Student Surveys*

<table>
<thead>
<tr>
<th>Subgroup Finding for Construct</th>
<th>Not High Need</th>
<th>High Need</th>
<th>Subgroup Finding for Constructs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Noyce</td>
<td>High Need</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 STAR teachers</td>
<td>3 STAR, 3 non-STAR teachers</td>
<td>Value of learning STEM subjects (***)</td>
</tr>
<tr>
<td></td>
<td>Not Noyce</td>
<td>High Need</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 STAR, 4 non-STAR teachers</td>
<td>1 STAR teacher</td>
<td>STEM career awareness (<em>); student perseverance (</em>**)</td>
</tr>
<tr>
<td></td>
<td>Subgroup finding for construct</td>
<td>Classroom practices (negative coefficient <strong>); student perseverance (</strong>*)</td>
<td>STEM career awareness (<em>); value of learning STEM subjects (</em>); student perseverance (***)</td>
</tr>
</tbody>
</table>

Findings from the interview analysis gave some insights into potential factors contributing to student survey responses. In particular, STAR alumni noted that their efforts to promote STEM career awareness and to promote the value of learning STEM subjects were more agnostic to a particular STEM subject or topic. Rather, the STAR teachers emphasized STEM learning as having value in any career or discipline beyond high school and valued the role of scientific thinking in general. Additionally, STAR alumni were able to draw upon their own experiences doing research and their own connections for resources related to STEM careers. Comparison non-STAR teachers were more likely to talk about preparing students for specific STEM careers and relied more heavily on online resources or other sources to support career connections.

Interviews with teachers highlighted STAR teachers’ empathy regarding student perseverance as a result of challenges faced during their summer research experiences. While not the only contributing factor, STAR alumni appreciation for working in an unfamiliar laboratory environment
on a research problem that does not have an easily defined or scripted solution may have contributed to enhanced responses with regard to student perseverance. Interview findings also revealed differences in how STAR teachers talked about engaging their students in science and engineering practices more often in the classroom.

STAR teachers discussed how their own research informed engaging students in more open inquiry activities, their comfort with letting students explore questions for which they did not already know the answer, and the importance of problem-based activities.

Overall, the findings of this study revealed measurable differences in classroom practices described by STAR teachers and outcomes for students measured through student perceptions. The implication of this work is that engaging in research experiences with pedagogical support may have a strong impact on classroom practices, which can be detected both through conversations with teachers and through student perceptions.

Study 2: Student Achievement

The purpose of the second study was to determine if changes in teacher effectiveness found in the first study were detectable in student achievement scores. Data for this study included standardized student achievement test data collected for STAR and non-STAR teachers who taught similar grades and subjects in the same districts. Inspired by gains in performance on the New York Regents Board exam shown by students of 2-year participants in a summer research experience (Silverstein et al., 2009), this study was guided by the following research question:

Compared with other teachers at their schools and in their districts, are STAR teachers (Noyce and non-Noyce) more effective at increasing student achievement in science and mathematics, particularly in high-need settings?
**Methods for Investigating Student Achievement**

The project worked with administrators from five partner districts that hosted our case study teachers involved in Study 1. Each district was asked to provide student achievement data in mathematics and English language arts from the Smarter Balanced Assessment (California Department of Education, 2022) and in science (from the California Science Test, or CAST). Data were collected for students of nine STAR teachers (five of whom were also involved in data collection for Study 1) matched with students of comparison teachers from their districts. Districts provided student achievement scores from students as eighth graders and as 11th graders along with a flag about whether and how often the students had been taught by a STAR teacher during grades 9, 10, or 11.

Propensity scores matching was used to pair students of STAR science teachers with students of non-STAR science teachers in their districts. This resulted in 415 student pairs who completed the science assessment across 17 schools in three districts, 558 student pairs who completed the mathematics assessment across 30 schools in five districts, and 566 student pairs who completed the ELA assessment across 30 schools in five districts, with no duplicate matching of comparison students. Matching was based upon students’ prior student achievement scores from eighth grade; background characteristics of race, gender, special education status, and English learner status; and percent of students in free or reduced-price lunch programs at the school level. Baseline equivalence was measured to ensure that standardized mean differences were lower than 0.25 standard deviation units. Across all three samples, about half of the students were female, most of the students were non-White, and very few students were English language learners or had special needs. **TABLE 4** presents the percentages and sample sizes for the science test, as an example of matching, by condition (e.g., STAR or non-STAR).
Impacts of the STEM Teacher and Researcher (STAR) Program on Teachers, Students, and Classrooms

TABLE 4

Student Achievement Sample Characteristics

<table>
<thead>
<tr>
<th>Student Characteristic</th>
<th>Students of TRE Fellows</th>
<th>Matched Comparison</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science Achievement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>50.1%</td>
<td>52.0%</td>
<td>51.1%</td>
</tr>
<tr>
<td>Non-White</td>
<td>88.2%</td>
<td>87.2%</td>
<td>87.7%</td>
</tr>
<tr>
<td>Special education</td>
<td>1.0%</td>
<td>1.7%</td>
<td>1.3%</td>
</tr>
<tr>
<td>English learners</td>
<td>1.7%</td>
<td>2.9%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Average eighth grade score</td>
<td>0.86</td>
<td>0.67</td>
<td>0.76</td>
</tr>
<tr>
<td>Number of students</td>
<td>415</td>
<td>415</td>
<td>830</td>
</tr>
<tr>
<td>Number of schools</td>
<td>4</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Number of districts</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Note. For students of TRE alumni, the number of schools represents the number of schools attended during the year they were taught by a TRE Fellow. For the matched comparison group, the number of schools represents the number of schools attended in 2018–2019, the post-intervention outcome year.

For each of the three subject areas, regression analyses were conducted using a multilevel model to determine if a correlation existed between student achievement scores and being taught by STAR alumni during 9th, 10th, or 11th grade. Effect sizes and confidence intervals were calculated for each subject area by district to determine statistical significance.

Student Achievement Findings

For all districts and in aggregate, regression analysis indicated no statistically significant differences in mathematics and science achievement when comparing students of STAR teachers and students of other teachers in the school or district. Similarly, no significant differences were found for English language arts (ELA) within four of the five districts, but we did find a statistically significant decrease in ELA scores amongst the students of three STAR alumni compared with other students in the district (effect size of -0.33 with confidence
interval of 0.28). The full analyses, results, and findings can be found in Keller et al. (2022).

In summary, our efforts to investigate student achievement gains revealed no measurable differences across all outcomes and districts sampled except in a single district with regard to English language arts. We discuss these findings and implications for future research at further length in the Discussion section of the chapter.

**Study 3: The Impact of Productive Mind-Sets**

The third study was of active STAR Fellows, those participating in STAR actively either as preservice or early-career teachers during the 2018 and 2019 summers research programs. This study investigated the following research question:

To what extent does an explicit focus on growth mind-set and belonging lead STAR Fellows to (a) adopt the view that STEM intelligence is a malleable quality that can be increased with effort and engagement, and (b) strengthen their feelings of belonging to the STEM community?

**Methods for Investigating Productive Mind-Set**

Data were collected during the 2018 and 2019 summers as well as the academic years that followed. STAR Fellows ($n = 103$) completed a survey comprised of questions that measured Fellows’ (a) mind-sets of the nature of STEM intelligence as either a fixed trait or a malleable quality (“You can learn new things in STEM, but your basic STEM intelligence stays the same,” Good et al., 2012), and (b) feelings of belonging to the science community (“I feel like a member of the STEM community,” Good et al., 2012). The survey items were drawn from the literature and had strong reliability (alpha = .86). On the survey, Fellows rated a series of statements on a scale from 1 to 8 and then averaged their score for each category. For fixed mind-set, scores closer to 1 show that Fellows have more of a growth mind-set regarding STEM intelligence.
For Belongingness, scores closer to 8 indicate Fellows’ feeling that they are a member of the STEM community.

The survey was administered at three time points: (1) the beginning of the summer prior to participation in the STAR summer workshops and internships (pre, $n = 87$), (2) immediately after the summer experience (post, $n = 90$), and (3) approximately 6 months after the intervention around the closing conference in January (follow up, $n = 63$). Analysis included comparison of descriptive statistics as well as paired t-tests to compare results from pre to post and post to follow-up. This analysis was used to compare different sets of STAR Fellows who completed surveys at different time points. Due to the multiple comparisons, a more stringent alpha was set to mitigate type 1 errors (significant differences that do not exist but are a result of multiple tests on the same data).

An additional set of questions was added in 2019 that asked STAR Fellows about strategies they may or may not employ for different hypothetical students who may be in their classes. STAR Fellows were asked to rate statements that represented how they would respond to students in a variety of scenarios (e.g., a student who tried hard but still struggled versus a student who did not try hard and did not do well). Strategies included both comfort strategies (praising students, telling them that they could do well in other classes) that align with a fixed mind-set as well as effort strategies (telling them they would do better if they put in more effort) that align with a growth mind-set. Each statement was rated on a scale from 1 (Would use most infrequently because it would not meet my instructional goals) to 5 (Would use very frequently because it would meet my instructional goals). Analysis of these questions was conducted with descriptive statistics to look for trends in the relative use of comfort strategies and effort strategies for students at different time points.
**Productive Mind-Set Findings**

As can be seen in **TABLE 5** below, STAR Fellows’ responses to the fixed mind-set measures changed significantly over time. Specifically, participation in STAR led to stronger growth mind-set post-summer compared to pre-summer (p < .001) with a small effect size. This difference persisted over time such that the differences between the post-survey and the follow-up survey 5 months later were not significantly different. Thus, we found that despite the passage of time and not actively being in the weekly workshops during the academic year (which served as a mind-set intervention), Fellows persisted in their growth mind-set.

STAR Fellows’ responses to the measure of sense of belonging to the STEM community also changed across the summer. Specifically, participation in STAR led to stronger feelings of belonging to the STEM community on the post-survey compared to the pre-survey with a medium effect size. These feelings were not retained over time and diminished significantly with a small effect size from the post-survey to the follow-up survey 5 months later.

**TABLE 5**

*Summary of Mind-Set and Belongingness Scores on Pre- and Post-Survey*

<table>
<thead>
<tr>
<th>Mind-Set Concept</th>
<th>Average Scores and SD on Pre-Survey</th>
<th>Average Scores and SD on Post-Survey</th>
<th>Significant Difference and Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Mind-Set (n = 83)</td>
<td>1.98 (1.26)</td>
<td>1.55 (1.02)</td>
<td>p &lt; .001, d = .37</td>
</tr>
<tr>
<td>Belongingness (n = 88)</td>
<td>5.99 (1.3)</td>
<td>6.86 (1.1)</td>
<td>p &lt; .001, d = .67</td>
</tr>
</tbody>
</table>
TABLE 6

Summary of Mind-Set and Belongingness Scores on Pre- and Post-Survey

<table>
<thead>
<tr>
<th>Mind-Set Concept</th>
<th>Average Scores and SD on Post-Survey</th>
<th>Average Scores and SD on Follow-Up Survey</th>
<th>Significant Difference and Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Mind-Set (n = 54)</td>
<td>1.56 (1.1)</td>
<td>1.59 (1.02)</td>
<td>$p = .891, d = .03$</td>
</tr>
<tr>
<td>Belongingness (n = 55)</td>
<td>6.79 (.97)</td>
<td>6.41 (1.33)</td>
<td>$p &lt; .01, d = .4$</td>
</tr>
</tbody>
</table>

During the 2019–2020 academic year, STAR Fellows’ responses decreased in comfort strategies (e.g., praising their “students,” telling them they had more chances) and increased in effort strategies (e.g., telling them they would do better if they put in more effort) from pre- to post-summer. Fellows’ open-ended responses also showed a shift from being afraid to make students feel bad about their performance to more constructive thinking on how they wanted to encourage students to put in more effort. A representative comment from the pre-survey that embedded more of a comfort strategy was, “I don’t think you’re putting enough effort toward this class.” I think this could be phrased more gently, in a way that leaves room for understanding that some students may have a valid reason for not putting a lot of effort into a class.” A representative comment from the post-survey that showed more effort strategies was, “I would encourage the student to continue to try hard and work on new strategies to help them be successful.”

These preliminary results suggest that STAR workshops are effective and enduring interventions to foster growth mind-sets in STEM teachers, and that the effect persists even when teachers are not actively engaged in ongoing professional development around growth mind-set. The results also suggest that STAR is an effective intervention to foster feelings of belonging to the STEM community, but that ongoing support may be necessary to maintain these feelings of belonging once the Fellows leave their research labs. Lastly, the results show that productive mind-sets are reflected in how STAR Fellows plan to react to students and may impact their classroom practice.
Work in Progress: Teacher Retention

In addition to studying teacher effectiveness, an ongoing comparative study has collected state administrative employment records and individual interviews with STAR teachers and comparison non-STAR teachers to determine if STAR Fellows are more likely to be retained in the teaching professions, especially in high-need settings. Researchers used the California Department of Education’s classroom census data from the 2012–2013 through the 2017–2018 academic years for credential completers from three pools: STAR alumni, STAR applicants, and credential candidates from the four California State University campuses involved in the first two studies described above, which had high percentages of STAR alumni and applicants. In addition, interviews were conducted with the teachers involved in Study 1 to learn more about retention. Results of this investigation will be reported elsewhere.

Discussion and Conclusion

Discussion and Reflection

The STAR Program is the largest program in the United States that provides mentored research experiences with pedagogical support for prospective and preservice teachers. With an aim to prepare students to enter the STEM teacher workforce, it is a unique undergraduate research experience, distinct from the intention of other undergraduate research programs that work to prepare students to enter the STEM workforce. Also, while traditional TREs often focus on supporting inservice teachers in growing in their knowledge and skills necessary to engage their students in authentic and appropriate research practices, the STAR Program exists at the intersection of undergraduate research and teacher professional development. STAR serves a group of self-selected students who may have limited research experience, do not have the intention to become professional researchers or work in STEM-related industry, and
have not yet experienced classrooms as independent teachers. Through these studies, we provide evidence that engagement of preservice and early-career teachers in paid summer research with intentional professional development can lead to positive impacts on teachers’ classroom practices and growth mind-sets. Specifically, teachers who participated in STAR may prepare students for STEM careers differently and support enhanced perseverance in STEM. There is evidence from teachers’ narratives that these practices are directly related to their personal experiences in the STAR Program.

STAR Fellows deepened their growth mind-set and sense of belonging in STEM and changed their views on how to best support students to encourage more effort, which may help students persist when faced with challenges. The study of student achievement revealed no significant gains in student achievement that were measured in mathematics and science state tests (both by district and in aggregate), while students of STAR science teachers in a single district performed less well in English language arts than did their matched peers. While trying to replicate other studies of student achievement, this study employed a more general high-stakes assessment that was not aligned to a specific content area. This is an area that would benefit from additional research focused on creating more closely aligned assessments that can detect student achievement on relevant skills and topics consistent with research practices. Overall, these findings not only support other work demonstrating positive outcomes of TREs (e.g., Krim et al., 2019; Miranda & Damico, 2013; Southerland et al., 2016) but also add to the few studies that include student outcomes as a measure of TRE impact.

We wish to highlight limitations and nuances of these studies to frame not only our findings but also challenges that researchers may face in doing related research. The STAR Program provides research experiences as a component of teacher preparation and induction (participants must not have taught full time when they first participate in the program and cannot be beyond their second year of full-time teaching). Thus, these
studies, and any others, involving preservice participants lack the ability to collect baseline data of teacher effectiveness prior to participation in the intervention. With inservice TRE programs, surveys, interviews, classroom observations, instructional artifact collection, and student achievement scores for a specific teacher can all be collected in advance of participation in the research experience and then compared with changes following the intervention. While we strongly encourage further research studies of inservice teachers that make use of baseline data, our study of preservice teachers utilized propensity matching with prospective comparison teachers instead of pre- and post-participation comparisons to investigate teacher effectiveness. Another nuance is the limited number of STAR teachers included in Study 1 and Study 2. This was driven primarily by resources, capacity, and limited tracking of STAR alumni teacher placements prior to this investigation. While the project worked with the four CSU campuses that have involved the largest numbers of STAR participants, the STAR alumni are in actuality teaching in positions across the state and the country. Of all teachers in the five districts that partnered in this work, we were only able to identify and obtain consent from eight STAR alumni. With teacher employment records from 2010 to 2018 obtained through our teacher retention efforts, we are now in a better position to identify districts with higher numbers of STAR alumni, but this information was not available in summer 2018 when the case study on teacher effectiveness was being implemented.

In the second study, only five of our eight district partners were able to share the requested student achievement data due to district resources. Additionally, in cases involving STAR alumni who primarily taught senior or junior/senior classes, junior year student achievement data were not relevant or useful. Overall, we want to highlight the complexity of gathering this targeted teacher and student data related to a research program for teachers. Early planning and strong partnerships were required for the work we were able to achieve, and we encourage other researchers to ensure sufficient resources are available for the gathering of such data. Although the findings about mind-set and belongingness
within the same year as the STAR experience are promising, they do not include impacts on teachers’ classrooms. This is another avenue of research that will be important to investigate alongside those of other research classroom practices. We plan to study more classroom outcomes related to the infusion of productive mind-set in our summer education workshops to better understand the intersection between belongingness in STEM, productive mind-set, and student outcomes.

Taken together, these three studies demonstrate the value of TREs for preservice teachers. Literature already demonstrates the value of TREs for inservice teachers, both for classroom practice and student outcomes, and this work contributes the finding that research experiences early in a teaching career can also have a measurable impact on teaching in the field. All three studies will be of interest for programs that support, or aim to support, TREs for preservice teachers as well as for researchers who want to undertake similar work. As next steps for this kind of research, we plan to explore new ways to investigate student achievement, potentially through custom assessments that are better aligned to practices. Additionally, classroom observations will add more insights into teachers’ practices and students’ work. The innovations of summer workshops to augment teacher research experiences to support teachers’ integration of their research experiences through the lens of productive mind-set provides several avenues for future work.

Implications for the Field and Future Work

The first two studies described here represent some of the initial efforts by a preservice TRE program to extend assessment beyond teacher self-report to include data from students in order to provide evidence of teacher effectiveness and classroom practices. While the field of inservice TRE programs has a few comparative studies that go beyond self-report data analysis (e.g., Silverstein et al., 2009), the field of preservice TRE programs is even more limited. While the case study sample for Study 1 is small, the study demonstrates that student surveys can be used along with triangulation with teacher interviews to meaningfully discriminate
between teachers in terms of student perceptions of classroom learning constructs. Indeed, in another study of STAR, a broad sample of 136 STAR alumni and 60 STAR applicants responded to a teacher survey involving many of these same constructs, and we were not able to differentiate between the two groups from self-report data. Thus, we recommend the strategy of collecting student perceptions to further inform perspectives on the classroom experience integrated over the course of the year.

In teacher interviews conducted during the case studies, amongst both STAR and non-STAR teachers, we found that most of the teachers had some experience in industry or research, leading us to new questions about these experiences and the role, or lack of role, of supporting professional development. Because nominal research experience across a spectrum of opportunities exists in STEM education, more attention to the role that an emphasis on metacognition and professional development plays in teacher preparation is warranted.

Teacher interview data was helpful for discerning some preliminary qualitative factors behind measurable constructs for teacher effectiveness found in student survey findings. These included STEM career awareness and perseverance, as well as the ability to integrate research into the classroom. Surveys or focus groups with students who completed surveys for the project may have been additionally useful. Each of these measures represents meaningful avenues for any future research to examine the impact of research experiences for teachers. Future research could also be conducted involving analysis of student artifacts and classroom observations to better understand learning experiences related to teachers’ classroom practices.

The success of this project to secure student achievement data for nine STAR teachers and comparison teachers in five districts for teachers from 2010 to 2018 represents a significant accomplishment. Additionally, the data we are currently collecting on employment and retention represents a significant partnership with the California Department of Education. To successfully do this type of work, we recommend researchers work with
state departments of education to learn the extent to which access can be obtained to external, third-party employment data.

In addition to the results described above, ongoing evaluation findings have demonstrated that participants in the STAR Program develop and strengthen an identity as teacher-researchers, which is a central goal of the program. This shift in participants’ identity from either a STEM teacher or a STEM researcher toward that of a teacher-researcher is a significant outcome of STAR. These preliminary findings align with NSF’s own recent strategy for the Robert Noyce Scholarship Program to encourage grantees to provide research experiences for teachers (Marrongelle, 2021). This parallels other work in identity formation in both science and education and contributes to efforts to better understand how experiences impact identity. We also suggest that investigations of the development of STEM identity amongst the students of teacher-researchers may be a productive avenue of research.

Our findings are exciting, and hopefully aspirational, for those who actively research TREs and work with Noyce Fellows. Additionally, this work is valuable to STEM teacher educators, as we provide insight into new ways to prepare teachers to engage students in research practices, foster productive struggle and mind-set, and show evidence of the potential efficacy of this model of teacher professional development and preparation.
Impacts of the STEM Teacher and Researcher (STAR)
Program on Teachers, Students, and Classrooms

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Impacts of the STEM Teacher and Researcher (STAR) Program on Teachers, Students, and Classrooms


CHAPTER 5

Understanding High Need: Exploring School and District Employment and Retention Patterns of Noyce Scholars in Texas
Understanding High Need: Exploring School and District Employment and Retention Patterns of Noyce Scholars in Texas

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University of Houston
Collaborative: NSF DUE-1557273, 1557295, 1557290, 1557276, 1557278, 1557294, 1557410, 1557286

When the placement and retention of STEM teachers at highest-need schools were examined, researchers found no statistical difference between Noyce recipients’ employment at highest-need schools and employment of their non-Noyce recipient peers (34% to 38%), or in retention into the second year of teaching at highest-need schools (64% to 73%). Given the spirit of the program’s intent—to ensure that students with highest need have access to top-flight STEM teachers—findings suggest that more work could be done to ensure that such teachers are going to and staying in classrooms with the highest need.
ABSTRACT

A majority (61%) of Texas’s 5.4 million public school students are from economically disadvantaged backgrounds, ensuring that essentially all districts are serving substantial numbers of students with high need. This study seeks to understand a more nuanced story of Texas’s unique context by exploring the employment and retention patterns of Noyce Scholars at the school level. In particular, this study uses a descriptive analytical strategy to explore the first-year employment and retention patterns of Noyce program graduates from four Texas institutions. When the placement and retention of STEM teachers at highest-need schools were examined, researchers found that Noyce recipients were employed at highest-need schools at a modestly lower rate than their non-Noyce recipient peers (34% to 38%) and were retained into their second year of teaching at those schools at a lower rate than their non-Noyce peers (64% to 73%). Though Noyce participation had no observable association with placement or retention at highest-need schools, as indicated by a lack of statistical difference, more work could be done to ensure that those teachers are going to and staying in classrooms with the highest needs. The sustained federal investment in increasing the supply of quality STEM teachers in high-need districts brought about by the Noyce program continues to be an essential part of that effort. The findings here suggest that future iterations of this program and similarly designed interventions may benefit from increasingly intentional efforts to recruit and retain Noyce Scholars in the highest-need schools.
Introduction

Education research has established the strong positive influence quality teaching has on both short- and long-term student outcomes (e.g., Ashton, 1984; Chetty et al., 2014; Darling-Hammond, 2000; Goldhaber, Theobald, & Fumia, 2018; Hanushek, 2011; Rivkin et al., 2005; Rockoff, 2004; Stronge et al., 2011). In the context of the important role that educators play, it is especially worrisome that the country is experiencing teacher shortages in key disciplines such as science, technology, engineering, and mathematics (STEM) and in specific school types (e.g., schools serving students from disadvantaged backgrounds).

Science and mathematics teachers are in particular demand (Dee & Goldhaber, 2017). Data from the U.S. Department of Education (2021) show that for both science and mathematics, more than 40 states indicated a teacher shortage in one or more disciplinary areas during the 2020–2021 school year (U.S. Department of Education, 2021).

Teacher shortage is often further exacerbated in schools serving higher proportions of low-income students. In particular, research shows that these schools generally maintain higher rates of teacher attrition and increased teacher mobility (Boyd et al., 2008; Cowan, Goldhaber, Hayes, & Theobald, 2016; Ingersoll, 2004; Simon & Johnson, 2015; Sutcher et al., 2016). Teachers working in schools with high need often leave for advancement opportunities and increased salaries or more lucrative reward structures (Guarino et al., 2006); greater support from school leadership and a more inclusive culture (Simon & Johnson, 2015; Sutcher et al., 2016); or improved working conditions (Johnson et al., 2012).
In an effort to increase the number of STEM teachers and improve their retention—specifically in schools with high need—the National Science Foundation (NSF) in 2002 created the Robert Noyce Teacher Scholarship Program, which encourages STEM students and professionals to pursue teaching roles in “high-need local educational agencies” (National Science Foundation, 2021; U.S. Department of Education, 2021). Borrowed from the Higher Education Act of 1965, the term “high-need local educational agency” is defined by NSF as a school or school district with a high percentage of students from low-income families, a high percentage of educators teaching outside their certification area, or high teacher turnover rates (National Science Foundation, 2017). In alignment with the program’s mission, Noyce recipients are provided with teacher preparation support through a variety of mechanisms. In exchange for a commitment to teach in a high-need setting (school or district) for at least 2 years post-graduation, STEM students gain access to scholarships and internship opportunities aimed at facilitating their path to becoming STEM educators.

Texas is among the many states experiencing a STEM teacher shortage, with chronic need in mathematics, for example, for more than a decade (Horn, Burnett, Lowrey, & White, 2021). Texas has taken a multipronged approach to reversing this challenge, including importantly through the implementation of more than 30 Noyce projects (National Science Foundation, 2017). A majority (61%) of its 5.4 million public school students are from low-income or economically disadvantaged backgrounds, ensuring that essentially all districts are serving substantial numbers of students with high need. As such, while the Robert Noyce Program only requires that awarded Scholars serve in local education agencies (LEAs) with high need, this study seeks to understand a more nuanced story of Texas’s unique context by exploring the employment and retention patterns of Noyce Scholars at the school level.

In particular, this study seeks to descriptively explore the first-year school-based employment and retention patterns (defined in this study
as remaining as a teacher in a high-need classroom after 1 and 2 years, respectively) of Noyce program graduates from four Texas institutions relative to their non-Noyce peers to understand with greater nuance in what contexts Noyce graduates are contributing. This work is guided by two research questions. Relative to their non-Noyce peers:

- To what extent does participation in a Noyce project associate with employment in a high-need school?
- How does participation in Noyce-funded programming influence retention of teachers?

Recognizing the overall contributions Noyce has made to the Texas teacher workforce (e.g., Evans et al., 2019), this study adds to the discussion by understanding with greater nuance the kinds of schools to which Noyce teachers are contributing within high-need LEA contexts.

The chapter proceeds with a review of the relevant literature on the power and impact of the Noyce Program. An ambiguity-conflict model of policy implementation conceptually guides this work and is also described in detail. Findings, discussions and recommendations for policy makers and educational preparation programs conclude the chapter.

Literature Review

The United States faces persistent shortages of STEM educators in high-demand fields such as chemistry, physics, and computer science (Ingersoll, 1999; Hutchison, 2012; U.S. Department of Education, 2021), creating what researchers have described as an impending crisis with the potential to drastically impact the nation’s capacity to increase mathematics and science literacy and advance technological innovation (National Academy of Sciences, 2006; McConnell, 2017; Sutcher et al., 2016). Such trends are particularly visible at schools serving large numbers of students with high economic needs (Yang, 2015). As a result of
the teacher shortages, many of those teaching in the STEM content areas do so without certification or preparation (Hough, 2000), often relying on temporary certifications to teach year to year (Abell et al., 2006).

Investigations into the causes of STEM teacher shortages identify concerns with both recruitment and retention (Carver-Thomas & Darling-Hammond, 2017; Hutchison, 2012; Ingersoll & May, 2012). Recruitment into teaching programs suffers from a lack of awareness and understanding of both university-based initial STEM certification programs (Hutchison, 2012) and alternative certification programs for professionals seeking a career change (Darling-Hammond & McLaughlin, 1995; Ingersoll & Smith, 2003). Another challenge unique to STEM teacher recruitment is the deep learning in content and pedagogy necessary for STEM classroom success (e.g., Eckman et al., 2016). Finding teachers with substantial content knowledge in highly specific areas and the pedagogical training to facilitate STEM classrooms has proven difficult, demonstrated in part by the fact that many science and mathematics teachers do not hold degrees in STEM-related fields (President’s Council of Advisors on Science and Technology, 2010).

In addition to the specific challenges of recruitment, STEM teacher retention has been shown to be lower than that in other fields of teaching (e.g., Ingersoll, 2006; Ingersoll, Merrill, Stuckey, Collins, & Harrison, 2021; Kersaint, Lewis, Porter, & Meisels, 2012; Sutcher et al., 2016). Though STEM teacher retention is similarly affected by the known factors contributing to teacher retention generally (e.g., job satisfaction, age, and leadership), Suárez and Wright (2019) found STEM teacher retention to be distinctively affected by dissatisfaction with the lack of autonomy that has accompanied the high-stakes testing environment of the 21st century as well as by school differences attributable to principal characteristics.

Among mathematics and science teachers specifically, research reveals significant differences in teacher turnover across school types. Urban schools, high-poverty schools, and schools serving more students of color all have higher rates of turnover relative to their counterparts.
(Carver-Thomas & Darling-Hammond, 2017; Ingersoll & May, 2012). In addition to the cross-school differences, Ingersoll et al. (2021) found that “pre-retirement voluntary turnover” (p. 10) is more common among teachers in mathematics and science subject areas overall. In sum, the factors contributing to decreased STEM teacher retention compound the STEM teacher shortage problem and exacerbate challenges related to diversifying the teacher workforce and recruiting new teachers to high-need schools (Ingersoll et al., 2021).

To address challenges with pedagogy and content knowledge, the National Academy of Sciences (2007) encouraged collaborations between STEM departments and education departments to build cross-disciplinary strategies that support preservice teachers in gaining the content knowledge and pedagogical skills needed to successfully teach in STEM-related classrooms. One example, the STEM teaching co-op, was a cross-college STEM teacher preparation model designed to mimic an engineering industry co-op model that generated higher levels of confidence, greater comfort with content knowledge, and more confidence in teaching abilities—including the skills needed to teach students in high-need settings—among STEM preservice teachers (Eckman et al., 2016). Another well-regarded program in this area is the UTeach Institute founded by the University of Texas, a multi-school network of teacher preparation programs that aims to grow the population of well-prepared secondary STEM educators. The UTeach model is designed to close the gaps between teacher pedagogy-based courses and STEM major courses by facilitating dual enrollment for students seeking certification (UTeach, 2020).

In response to broader recruitment and retention challenges, a wide variety of state and federal policy interventions have also been developed. At the state level, incentive programs like loan forgiveness and financial motivations, particularly for targeted areas, have been regularly used tools for expansion of teachers (Feng & Sass, 2017; Goldhaber, Krieg, Theobald, & Brown, 2016). For example, Georgia recently implemented a
salary-bonus program for certified teachers in mathematics and science, which allows starting teachers in these subjects to advance several steps on the state’s salary schedule. There has also been state policy aimed at educator preparation programs and intended to improve teacher preparation and quality through a variety of accountability strategies (e.g., Cochrane-Smith et al., 2018; Crowe, 2010; Espinoza, Saunders, Kini, & Darling-Hammond, 2018; Lewis & Yong, 2013). At the federal level, the Elementary and Secondary Education Act (reauthorized most recently in 2015 as the Every Student Succeeds Act) and the Higher Education Act (last comprehensively reauthorized in 2008) serve as primary legislation directed at teachers. Similar to state efforts, these and other federal policies influence teacher recruitment and retention through efforts like loan forgiveness, increased access to alternative route programs, and teacher accountability (e.g., Catherine & Yannelis, 2021; Heilig, Cole, & Springer, 2011; Sykes & Dibner, 2009).

The Noyce Program as a Unique National Intervention

The Noyce Program represents an important additional federal effort aimed at increasing the number of STEM teachers in high-need settings across the country. A body of research has sought to understand its relative effectiveness. Prior qualitative investigations, for example, have found Noyce scholarship requirements to influence placement of students in high-need schools (Kirchhoff & Lawrenz, 2011; Liou et al., 2010; Morrell & Salomone, 2017; Ticknor et al., 2017), though there is less evidence of an impact on retention of teachers in high-need schools beyond the 2-year commitment\(^\text{1}\) (Liou et al., 2010). Those students who successfully transitioned into and remained in teaching in high-need school districts often cited faculty and peer support systems (Kirchhoff & Lawrenz, 2011; Ticknor et al., 2017), the development of positive self-views of themselves

\(^\text{1}\) As required by the Noyce Scholarship Program, undergraduate STEM majors must commit to serving as science or mathematics teachers in high-need school districts for at least 2 years for every year of scholarship funding received. Scholars who do not fulfill this requirement must pay back their scholarships. For more information on the requirements, see https://www.nsfnoyce.org/become-a-noyce-scholar-or-teacher-leader/.
as STEM teachers (Bischoff et al., 2014), and the scholarships’ financial support (Morrell & Salomone, 2017; Ticknor et al., 2017) as critical success factors. Research on the projects’ direct influence in increasing the pool of future teachers is mixed. Some studies identify that Noyce scholarship recipients typically have already decided to pursue teaching roles upon entrance to the program (Liou et al., 2010; Ticknor et al., 2017). However, Scott et al. (2006) find that one project, partially supported through the Noyce Program, revamped certification processes and experiences in ways that increased the number of undergraduate majors in mathematics and science considering teaching as a career (Scott et al., 2006). While these findings offer important insight into the effectiveness of Noyce projects, further empirical work is needed to increase our understanding of the impact of the Noyce Program on teacher recruitment and retention, particularly with respect to a fuller understanding of the types of K–12 schools and students served. It is to that end that this paper turns.

Conceptual Framework

Research identifies multiple influences at play in the process of policy implementation. Matland (1995) synthesizes these conditions in a four-quadrant model (FIGURE 1), where implementation is understood as a function of the levels of both ambiguity and conflict present. Ambiguity represents a lack of clarity of goals, of means, or of both. Similarly, conflict derives from the extent to which goal congruence exists and increases relative to perceived stakes and degree of incompatibility among stakeholders.
In circumstances where low conflict and low ambiguity exist, achieving desired policy outcomes, assuming sufficient allocation of resources, is largely derived through administrative implementation. The process in this quadrant often takes a “top down” approach, “dominated by technocratic questions of compliance and follow-up” (Matland, 1995, p. 162). Where low ambiguity exists alongside high conflict, political policy implementation prevails. As Matland (1995) describes, for such policies, “compliance is not automatically forthcoming. While there is an explicit policy, essential resources are controlled by skeptical actors outside the implementation. Such a system is more open to influences from the environment than from administrative implementation” (pp. 163–164). In process, clear policy directives provide space for assessment of policy compliance even in a complex implementation environment. When both conflict and ambiguity are high, the situation is captured by the symbolic implementation quadrant. In this quadrant, “The high level of conflict is important, because it structures the way resolutions are developed. The high level of ambiguity results in outcomes that vary across sites. The central principle is that local level coalitional strength determines the outcome” (p. 168; emphasis in original).
The Noyce Program implementation can be viewed as an instance of the final quadrant, experimental implementation. In particular, substantial political and empirical agreement exists with respect to the value and importance of the Noyce projects in their effort to “encourage talented . . . STEM majors and professionals to become K–12 mathematics and science . . . teachers” (https://www.nsfnoyce.org/about/), specifically in “high-need local educational agencies [LEAs]” (National Science Foundation, 2021b; U.S. Department of Education, 2021). In implementation, if at least one school in the school district meets the high-need definition, the entire district is considered high-need for purposes of the Noyce Program (NSF, 2021). This definition introduces ambiguity, essentially establishing an experimental environment in which to understand policy implementation. Matland (1995) describes the process in the following way.

The central principle driving this type of implementation is that contextual conditions dominate the process. Outcomes depend heavily on the resources and actors present in the microimplementing environment. These are likely to vary strongly from site to site, therefore broad variations in outcomes will occur. . . . The lack of conflict is likely to open the arena for a large number of actors to participate and to provide those who have intense interests, or substantial slack resources, with an opportunity to mold policy significantly. The opportunities are excellent for bureaucratic entrepreneurs to create policies to deal with local needs (pp. 165–166; emphasis in original).

This study argues that Noyce implementation occurs in a frame of low conflict and high ambiguity. Specifically, the Program’s definition of high-need resting at the district rather than the school introduces a level of ambiguity for Scholars seeking to fulfill their teaching responsibility as a function of participation. Aiming to clarify the impact of this ambiguity on employment and retention choices, this study descriptively explores teacher-level patterns of a specific set of Noyce projects over a 3-year period.
Analytic Approach

This project sought to answer the following research questions: To what extent does participation in a Noyce project associate with employment in a high-need school? How does participation in Noyce-funded programming influence retention of teachers? Noyce Scholars from four different institutions in Texas were identified in Texas’s state-level data repository that allows for individuals to be followed throughout the public education system, through higher education, and into the workforce. Access to this data provided researchers with the opportunity to follow students from their participation in Noyce projects through their employment as teachers. For brevity, individuals who participated as Noyce Scholars are referred to as teachers, meaning preservice teachers in preparation who then become certified classroom teachers of record. Those teachers who participated in Noyce projects are referred to as Noyce Scholars. Once the data set of teachers was constructed, descriptive statistics as well as chi-square tests of independence comparing the certification, employment and retention of Noyce Scholars and peer teachers were also reported. The data and methods are described in detail in the following sections.

Data

The data for this study primarily derive from a state-level administrative data repository of teacher preparation, certification, and teaching. A data set was created that followed individuals, both Noyce Scholars and non-Noyce peers from the same institutions, from preparation through school placement. The next sections describe the operationalization of terms used in the construction of the data set and also describe the aggregate data set.
Participating Institutions

The participating public universities that served as certifying institutions for teachers in the data set varied in classification, size, location, and student population served. Two of the universities are quite similar, as they are both located in urban areas, classified as research-intensive universities in the Carnegie Classification of Institutions of Higher Education,\(^2\) classified as Hispanic-Serving Institutions,\(^3\) and serve roughly 35,000 undergraduate students per year (labeled Urban R1-1 and Urban R1-2). A third participating university is a doctoral degree-granting institution serving about 12,000 students each year in a rural area of the state (labeled Rural Doctoral). Finally, another Hispanic-Serving Institution in the sample is located in an urban area and is an open-access public university offering bachelor’s and master’s degrees to more than 14,000 students each year (labeled Urban Open Access).

**TABLE 1** displays key Noyce project characteristics of each participating university. A Noyce project award was first made to the Urban R1-1 and Urban R1-2 in 2008 and 2009, respectively, with both focusing on undergraduate and post-baccalaureate teachers from the mathematics, chemistry, physics, biology, and geology disciplines. Rural Doctoral was first awarded the Noyce project in 2009 and focuses on undergraduate and post-baccalaureate teachers in mathematics, chemistry, physics, biology, and geology disciplines. Noyce project funding was initially awarded at Urban Open Access in 2011 and focuses on developing undergraduate mathematics teachers.

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TABLE 1

Key Noyce Project Characteristics of Participating Universities

<table>
<thead>
<tr>
<th>Discipline Focus</th>
<th>Program Level</th>
<th>Year Initially Awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban R1-1 Math, Chemistry, Physics, Biology, Geology</td>
<td>Undergrad, Post-Bac</td>
<td>2008</td>
</tr>
<tr>
<td>Urban R1-2 Math, Chemistry, Physics, Biology, Geology</td>
<td>Undergrad, Post-Bac</td>
<td>2009</td>
</tr>
<tr>
<td>Urban Open Access Math</td>
<td>Undergrad</td>
<td>2011</td>
</tr>
<tr>
<td>Rural Doctoral Math, Chemistry, Physics, Biology, Geology</td>
<td>Undergrad, Post-Bac</td>
<td>2009</td>
</tr>
</tbody>
</table>

Noyce Scholars and Peers

As part of a larger NSF study (begun in 2016), the four participating universities identified 169 teachers who were Noyce Scholars between 2010 and 2018. Because this research sought to understand the influence of Noyce project participation on STEM teacher recruitment and retention, a data set inclusive of the Noyce Scholars was constructed; the data set for this study captured all individuals who were recommended for initial teaching certification from each of the four participating universities and taught at least one STEM course at a middle school, high school, or mixed grade level school for at least 1 school year between 2010 and 2018 (n = 948).

4 STEM courses included Aerospace Aviation; Agricultural Science; Agricultural Science and Technology Education; Agriculture, Food, and Natural Resources; Biology; Chemistry; Computer Science; Earth Science; General Science; Health Science; Health Science Technology; Information Technology; Mathematics; Physical Science; Physics; Science; Science, Technology, Engineering, and Mathematics; and Technology Education.

5 While the Noyce scholarship allows for elementary school teachers, only two out of the total 169 at the four universities examined taught in an elementary school (grades K–5). To construct the most accurate comparable data set, the data set was limited to participants teaching in a middle school (grades 6-8), high school (grades 9-12), or mixed grade level school (grade levels spanning two or more categories: elementary, middle, high).
TABLE 2 displays the number and racial and ethnic composition of teachers from each participating university. The largest overall (i.e., Noyce and non-Noyce) number of teachers in the data set (449) were recommended for certification through the Urban R1-1 university, where 39% identified as White, 27% as Hispanic, 19% as Asian, 13% as African American, 1% as Native American, and 1% as two or more races. The second research university (Urban R1-2) in the study recommended a total of 208 teachers in the data set for certification, of whom a majority identified as White (59%). The Rural Doctoral university recommended for certification 236, of whom most identified as White (84%). The Urban Open Access institution recommended the fewest number of teachers for certification in the data set (55) and had the highest proportion of non-White teachers (69%).

TABLE 2
Racial and Ethnic Composition of Teachers per University, 2010–2018

<table>
<thead>
<tr>
<th>University</th>
<th>Total Participants</th>
<th>African American</th>
<th>Asian</th>
<th>Hispanic</th>
<th>Native American</th>
<th>Two or More Races</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban R1-1</td>
<td>449</td>
<td>13</td>
<td>19</td>
<td>27</td>
<td>1</td>
<td>1</td>
<td>39</td>
</tr>
<tr>
<td>Urban R1-2</td>
<td>208</td>
<td>6</td>
<td>9</td>
<td>24</td>
<td>0</td>
<td>2</td>
<td>59</td>
</tr>
<tr>
<td>Urban Open Access</td>
<td>55</td>
<td>15</td>
<td>9</td>
<td>40</td>
<td>2</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>Rural Doctoral</td>
<td>236</td>
<td>7</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>84</td>
</tr>
<tr>
<td>Total</td>
<td>948</td>
<td>10</td>
<td>12</td>
<td>22</td>
<td>0.40</td>
<td>2</td>
<td>54</td>
</tr>
</tbody>
</table>

The teacher data set for this study included 167 of the original 169 identified Noyce scholarship or stipend recipient teachers. Two were removed from the original data set, as they taught at an elementary school in their first year of teaching. This small number and the increased

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6 The racial category of white is intentionally written in lowercase because it does not reference a specific cultural group (Crenshaw, 1990).
retention typically demonstrated at elementary schools (Hughes, 2012) suggested they be dropped from the data set. TABLE 3 shows the number of Noyce recipients and the teachers who make up the comparison group for this study from each university.

**TABLE 3**

*Noyce and Non-Noyce Recipients per University, 2010–2018*

<table>
<thead>
<tr>
<th>University</th>
<th>Noyce Recipients</th>
<th>Non-Noyce Recipients</th>
<th>Total Noyce Recipients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>167</td>
<td>18</td>
<td>781</td>
</tr>
<tr>
<td>Urban R1-1</td>
<td>48</td>
<td>11</td>
<td>401</td>
</tr>
<tr>
<td>Urban R1-2</td>
<td>92</td>
<td>44</td>
<td>116</td>
</tr>
<tr>
<td>Urban Open Access</td>
<td>13</td>
<td>24</td>
<td>42</td>
</tr>
<tr>
<td>Rural Doctoral</td>
<td>14</td>
<td>6</td>
<td>222</td>
</tr>
</tbody>
</table>

In total, 18% of teachers in the data set were Noyce recipients, but the distribution among participating universities was not consistent ($\chi^2(3, n = 948) = 139.9, p < 0.001$). At the Urban R1-2 university, 44% of teachers in the data set were Noyce recipients. Noyce participation was least at the Rural Doctoral university, where only 6% of teachers in the data set were Noyce recipients. The variability in Noyce participation is due to differences in grant intent and specifications (Evans et al., 2019).

**Highest-Need Schools**

Of particular interest to this study is teacher employment in highest-need schools. For the purposes of this study, “highest-need” is defined as a school with a population of at least 75% students who are economically disadvantaged. This operationalization of highest-need schools was chosen primarily because of the large proportion of low-income students served in the Texas public school system and the established relationship between teacher turnover and low-income student populations (Ingersoll, 2004; Simon & Johnson, 2015). Between
2010 and 2018, the Texas public school student population grew by more than half a million students, yet the student population remained 59% economically disadvantaged, as measured by the percent of students qualified for the federal free or reduced-price lunch program (Texas Education Agency, 2010; 2018). Given that the majority of students in Texas are low-income and 70% of schools have a majority of low-income students (Texas Education Agency, 2018), this study purposefully classifies schools as highest-need to offer distinction within a state with such a widespread low-income student population.

The majority of students in the highest-need schools were found to be African American and Hispanic. In particular, highest-need schools serve a larger proportion of African American students than the average school in the state. The average student composition of highest-need schools in the data set is 18.67% African American, 50.12% Hispanic, 23.76% White, and 7.45% other races and ethnicities. By comparison, the average student composition across all schools is 12.35% African American, 51.59% Hispanic, 29.87% White, and 6.19% other races and ethnicities.

**First-Year Employment**

As an outcome variable of interest to this study, teacher employment in their first year following the completion of a teacher preparation program was determined. After completion of certification, teachers were tracked into the public school workforce. Teachers were classified as employed in their first year of teaching if they were reported as a teacher of record in the school year following the award of their initial certification. The teacher of record distinction is reserved for the teacher ultimately responsible for delivering the curriculum and determining the final outcomes for each student in the class.

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7 These racial and ethnic groups represented in highest-need schools are the only ones discussed because students identifying as Two or More Races, American Indian, and Asian are represented in small numbers, collectively only making up 7% of the average total student population in the data set.
Retention

For the purposes of this study, retention was defined specifically as retention in a classroom as teacher of record after the first and second years of teaching, because of the importance of the first several years to multiple aspects of the teaching career (Ingersoll et al., 2014). Teacher attrition has been well documented by previous studies of state and national data to be highest after the first year of teaching (Boyd et al., 2008; Liu, 2007) and was recently documented as such for Texas teachers (Horn, Burnett, Lowrey, & White, 2021). Further, the effects of teacher preparation programs are strongest early in the teaching career, and the study of the effects of such programming is best conducted in the first few years of a teacher’s career (Kaplan & Owings, 2003). Thus, in an attempt to monitor the effects of a preparation program on retention, this research focuses on retention after the first and second year of teaching. To determine teacher retention after the first year of teaching, teachers are counted as retained at a highest-need school if they are teaching in a highest-need school in subsequent years, without regard for the specific classroom assignment, school, or district. A teacher is counted as retained if they move from one district to another but remain a teacher of record.

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8 Three years is still within the repayment period for Noyce alumni who had 2 years of scholarship support.
Methods

This study applies a rich descriptive analytical strategy to explore the extent to which participation in a Noyce project is associated with the level of need present on employment school and retention of first-year STEM teachers relative to their non-Noyce peers. The chi-square test of independence was specifically selected to establish difference between the Noyce Scholars and their peers. The chi-square test of independence is ideal for an unbalanced data set such as the one constructed for this study, in which Noyce Scholars make up 18% of the entire data set, as the chi-square test relies on proportion, not balance, to determine difference. Thus, the relatively small population of Noyce Scholars can be appropriately compared to their peers from the same four institutions.

Findings

We have organized findings by progression to employment through retention, including certification, first-year employment location, and first-year retention.

Certification

The Noyce Program requires recipients to obtain a certification in the field of mathematics or science. TABLE 4 shows the number of teachers by initial certification area and Noyce Program participation. The table shows that 350 (45%) of the 781 non-Noyce teachers in the data set and 107 (64%) of the 167 Noyce recipients in the data set received an initial certification in mathematics. The Noyce recipients were certified only in mathematics or science, per programmatic requirements. Because the focus of this study is employment and retention, the comparison group of non-Noyce teachers was identified using the criteria of teaching a STEM
course. This condition means that teachers whose initial certification was not necessarily in mathematics or science but who were teaching in these or other STEM fields were included. Importantly, 269 (34%) members of the comparison group teaching in STEM classrooms did not have mathematics or science certification.

**TABLE 4**

*Initial Certification Area by Noyce Participation, 2010–2018*

<table>
<thead>
<tr>
<th></th>
<th>Noyce Recipients</th>
<th>Non-Noyce</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Subjects</td>
<td>0</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Bilingual Education</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>English Language Arts</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Fine Arts</td>
<td>0</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Foreign Language</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>General Elementary</td>
<td>0</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Health and Physical Education</td>
<td>0</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Mathematics</td>
<td>107</td>
<td>350</td>
<td>457</td>
</tr>
<tr>
<td>Science</td>
<td>60</td>
<td>162</td>
<td>222</td>
</tr>
<tr>
<td>Social Studies</td>
<td>0</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Special Education</td>
<td>0</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>Vocational Education</td>
<td>0</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

First-Year School of Employment by Grade Level

As the teachers included in this study completed their teacher preparation program and certification, they were followed into the teaching workforce. The types and characteristics of schools hiring both Noyce Scholar and non-Noyce first-year teachers in the data set were analyzed. **TABLE 5** shows the school types by Noyce project participation.
In Texas, schools are categorized as elementary schools if they serve students in kindergarten through fifth grade, middle schools if they serve students in sixth through eighth grade, and high schools if they serve students in 9th through 12th grade. The schools that serve a range of students spanning two or more of these categories (e.g., K–12 or 6–12) are categorized as mixed grade level schools. The large majority (83%) of Noyce Scholars go on to teach in high schools (TABLE 5), which is statistically distinct from the teachers not receiving a Noyce scholarship, who primarily teach in middle schools (59%) ($\chi^2(2, n = 948) = 139.3, p < 0.001$).

<table>
<thead>
<tr>
<th></th>
<th>Noyce Recipients</th>
<th>Non-Noyce</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>167</td>
<td>781</td>
<td>948</td>
</tr>
<tr>
<td>Middle schools</td>
<td>22</td>
<td>461</td>
<td>483</td>
</tr>
<tr>
<td>High schools</td>
<td>139</td>
<td>263</td>
<td>402</td>
</tr>
<tr>
<td>Mixed grade level schools</td>
<td>6</td>
<td>57</td>
<td>63</td>
</tr>
</tbody>
</table>

**First-Year School of Employment by Proportion of Students Experiencing Economic Need**

In their first year of teaching, 595 (63%) of the 948 teachers in the data set were hired by schools serving less than 75% low-income students, and 353 (37%) were hired by schools serving at least 75% low-income students. **TABLE 6** displays the number and percentage of Noyce scholarship recipient teachers and non-Noyce teachers working in each of these settings. Of the 167 Noyce recipient teachers in the data set, 34% were hired at a highest-need school in their first year of teaching. In comparison, 38% of the 781 non-Noyce recipient teachers were hired at highest-need schools in their first year of teaching. No statistical
differences existed, however, between distributions of non-Noyce and Noyce teachers by level of school need ($\chi^2 (1, n = 948) = 0.68, p > 0.05$).

**TABLE 6**
First-Year Teacher Employment Location by Level of School Need and by Noyce Participation, 2010–2018

<table>
<thead>
<tr>
<th></th>
<th>Noyce Recipient n (%)</th>
<th>Non-Noyce Recipient n (%)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Need School (&lt; 75%)</td>
<td>111 (66)</td>
<td>484 (62)</td>
<td>595 (63)</td>
</tr>
<tr>
<td>Highest-Need School (≥ 75%)</td>
<td>56 (34)</td>
<td>297 (38)</td>
<td>353 (37)</td>
</tr>
<tr>
<td>Total</td>
<td>167</td>
<td>781</td>
<td>948</td>
</tr>
</tbody>
</table>

**Retention**

It is important to note the definitions of “teacher retention” and “teacher retention at highest-need schools.” When examining teacher retention at highest-need schools, remaining in a teaching role at a highest-need school is considered retention. For example, a teacher could move from a sixth-grade science classroom in one highest-need school to a seventh-grade science classroom in a different highest-need school and be counted as retained. But if the teacher moved from a highest-need school to teach at a school with less than 75% low-income students, the teacher would be included in teacher retention but would not be included in teacher retention at highest-need schools.
TABLE 7
Teacher Retention in Non-Elementary Schools by Level of School Need and by Noyce Participation

<table>
<thead>
<tr>
<th></th>
<th>Noyce Recipient n (%)</th>
<th>Non-Noyce Recipient n (%)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Need Schools (&lt; 75%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st year</td>
<td>111 (–)</td>
<td>484 (–)</td>
<td>595 (–)</td>
</tr>
<tr>
<td>2nd year</td>
<td>85 (77)</td>
<td>356 (74)</td>
<td>441 (74)</td>
</tr>
<tr>
<td>3rd year</td>
<td>73 (66)</td>
<td>336 (69)</td>
<td>409 (69)</td>
</tr>
<tr>
<td>Highest-Need Schools (&gt; 75%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st year</td>
<td>56 (–)</td>
<td>297 (–)</td>
<td>353 (–)</td>
</tr>
<tr>
<td>2nd year</td>
<td>36 (64)</td>
<td>218 (73)</td>
<td>254 (72)</td>
</tr>
<tr>
<td>3rd year</td>
<td>16 (29)</td>
<td>138 (46)</td>
<td>154 (44)</td>
</tr>
</tbody>
</table>

As an overarching context relative to all schools in the state, the retention rate of teachers in the data set for this study was slightly lower than the documented second-year retention rate for all teachers in Texas. Statewide, middle and high school teachers in Texas have demonstrated an average 90% retention rate into the second year of teaching for the past decade (Performance Analysis for Colleges of Education, 2008–2018). TABLE 7 displays the retention of all teachers in the data set and the retention of teachers at highest-need schools.

The retention rates of the 111 Noyce recipients employed in their first year of teaching at a high-need campus (one serving less than 75% low-income students) were 77% into the second year of teaching and 66% into the third year of teaching. By comparison, the 484 non-Noyce recipients employed at high-need campuses in their first year of teaching were retained at 74% into their second year of teaching and 69% into their third. There were no statistical differences between the second- and third-year retention rates of Noyce Scholars and their peers ($\chi^2 (1, n = 595) = 0.25, p > 0.05$) at schools of highest need.
Of the 56 Noyce recipient first-year teachers hired by highest-need schools, 64% remained teachers at highest-need schools in their second year; 73% of the 297 non-Noyce recipient teachers who taught their first year at a highest-need school remained in a teaching role at a highest-need school in their second year. Though a significant difference was found between the 29% of Noyce recipients and the 46% of non-Noyce recipients retained into their third year at schools of highest need ($\chi^2 (1, n = 353) = 7.39, p < .01$), these results should be interpreted with caution. Especially in the second- to third-year retention rate comparisons, the relatively few Noyce Scholars originally employed in schools of highest need ($n = 56$) reduces the power of our chi-square analysis (power = 0.08). The low power of the analysis prevents us from being certain that the findings of our analysis would be an accurate characterization of the entire Noyce Scholar population.

Discussion

In relationship to the assumed role that ambiguity might play in meeting the spirit of policy implementation—to serve students with high need in the classrooms in which they situate—Noyce Scholars are entering highest-need schools at similar rates to their non-Noyce peers. These findings suggest that while Noyce is having clear success in many respects, there may be, as Matland (1995) describes, contextual conditions dominating the process. The choices teachers are ultimately making about the campus on which they will work may depend as heavily on “the resources and actors present in the microimplementing environment” (Matland, 1995, p. 167) as on the overarching guidelines of the Noyce Program. Though Noyce participation had no association with placement or retention at highest-need schools, more work could be done to ensure that those teachers are going to and staying in classrooms with the highest needs.
Previous literature published regarding Noyce recipients has focused primarily on the decisions of recipients to become teachers and the influence of Noyce participation on perceived preparedness, rather than on placement and retention at highest-need schools (Kirchhoff & Lawrenz, 2011; Liou et al., 2010; Morrell & Salomone, 2017; Ticknor et al., 2017). This study provides a contemporary extension of previous literature by investigating the influence of Noyce participation on teacher employment and retention specifically in the highest-need schools. In 2018, 70% (6,104) of Texas public schools served a majority low-income student population and had a statewide teacher turnover rate of 16.65% (Texas Education Agency, 2018). Based on the Noyce Program definition of a high-need school district (National Science Foundation, 2021b; U.S. Department of Education, 2021), Noyce Scholars could teach at virtually all Texas schools and meet the high-need requirement. Considering a more nuanced definition (serving at least 75% low-income students) brings special focus on the 39% (3,438) of schools in Texas most in need of STEM teachers.

When the placement of STEM teachers was examined, researchers found no statistically significant difference between Noyce Scholars and their peers at high-need schools—those serving less than 75% low-income students—and at highest-need schools—those serving at least 75% low-income students. Noyce Scholars and their peers were not placed in high-need (66% and 62%) or highest-needs (34% and 38%) schools at statistically significantly different rates.

When retention of STEM teachers was examined, the retention of Noyce Scholars and their peers was similar for those placed in high-need schools, but differences were found in those placed at the highest-need schools. At high-need schools, retention of Noyce Scholars was similar to that of their peers into the second year of teaching (77% and 74%) and into the third year of teaching (66% and 69%). However, for teachers placed in the highest-need schools, retention into the second year of teaching was similar (64% and 73%), but retention into the third
year was different. At highest-need schools, 29% of Noyce Scholars and 46% of their peers were retained into their third year of teaching. Though the power of the analysis does not encourage generalization, the results do provide opportunity to explore further the relationships between retention, the demographic makeup of campuses employing teachers, and Noyce Scholar requirements. This finding may tie back to the demographic realities of Texas that make engagement with high-need and highest-need schools a typical context in teaching.

This study also established that Noyce Scholar teachers were primarily placed in high school teaching positions, which was significantly different from the placement of their non-Noyce peers, who were primarily placed in middle schools. This outcome may be a function of initial certification more closely aligned with specific STEM course needs at the high school level (relative to more general STEM courses offered at the middle school level). In relationship to Matland (1995), this finding may also reinforce the role that the “microimplementing environment” plays in where one is choosing to work.

Considerations for Practitioners

The findings of this study add nuance to our understanding of the ways in which policy in experimental implementation—facing low conflict but high ambiguity—might be further refined to ensure broad efficacy of outcomes. For preparation programs, this study may prompt further consideration of the kinds of early and sustained opportunities preservice teachers receive so we can better understand the strengths and needs of schools with a range of economic conditions. Developing a connection early to the meaningful opportunities that present themselves at high-need and highest-need schools may develop connections that are sustained into service as a classroom teacher. Such opportunities in a state like Texas also importantly expose preservice teachers to a likely set of conditions that will contextualize their teaching experiences. Specific to programs supported by Noyce scholarships, universities might consider the ways in which preservice placement in middle versus
high school experiential settings as well as employment demand and job placement assistance may influence first year employment and early career retention of Noyce Scholars.

Considerations for Policy Makers

For policy makers, this descriptive study provides an opportunity to continue to balance the benefits of an ambiguous framing of high-need LEAs with the low-conflict commitment to the value of the Noyce Program generally. While much has been gained by the sustained investment in schools brought about by the Noyce Program, it may be advantageous to consider whether a portion of funding might be designated to prepare teachers interested in working in schools with greatest need. As another example, programs that propose (with sufficient supporting documentation) to concentrate on preparing teachers to staff highest-need schools might receive priority in determination of grant awards. Track 4 funding might also carve out specific funding for research focused specifically on teachers situated in highest-need contexts. Policy ambiguity on its own is not necessarily a flaw. As Matland (1995) describes, for example, such conditions often cultivate opportunities for “bureaucratic entrepreneurs” to create policy that increasingly meets local need. This study suggests, though, that there may be advantages to moving nearer the nexus between such conditions and ones in which policy conflict remains low but so does ambiguity. Outcomes are largely determined by resources (rather than context), and when resources are sufficiently deployed, outcomes are “virtually assured” (p. 160).
Future Research

Findings of this study suggest a need for further qualitative investigation to better clarify the views of STEM teacher educators as well as preservice and inservice teachers with respect to campus selection. Better understanding how they consider and navigate policy ambiguity in their choice process could be helpful for informing potential updates to the Noyce Program. Further inferential modeling is also needed to increase our understanding of the relative influence of individual and school indicators that contribute to employment choice and retention. For example, future exploration might consider the influence of race and ethnicity congruence among teachers and students in teacher placement and retention. Prior research shows that minority teachers are likely to stay in high-need schools (Podolsky et al., 2019) and minority students benefit from having a teacher of their own race and ethnicity (Clotfelter et al., 2007; Egalite et al., 2015). In light of available literature identifying the benefits of Noyce financial support (Evans et al., 2019; Scott et al., 2006; Ticknor et al., 2017), such targeted efforts may also induce additional financial benefits—namely aiding in the reduction of college affordability-related disparities experienced by students of color in the teacher pipeline.

Continued work exploring the myriad positive impacts of the Noyce Program remains important as well. This study identified that one-third of the non-Noyce comparison group teaching in STEM classrooms did not have mathematics or science certification, for example. Understanding the implications Noyce project experiences have for student outcomes adds important additional insight. Additional work could also look at differences by Noyce project characteristics such as student teaching setting and mentor teacher quality. Finally, there is blue-sky opportunity to engage in intentional experimental design with factors within Noyce and other STEM teacher preparation programs to increase capacity to understand with stronger causal precision the ways in which particular aspects of intervention increase desired employment and retention outcomes.
Limitations

Importantly, the findings presented should be appropriately contextualized within the limitations and specific definitions of the study. This study was limited to the data provided by four institutions that agreed to participate in the study, and as such, is descriptive in nature and did not generate the statistical power necessary for inference. While the findings are informative to illuminate areas of future research, the small subset of Noyce Scholars available to study combined with the natural diminishment of data in the study of retention yielded statistical power far too weak for causal inference. This study did not consider the race and ethnicity of the student populations served, which in Texas is strongly related to the percent of low-income students served in the schools. Also, though previous scholarship highlights the importance of a variety of school characteristics with regard to teacher retention (Harris & Sass, 2011; Johnson et al., 2012; Kraft et al., 2016; Loeb et al., 2005), the current study data did not support analysis of such variables. The absence of this data may contribute to the differences in teacher recruitment and retention outcomes seen among certifying organizations. Additionally, time parameters of the data made available by participating institutions limited the number of years over which retention of Noyce recipients could be analyzed.
Conclusion

Preparing and retaining a strong supply of highly effective teachers is one of Texas’s most critical public workforce issues. The quality and effectiveness of public school teachers profoundly influences the academic, civic and social development of the state’s burgeoning student population, and it can be argued that cultivation of a competent and caring teacher workforce for Texas schools is ultimately the key linchpin in state efforts to assure economic prosperity and a high standard of living for all Texans. Maximizing stewardship of programs like the Noyce scholarship is essential. Given the findings presented here, the Noyce Program should consider updating program requirements and supports to place more intentional focus on highest-need schools and districts to ensure that Scholars are employed and remain in the school settings with the greatest need for STEM teachers.
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Uteach Institute. Who we are. Retrieved from [https://institute.uteach.utexas.edu/who-we-are](https://institute.uteach.utexas.edu/who-we-are)


CHAPTER 6

Making Sense of Science Teacher Retention: Teacher Embeddedness and Its Implications for New Teacher Support
Making Sense of Science Teacher Retention: Teacher Embeddedness and Its Implications for New Teacher Support

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By learning what factors help create the organizational and community contexts that permit a novice science teacher to remain and grow as a teacher, we hope to strengthen science teaching on a wider scale and to diminish the flow of well-qualified individuals out of the profession.
ABSTRACT

This chapter reports initial findings from IMPREST, a 5-year research project that aims to investigate novice science teacher retention in the United States, with a focus on the underlying factors influencing retention for the teachers who stay. The goal of this project is to describe efforts to support novice science teachers across a wide range of school and community environments in places where the retention rate of novice science teachers is demonstrably well above average. In such districts, there are stakeholders who know and have learned a great deal about how to support novice science teachers and create conditions for their success, including district administrators, science supervisors, teachers, and community members, and a core aim of this project is to spread their hard-won practical wisdom to a wider audience. In this chapter, we report the design of the project, introduce the theory of teacher embeddedness used in this research, and share preliminary findings from case studies in six school districts.

This study found that retained teachers placed a high value on collaborative environments, adequate resources and salary, and the relationships they developed both within the school organization and the community. In many of the case study districts, the collective mentoring efforts of the science department as a whole was viewed by teachers as more important for retention than individually assigned mentors. In these districts, the human resources process of “onboarding” into the job was distinct from induction efforts to provide longitudinal new teacher supports. One clear implication from this study is the value of adequate common planning time, shared spaces, and engagement in informal relationship-building efforts because doing so helps teachers develop the links necessary to sustain themselves professionally over time.
Introduction

This chapter reports initial findings from a 5-year Noyce Track 4 research project at Montclair State University in New Jersey. The Induction and Mentoring Programs for the Retention of Science Teachers (IMPREST) project aims to investigate factors influencing novice science teacher retention in the United States. The goal of our research is to describe what is being done to support novice science teachers across a wide range of school and community environments in places where the retention rate of novice science teachers is demonstrably well above average.

In this chapter, we will describe how we adapted the framework of “job embeddedness” from the field of career research to create a conceptual framework of “teacher embeddedness” specifically for teacher retention. We have used this framework to make sense of novice science teacher retention in our study as well as of some of our preliminary findings.

The research reported in this chapter relied on two distinct definitions of “novice.” The first, and narrower, definition is that of a first-year teacher who is in their first full-time position as a teacher of record. In our analysis of state staffing data, this is the definition we used because it allowed us to track individual teachers over time and identify the districts that were successful in retaining them. We used the second, more expansive, definition when we conducted interviews with teachers in these districts because we wanted to hear from first-, second-, and third-year teachers about the factors they considered in their decisions to remain or not remain in the district.
In the tradition of qualitative education researchers like Sara Lawrence-Lightfoot (1983), Gloria Ladson-Billings (2005), and John Goodlad (2004), we see the value in researching what is good and what is working in science teacher retention, as opposed to a pathological approach that seeks to diagnose what is wrong. Much of the existing body of research on teachers’ careers frames the issue of retention in terms of attrition, with attention to investigating the reasons why teachers leave the classroom (e.g., Borman & Dowling, 2008; Guarino et al., 2006; Ingersoll & May, 2012; Ingersoll & Perda, 2010; Ingersoll & Strong, 2011; Rinke, 2014; Saka et al., 2013; Santoro, 2011). This work has been valuable in helping to identify variables that contribute to teacher attrition such as poor administrative support, lack of autonomy, contradictions between theory and practice, demanding teaching schedules, and difficulties with classroom management and student discipline. Our study flips this framing of teacher attrition and asks instead: Why do teachers stay? We argue that the answer to this question is not simply a matter of minimizing the factors above that contribute to teacher attrition, though such efforts remain important.

In districts with a track record for retaining novice science teachers, there are stakeholders who know and have learned a great deal about how to support novice science teachers and create conditions for their success. This group includes district administrators, science supervisors, and teachers, and a core aim of this project is to disseminate their hard-won practical wisdom to a wider audience.

Over the past decade there has been a fundamental reconceptualization of the shortage of science teachers in U.S. schools. For a long time, the problem was considered to be one of recruitment. However, a sustained program of research begun primarily by Richard Ingersoll’s detailed investigation of multiple decades of data from the School and Staffing

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1 In this chapter, we use the term “district” or “school district” as a shorthand reference to the more awkward but accurate term “local education agency,” or LEA. In some cases, such as in the technical and charter schools described in this chapter, the LEA comprises a single school building.
Survey has led to the finding that the labor shortage in middle and high school science and mathematics teachers is driven primarily by teacher attrition and mobility (Ingersoll, 1997, 2007, 2011; Ingersoll & May, 2011, 2012; Ingersoll & Smith, 2003). In other words, science teacher shortages can be addressed by improving science teacher retention.

Even when school districts hire science teachers carefully, it is difficult to predict whether a given teacher will remain. Certainly, as the work of a teacher unfolds over their time in a district, a teacher may accrue a mental tally of reasons to leave and reasons to stay. Even school districts that do well in supporting teachers may falter when it comes to their novice science teachers, precisely because of their specialized needs in both the subject matter and pedagogy of secondary science teaching. Teaching is challenging in many ways, and not every science teacher will be able to meet the demands of the job. However, it may also be the case that a promising novice science teacher is hired into a district that fails to provide appropriate support. In this situation, the teacher is less likely to be retained in that initial position and may choose to leave the position or even choose to leave the profession. In the worst case, the district continues to repeat the pattern without ever coming to know what is necessary to support novice science teachers. The present study is motivated by the need to interrupt such a cycle. Conversely, within the districts we examine in our study, something is going right. To this end, our project aims to learn from districts that are successfully retaining novice science teachers, and to make sense of teacher retention in ways that enable other districts to learn from these efforts.
Teacher Retention

The definition of “retention” varies across colloquial and academic usage, and in this chapter, we distinguish between two types of teacher retention in reporting our study’s findings. To the school or district that hires a science teacher whom they wish to keep, the intention is that the teacher becomes an effective, reliable employee who does not have to be replaced for a long time. Such a teacher is defined here as retained-in-position because they are working for the same employer in the same position across two different points of time.

From the perspective of a given teacher, simply remaining in a position may not comprise the whole of retention. A chemistry teacher who moves from one district to another, or to a different position either within or outside their district, perceives a continuity in their own work as an educator that their employers may not. Therefore, we also apply the descriptor retained-in-profession to those who transfer to other districts, teachers who are taking a break in service but intend to return to teaching, and those who remain in the field of education by building on their experiences as classroom teachers (e.g., school counselor, museum educator, positions in higher education, etc.). This distinction is necessary because from the perspective of the field, those individuals who leave employment as a P–12 teacher for work in education-related positions are engaging in work that is not only positive but necessary for the field of teaching (Cochran-Smith, 2004; Nieto, 2003). From the perspective of teachers, it simply does not seem correct to say that such individuals have left teaching, or ought to be counted as teacher attrition. Given that our unit of study is the individual school district, retention as discussed in this chapter refers solely to retention-in-position.

A more fine-grained analysis (e.g., Boyd et al., 2011; Larkin et al., 2022) might distinguish between retention-in-position and retention-in-district, in order to examine the movement of teachers across schools within a district. We do not make such a distinction in the present chapter.
A number of studies have taken up the task of analyzing the effectiveness of various retention factors, such as salary (Bang et al., 2007; Borman & Dowling, 2008; Geiger & Pivovarova, 2018), administrative support (Boyd et al., 2011; Geiger & Pivovarova, 2018; Greenlee & Brown, 2009), mentor support (Geiger & Pivovarova, 2018; Ingersoll & Kralik, 2004), student demographics (Geiger & Pivovarova, 2018; Greenlee & Brown, 2009), and working conditions/school characteristics (Achinstein et al., 2010; Bang et al., 2007; Geiger & Pivovarova, 2018). Papay et al. (2017) noted that with the tentative exception of the existence of collective bargaining (see also Goldhaber et al., 2016), there was little evidence of strong relationships between teacher retention and observable characteristics. Yet throughout this large body of research, there has been little clarity in identifying specific contextual factors that could be used to predict teacher retention.

Certainly, there are factors outside of the direct control of individual teachers that determine whether staying in a particular position or even in the profession is possible. Such reasons may include reductions in force, family obligations, unsatisfactory teaching evaluations, certification issues, and personal health. What these factors have in common is that they are larger than the individual and that, in their absence, the teachers in this category would likely intend to continue employment as a teacher either in the position or in the profession. Such factors are beyond the issues of retention discussed here, though certainly some—particularly those related to teacher performance—may be heavily influenced by teaching context and available supports.

However, for the vast majority of teachers, the decision of whether to remain in a teaching position falls on them personally, and such voluntary decisions (Swider et al., 2011) are not easily categorized. Such decisions are complex and may not be related to job satisfaction. For example, sometimes a teacher leaves a position when they would prefer to stay, such as when a partner’s job requires relocation. Other times, teachers stay in a position when they would prefer to leave, such as when the risk
of lost income or benefits is too high. Teaching itself can be considered an exploratory career (Rinke, 2014), and teachers may simply be ready to move on to another phase of their careers.

Methodology

Our study focuses on school districts in the United States that have above-average novice science teacher retention and seeks to learn how such districts support their new teachers. This study has two distinct phases, and in this chapter we focus primarily on the second phase. However, a brief description of the first phase is provided to explain the state-level data analysis, which is how the sites for the second phase were identified.

First Phase: State-Level Data Analysis and Site Selection

In the first phase, we used publicly available staffing data from 2007 to 2018 to construct a 5-year retention map for six cohorts of novice science teachers in each of four U.S. states (New Jersey, North Carolina, Pennsylvania, and Wisconsin). This approach permitted our team to map the career trajectories of each individual science teacher for a more comprehensive picture of teacher retention, mobility, and attrition. For example, in sample-based studies, the departure of a teacher at the end of 1 year might simply be categorized as attrition. In viewing a 6-year trajectory, we were better able to identify teachers who left a position in a given year not simply as attrited, but possibly as having transferred to a different district or taken time off and then returned. While these teachers were categorized as retained-in-profession, they were not retained within the district, and we did not count them as retained-in-position for the purposes of this study (Larkin et al., 2022).
After analyzing individual teachers’ career trajectories, we calculated the 5-year retention rate of newly hired science teachers in each of six cohorts for the years 2007–2012 for each school district. We then created an indicator to assess the retention rates of science teachers over the first 5 years in order to make cross-district comparisons. This retention rate indicator was calculated as the sum of the total number of years each novice science teacher taught in the district divided by the total possible years. For example, if a district hired three novice science teachers during our period of interest, and Teacher A taught for 1 year, Teacher B taught for 3 years, and Teacher C taught for 5 years, that would sum to a total of 9 person-years. When divided by the total possible of 15 person-years (5 person-years possible for each of the three teachers), the district would have a new science teacher retention rate of 9/15 or 60%. Only one of those teachers, however, Teacher C, would be counted as retained under our 5-year retention criterion. Both the retention rate indicator (in person-years) and total number of 5-year retained teachers (as a ratio of total novice science teachers hired) were used to identify districts for the subsequent phase of the study.

Five districts per state were identified for a more detailed case study on the factors influencing science teacher retention. Districts were sorted initially for higher-than-average rates of retention, as described above, and focus districts were selected from those in the top 10% of retained novice science teachers in each state. We then attempted to diversify our selection of districts by looking at factors such as school size, location within each state, type of community (urban, rural, suburban) and relative wealth of the district. We also looked for districts that had hired (and retained) a significant number of teachers of color, as well as those that had hired graduates who had benefited from the NSF Noyce Teacher Scholarship Program. In each state we included one or two districts that

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3 For example, the 2007–2008 cohort was examined through the 2011–2012 school year, while the 2011–2012 cohort was examined through the 2017–2018 school year.
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did not meet the National Science Foundation’s definition of a high-need school, particularly if they retained teachers of color or Noyce graduates.\(^4\)

At the time of this writing, data collection and analysis are still ongoing for the IMPREST project, yet we have completed enough case studies to illustrate the value of our teacher embeddedness theoretical framework and share some of the lessons learned so far about teacher retention in these districts. Information about the districts in this chapter is shown in TABLE 1, though because names and exact figures would permit district identification, values in the table are presented as approximations to maintain confidentiality, and district names are pseudonyms.\(^5\) Names of individuals and position titles are similarly obscured in order to preserve internal confidentiality. TABLE 2 shows further information about the relative size of the high school science faculty, retention rate, and the number of participants we interviewed in each district. The full district cases themselves may be found on our project website.\(^6\)

**Second Phase: Data Sources and Analysis Procedure**

The research team invited each of the selected districts to participate in the study, and upon securing district approval, made arrangements to interview administrators, novice science teachers, mentor science teachers, retained science teachers, and anyone else involved in supporting novice science teachers. Early data collection was conducted

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\(^4\) In the program solicitation for this grant (NSF 17-541), NSF defines “high-need” from section 201 of the Higher Education Act of 1965 (20 U.S.C. 1021) to mean “a local educational agency (for example, a school district) that serves an elementary or secondary school located in an area which is characterized by at least one of the following: (a) a high percentage of individuals from families with incomes below the poverty line; (b) a high percentage of secondary school teachers not teaching in the content area in which they were trained to teach; or (c) a high teacher turnover rate.” All of the districts labeled as “high-need” LEA in Table 1 were identified as such by the percentage of students receiving free or reduced lunch in 2017-18.

\(^5\) Pseudonyms were carefully selected at the start of the study in an effort to maintain project organization and communication of findings. New Jersey names are trees (Aspen, Birch, Chestnut, Hickory, etc.), Pennsylvania names are rocks (Granite, Sandstone, etc.), Wisconsin names are fish (Wallago, Tetra, etc.), and North Carolina names are birds (Egret, Kingfisher, etc.). No two cases begin with the same letter.

\(^6\) [www.montclair.edu/IMPREST](http://www.montclair.edu/IMPREST)
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through in-person site visits to individual districts; after March 2020 all data collection was conducted through remote interviews via Zoom in order to maintain health and safety during the pandemic. The goal of the interviews was to collect data that would help our team better understand the factors that may have influenced teacher retention during the focus period of the data (2007–2018) and also to investigate current practices around the mentoring and induction of new science teachers. Details on the number and type of interviews conducted at each site are shown in TABLE 2. Other data collected included publicly available district performance reports as well as any documents provided by the district related to the mentoring and induction programs.

At the conclusion of data collection from each site, all interviews were transcribed and then coded using NVIVO12 software. Tentative themes were generated by the research team, though these themes were modified, discarded, or supplanted by emerging themes arising from multiple passes of the data. The one *a priori* theme that was included in every analysis was that of induction and mentoring, given the importance of characterizing induction and mentoring efforts in the district regardless of their roles as factors in retention. For the first case of Aspen, all four researchers coded data independently before meeting to identify emerging themes related to the issues of interest to the case. All four members of the research team then collaborated on constructing the narrative of the instrumental case (Stake, 1995). Subsequently, each team member then took the lead on the analysis and writing of each case, with the other team members providing critical feedback. Upon completion, the written case was then shared as a member-check (Lincoln & Guba, 1985) with each person who had been interviewed in that district, along with an electronic form in which feedback could be provided anonymously. Any feedback from this member-check process was incorporated into the final version, which was then posted on the project website.
### TABLE 1

**Descriptions of Districts Discussed in This Chapter**

<table>
<thead>
<tr>
<th>District</th>
<th>Description</th>
<th>Total student enrollment in 2017–2018</th>
<th>Percent of students receiving free/reduced-price lunch in 2017–2018</th>
<th>Percent of students identified as limited English proficiency in 2017–2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen School District</td>
<td>Regional Secondary school district with one high school. Non-high-need LEA.</td>
<td>3,000</td>
<td>10%</td>
<td>2%</td>
</tr>
<tr>
<td>Birch Charter School</td>
<td>Urban charter school affiliated with a local university. High-need LEA.</td>
<td>500</td>
<td>75%</td>
<td>0%</td>
</tr>
<tr>
<td>Chestnut School District</td>
<td>Large suburban district with two high schools. Non-high-need LEA.</td>
<td>11,000</td>
<td>20%</td>
<td>3%</td>
</tr>
<tr>
<td>Hickory Island School District</td>
<td>Small district with one high school; seasonal population. High-need LEA.</td>
<td>1,000</td>
<td>70%</td>
<td>20%</td>
</tr>
<tr>
<td>Mulberry School District</td>
<td>Urban school district with three high schools and success in retaining teachers of color. High-need LEA.</td>
<td>9,000</td>
<td>60%</td>
<td>5%</td>
</tr>
<tr>
<td>Granite County Technical School</td>
<td>Regional vocational school with an academic program. Non-high-need LEA.</td>
<td>1,500</td>
<td>40%</td>
<td>2%</td>
</tr>
</tbody>
</table>
Making Sense of Science Teacher Retention: 
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**TABLE 2**  
*Department Size, Retention Rate, and Participants Interviewed*

<table>
<thead>
<tr>
<th>District</th>
<th>Number of district science teachers grades 9-12 (2017–2018)</th>
<th>Retention rate indicator for novice science teachers</th>
<th>Total number of teacher and administrator interviews</th>
<th>Number of novice science teacher (exp &lt; three years) interviews conducted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen School District</td>
<td>30</td>
<td>82%</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>Birch Charter School</td>
<td>3</td>
<td>85%</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Chestnut School District</td>
<td>43</td>
<td>83%</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>Hickory Island School District</td>
<td>5</td>
<td>100%</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Mulberry School District</td>
<td>30</td>
<td>65%</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Granite County Technical School</td>
<td>13</td>
<td>100%</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

7 Granite has had no science teacher vacancies since 2017, so there were no novice teachers to interview. In Chestnut, we interviewed six teachers who had been novices between 2007 and 2018, but no current novice science teachers elected to participate in this study.
Theoretical Framework

The Limitations of the Turnover Model of Retention

The turnover model of retention has a long history in organizational theory, and consists of two primary constructs: job alternatives and job satisfaction (March & Simon, 1958; Mobley, 1977). Turnover theory predicts that if someone is not satisfied with their job, and has somewhere else acceptable to go, they are more likely to leave, and “given the same level of dissatisfaction, people with more alternatives will be more likely to leave than those with fewer alternatives” (Holtom et al., 2006, p. 318).

In this model, job alternatives reflect both the state of the labor market and an individual’s personal capacity to change jobs.

Job satisfaction is a loosely defined term that captures whether someone finds the material, intellectual, social, and emotional conditions of their job acceptable in part or in whole (Lee et al., 2014). By this theory, if someone is satisfied in their position and the profession, they will likely choose to remain in the job. If someone is not satisfied but has few alternatives (or is unable to leave their job for any reason), they may also remain. In this model, if a teacher has the opportunity to take another position that promises greater satisfaction, the probability they will do so is increased.

In using the lens of job satisfaction to analyze voluntary turnover in a variety of professions, Holtom and Inderrieden (2006) found that more than half of the individuals in the study left due to a particular shock within the organization, not “accumulated job dissatisfaction” (p. 436). According to Lee et al. (1999) a shock is defined as “a particular, jarring event that initiates the psychological analyses involved in quitting a job” (p. 55). In general, shocks such as being assigned a new supervisor who is difficult to get along with or reckoning with the switch to a virtual workspace during a global pandemic are not unique to the field of education. However, some might argue that teachers experience shocks...
that other professions do not tend to encounter. For novice secondary science teachers, a common shock is being assigned to teach outside of their discipline or certification (Luft et al., 2020).  

The model of job satisfaction is consistent with market-based theories of labor supply and demand, yet has been shown to have limited predictive power when applied to actual cases of job retention and voluntary turnover (Mitchell et al., 2001). Reducing attrition to job dissatisfaction fails to capture why some people can withstand either an accumulation of bad circumstances or shock and others cannot. It also neglects factors that may be extra-organizational, such as those related to the community and a person’s own personal circumstances.

**Toward a Theory of Teacher Embeddedness**

We believe that the theory of job embeddedness, adapted specifically for the field of teaching and termed *teacher embeddedness* here, offers new insights on meaningful supports for novice teachers and is consistent with our aim to focus on why teachers stay, rather than why they leave (Lee et al., 2014).

The theory of job embeddedness originated in the fields of economics and applied psychology in order to serve as a better predictor of voluntary employee turnover than theories invoking job satisfaction and job alternatives (Holtom et al., 2006; Kiazad et al., 2015; Mitchell et al., 2001). Holtom et al. (2013) argued that job embeddedness grows over time as an individual makes more connections to both job and place, and therefore the longer a person remains at a job the more “stuck” they become, and the harder it is to leave. We note here that being stuck within an organization does not indicate whether such a state is desirable or undesirable on the part of either the individual or the organization.

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8 A study by Taylor et al. (2020) recently showed the pervasiveness of out-of-field teaching in U.S. middle schools, with 88% of all middle school science classes being taught by an out-of-field teacher.
In research on employee retention, the theory of job embeddedness has been used primarily for survey construction and subsequent quantitative analysis. Such job embeddedness surveys have been adapted for a broad variety of contexts and purposes, though in the existing literature its use tends toward prediction rather than as a guide to intervention (Mallol et al., 2007; Shah et al., 2020; Siedlok et al., 2015; Sun & Huang, 2020; Tröster et al., 2019). Even in the limited number of studies that examine novice teacher retention through the lens of job embeddedness, findings are typically presented in terms of a correlation between measures of job embeddedness and employee retention (e.g., Watson, 2018; Yildiz, 2018).

The main components of job embeddedness as originally described by Mitchell et al. (2001) are fit, links, and sacrifice, and are applied to two distinct domains: the organization and the community. In our teacher embeddedness framework, the organization refers to the workplace of the school and district itself, and community refers to the local area surrounding the school. Additionally, in our adaptation of the job embeddedness framework to the context of teaching, we have reframed the construct of sacrifice into assets, which we discuss below. In our research, we seek evidence of fit, links, and assets in both the organization and community domains.

Fit refers to the comfort and compatibility of an individual to the organization and community, and includes the degree to which the goals, values, and worldviews of the employee are aligned with those in evidence in those domains (Holtom et al., 2006; Watson, 2018). It also includes the degree to which there are emotional attachments and aspirational commitments to these workplaces and settings (Hom et al., 2017). Simply put, new science teachers who may flourish in some environments might find it difficult to continue in others.

Links are formal and informal social connections and relationships. Within the workplace (organization), these links may be to colleagues and associated professionals. Within the local area (community), these links may include family, religious, and other social affiliations. Links
with students and their families are also important, and may span the boundary between organization and community. Certainly all such links may also influence a person’s decision not to leave their place of employment (Mitchell et al., 2001). Reininger (2012) found that most young teachers in the United States live in close proximity to their hometowns, and Engel and Cannata (2015) noted that this localism in markets for teacher labor tends to reinforce inequities in teacher quality.

The third component of the original job embeddedness framework, sacrifice, refers to “the perceived cost of material or psychological benefits that are forfeited by organizational departure” (Holtom et al., 2006, p. 320), as well as to the ease or difficulty of breaking the links described above. The notion of sacrifice is closely related to the psychological phenomenon of loss aversion, described by Kahneman and Tversky (1979) as the idea that “a salient characteristic of attitudes to changes in welfare is that losses loom larger than gains” (p. 279). The original job embeddedness framework suggests that sacrifices may include such things as leaving coworkers or a familiar office space, as well as the various other job perquisites (commonly referred to as “perks”) that places of employment offer in order to sustain their workers without necessarily increasing their salary. Job perks may include retirement programs, health care benefits, and day care options. Leaving a position will entail losing assets that one values, and human psychology is such that these losses will be perceived as disproportionately larger than equivalent gains.

Within the original job embeddedness framework, the constructs of fit and links were defined in a positive sense with existing and identifiable indicators. However, the construct of sacrifice was defined as a conditional negative, with a close association to potential loss. Further complicating matters was the fact that such potential loss was often applied to aspects of the other two components, thus reducing the explanatory power of each construct. Within economics, assets are tangible and intangible things that have value, and being forced to give up assets is a reasonable
definition of sacrifice. Consequently, we use the term assets to describe those things which would be sacrificed if an educator voluntarily left a position. For our purposes, reframing sacrifice as a loss of assets allows for the positive identification of those assets.

**TABLE 3**

*The Teacher Embeddedness Framework*

<table>
<thead>
<tr>
<th>Component</th>
<th>Domain: Organization</th>
<th>Domain: Community</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fit</td>
<td>The comfort and compatibility of an individual with respect to the local educational context. This includes the degree to which the aspirations, career goals, values, culture, and worldview of the teacher are aligned with the environment of the local educational context in which an individual works.</td>
<td>The comfort and compatibility of an individual with respect to the community. This includes the degree to which the aspirations, career goals, values, culture, and worldview of the teacher are aligned with the environment of the local community in which an individual works.</td>
</tr>
<tr>
<td>Links</td>
<td>Personal relationships and connections made with colleagues, students, and others within the local educational context.</td>
<td>Personal relationships and connections made with individuals and groups within the community, which may include family, consumer, religious, and other social affiliations.</td>
</tr>
<tr>
<td>Assets</td>
<td>The sum of the tangible and intangible benefits from a job to an individual in terms of perceived material and psychological value. Such assets may include salary, workspace and materials, perquisites, established patterns of working, and support for professional growth.</td>
<td>The sum of the tangible and intangible benefits from a community to an individual in terms of perceived material and psychological value. Such assets may include housing, sense of place, established patterns of living, personal safety, favorable commutes to work, and other aspects of one’s quality of life influenced by the community.</td>
</tr>
</tbody>
</table>

*Note.* Adapted from Mitchell et al. (2001) and Holtom et al. (2006)
Reframing job embeddedness as teacher embeddedness appropriates elements of this earlier theory and applies them to the unique circumstances and contexts of teachers in order to better understand the reasons for teacher retention. The components of teacher embeddedness are shown in TABLE 3. One primary difference in this aspect of the framework is in its specialization to the work of educators. Through the naming of the local education context, and the identification of specific examples (such as links to students), the teacher embeddedness framework presents a novel reframing of the job embeddedness framework with appropriate scope for research on teacher retention.

We agree with Lee et al. (2014) in seeing the immense value of a framework based on job embeddedness:

*The overarching practical implication of job embeddedness is that contexts exist in which employees are more likely to stay. To the extent that organizations are able to influence those contexts, they will also influence individuals to stay within the organization (p. 212)*.

We see the greatest promise in this approach in our work with the retention of novice science teachers. By learning what factors help create the organizational and community contexts that permit a novice science teacher to remain and grow as a teacher, we hope to strengthen science teaching on a wider scale and to diminish the flow of well-qualified individuals out of the profession.
Findings

In this section, we draw from our case studies to describe examples of teacher embeddedness in each of the six sites. The role of each of the three components of the teacher embeddedness framework—fit, links, and assets—is discussed in terms of both the organization and the community. Although we have arranged our findings into discrete sections in order to illustrate the role of each component of the framework, there is likely much overlap. Our intent with this section is not only to illustrate the utility of viewing retention through a teacher embeddedness lens, but also to provide examples of how the districts in our study supported new teachers, a topic that will be addressed further in the Discussion section that follows.

The Role of Fit in the Organization

Although teachers included in our study may not have used the term fit, it was evident that what they were describing could be categorized as feeling a sense of shared values and goals. Much of this organizational fit was expressed in terms of work with colleagues, the alignment of values, and teachers’ self-efficacy in their work.

Though we discuss individual relationships in the next section, in many ways, fit was represented by the collective work of teachers and administrators, and by the science departments in particular. For many teachers in the six districts we visited, sharing similar values with their colleagues and administrators was cited as one of the reasons they remained at their schools. These values are not necessarily the same across districts, but the feeling of being on the same page was a common theme in teachers’ reasons for choosing to stay. At Granite County Technical School (GCTS), teachers valued having personal freedom within their classroom while at the same time sharing a desire to collaborate with one another. One retained teacher expressed, “I feel like our departments are very collaborative; like we’re very helpful with each other. People are willing to help each other out as far as pedagogy,
ordering equipment, sharing ideas, so I think that’s why I’ve stayed so long.” There was also some evidence that a shared view of teaching itself contributed to teachers’ sense of fit. At GCTS, the shared vision included a greater emphasis on what one administrator described as “good teaching” and less emphasis on “teaching to the test.”

The size of the school—and by extension the science department—was considered an important aspect of fit in both larger and smaller districts. In Birch Charter School, one of the novice teachers told us that because the school is small, the administrators were able to build community by creating opportunities for the staff and students to interact with one another. One of the Birch administrators echoed this idea: “I would say it’s because we’re like a family, we’re so small. We’re like a tight-knit family. Everybody knows everybody.” Working in a small district afforded teachers not only a feeling of family, but also a feeling of having a greater impact on their students. One of the novice teachers working in Hickory Island School District explained that for him, the autonomy that comes with being the sole chemistry teacher, as well as clearly perceiving his direct impact on the students, “really makes working here and staying here not a hard choice."

A sentiment that was echoed in every school we studied with a significant number of students from low-income families was the value teachers placed on being able to help students in need. A retained teacher at Hickory Island told us that a lot of the teachers do “as much as they possibly can to help any of the students that need help in school.” Being able to engage in such work was consistent with the values held by teachers in the school:

And, again it’s not—because there’s not any type of direction for us to do it—just most people that are hired, just naturally are doing that and so and that’s another reason why I do enjoy it here, is because many of the people here are very much like-minded like myself.
Another example of organizational fit that appeared for some of the teachers in our interviews was a sense of value alignment from having previously worked in nonteaching jobs within the science industry. Teachers explained that for the science teachers who share this work history, they felt they shared similar views on work ethic. One experienced science teacher at Granite County Technical School described it in this way:

*I can’t say that every other department in our school works the way we do. I think probably, whether it’s the sense of several of us came out of industry . . . I worked in industry and we all work together. I mean it was, you know, again the collective department. So as a science department, we share with each other—and I share things across other departments—but I wouldn’t say that that’s necessarily the way the whole building works.*

In a number of the districts, careful consideration was given to fit during the hiring process. At Granite, ensuring that teachers “fit” within the climate and culture of the school was emphasized from the very beginning. One administrator explained that during the hiring process:

*We kind of go through the routine of the interview, one, and then the best fit. I mean, because all of the people will apply with the same qualifications. They all have this and they all have the, you know, the experience or whatever. And then it’s just about who seems the best fit for this school.*

In Aspen, where current teachers were included in the hiring process, careful consideration was given to how well a prospective teacher would fit with the existing department. One administrator noted, “It’s nice when somebody has teaching experience for sure, but just because they have teaching experience does not mean they’re necessarily a good teacher or that their teaching philosophies align with our district mission and our philosophies on pedagogy.”
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The Mulberry School District was able to recruit and retain novice science teachers of color at a higher rate than any other district in the study, and in describing the reasons why, one administrator discussed a recent panel hosted by the superintendent with Mulberry graduates currently in college. Students who were attending historically Black colleges and universities noted that these schools were “almost like a continuation of where they came from,” while students who were attending predominantly White institutions had a more substantial adjustment to make. One teacher of color described her feeling of comfort in working in a district where the students looked like her:

I was kind of afraid to work in a district where there’s more White kids because I feel like the parents are . . . [trails off]. Well, the thing is, I don’t really have much experience with White people or other races, which is not really good at all.

The implication was that the high rate of retention of teachers of color was influenced by a supportive school culture that did not present the types of barriers to teachers of color that might have existed in other districts.

One final finding worth mentioning with respect to fit concerns the ways in which new teachers started their jobs. The very first days of employment for a new teacher can be a whirlwind of information, with forms to be signed, keys to be issued, and policies to be reviewed. One of the commonalities of the districts we studied was that the human resources process of “onboarding” into the job was considered to be very different from well-designed district efforts to provide longitudinal new teacher supports.
The Role of Fit in the Community

For many of the teachers in our study, the school itself was important, but so was the community in which the school was located. In some cases, this was because it was the same school they attended as a student or was in the area where they grew up. Teachers cited wide-ranging reasons for their desire to work in a particular community with its students, and many were willing to travel longer distances in order to do so. Still others reported that they had felt little connection with the community at first, yet ultimately grew to see themselves as a part of the greater community in which they teach, which gave them a reason to stay.

Some districts, such as Hickory Island, made intentional efforts to bring new teachers into contact with the local community. More than one administrator reported providing tours of the district so new teachers could get a feel for the area and become familiar with the lives of the students they would be teaching. Other districts, like Birch, Granite, and Mulberry, hosted community night events and adult education opportunities that provided teachers with a chance to interact with the community beyond their colleagues and students. At Granite County Technical School, students have the opportunity to work in their future fields through internships, and teachers seemed to greatly value their relationships with local businesses.

The Role of Links Within the Organization

Organizational links were often cited both as reasons why individuals continued to teach in their districts and as reasons they came to teach there in the first place. As with other professions, teaching leads to close relationships with colleagues and supervisors, but it also can lead teachers to build links with their students, their students’ families, and the local community. Current models of teacher induction also present opportunities for strong relationships to form between novice teachers and their mentors. Lastly, a distinctive opportunity for links in the field of education is the potential return of alumni students as teaching staff.
Throughout the case studies, teachers consistently mentioned that one of the reasons they remained at their schools was that they greatly valued their colleagues. One retained science teacher in Aspen High School stated, “The people that I work with in my department are a huge reason why I stay.” A defining characteristic of the culture for Aspen students and teachers alike was high expectations. The science supervisor told us, “The science department here, it’s a very strong group of teachers. They are devoted to their students. They hold each other and themselves to a very high standard.”

At Granite County Technical School, a change in the school to include academic as well as vocational education led to a large number of teachers being hired in a single year. This created a cohort effect in which teachers found themselves relying on one another to overcome challenges related to the school’s recent reorganization. One of the retained teachers explained that they were “all in the same boat,” and strong bonds were created in overcoming the challenges together.

Sometimes science teachers felt connected to individuals both within and outside of their own department. One retained science teacher in the Chestnut School District described these connections:

> It goes outside the science department, for sure. I’m closer with my science colleagues than, say, math or English, but the people that I work with every day . . . I think Chestnut Plains [High School] has a phenomenal staff. I would leave in a minute, because I know there are many other schools that have higher pay scales for the amount of years I’ve had, but I really like the people that I work with. I don’t know that that would be the case in anyplace else that I would go. I have a lot of respect for my colleagues.

For some of the teachers we interviewed, having the assurance that they would be working each day with colleagues they respected and enjoyed being around was more important than other job assets, such
as an increase in salary. Another teacher in Chestnut District said it well: “Better pay elsewhere might not mean better people. It may not mean being happier.”

Teachers also spoke about the importance of supportive administrators, a point that has been raised in much of the retention literature (e.g., Boyd et al., 2011; Campoli, 2017; Grissom & Bartanen, 2019), and here we distinguish between the material support provided by the administrators (discussed as assets below) and the personal connections novice teachers made with those who supervise their work. For example, one administrator in the Chestnut School District described the way the science supervisor nurtured relationships with teachers as a form of “individualized support”:

[Our] science supervisor in particular really, really pays attention to the teachers. He’s watching them carefully, he is supporting where they need supports, he meets with new people frequently, just as check-ins, just to kind of get a finger on the pulse to see how everything’s going and see what they need. And he runs that by me. He says, I met with so-and-so and this is what I’m thinking we need to do for her, or can we set her up with this? So that has been so critical, that individualized support, I think that is what. . . . And even for the people that . . . I mean I have to be honest, even for the people that are long-term subs, he’s taking that level of care with them.

It is important to note that the cultivation of a school and district environment where relationships are fostered, as described above, is itself a form of supporting the links for novice teachers.

In a similar manner, teacher induction programs have become commonplace in the field of education as a means to support novice teachers and promote retention. In many states, including New Jersey and Pennsylvania, a structured induction program is mandatory and
includes the matching of each new teacher with a more experienced teacher as their mentor. These mentor/mentee relationships may not always be sustained beyond the induction period, but when they are, it appears these relationships are a significant reason new teachers choose to stay.

In our study, the importance of mentor relationships came up several times. For example, one novice teacher at Birch Charter School described the influence of their mentor teacher and the link that was formed between them:

> My decision started like three years ago, when I applied for the Noyce program and I started the teacher internship program. I started work here as a trainee and then I met my mentor and other teachers in the field. That relationship [with the mentor] helped me get a job and I owe her for that. . . . She’s like my family and that’s how close a mentor to me she is. So, I’m very lucky to have her. I mean, everybody here loves her.

Another example of links that we identified through our analysis was that between teacher and student. Teachers consistently talked about the relationships they shared with their students and how important it was to remain in their school because of them. One of the experienced teachers at Hickory Island told us how building relationships with kids happened much more readily than building relationships with her colleagues:

> I remember just loving the kids and loving the science and conveying that into my lesson, so that wasn’t difficult at all, but I would say making interactions with other teachers and administration building those relationships were definitely difficult in the first years. . . . I’m not sorry that I built a relationship with the kids, because I still have those relationships. But looking back, if I would have made other administrative or faculty relationships it probably would have made things easier.
At Chestnut School District a teacher also noted that “the students are definitely a motivating factor” to remain teaching there.

One important takeaway from the districts we studied was that mentoring was considered to be the responsibility of the whole science department, and not just of one assigned person. Even though new teachers were assigned individual mentors, in most cases, the school or district science department served a collaborative role in mentoring the new teacher, particularly in terms of content and curriculum. When other assets, such as resources, and autonomy, were taken into account, many retained science teachers expressed that it was not worth leaving their district for more competitive pay because they did not want to leave their science department colleagues.

The Role of Links in the Community

The teacher embeddedness framework suggests that the links individuals make in the community where they teach, beyond interactions with the colleagues and students with whom they regularly work, are an important component of their retention. In contrast with professional external links (such as those acquired through professional organizations, professional development, and continuing higher education), community links serve as a way for teachers to better understand the worlds of their students and provide conduits for information to flow in both directions.

Many opportunities for developing community links were facilitated by the districts we studied. For example, at Mulberry, the district held events where teachers and parents could get together to talk about science:

*Here we have science night, STEM night, we have just meetings where parents learn about the content. It’s a whole variety and I’m just talking about science, so even in the other content areas, we have all types of events where we involve our community.*
In a number of the districts we studied, new teachers were provided with opportunities to familiarize themselves with the communities in which the students lived. For example, in Hickory Island School District, the district tour for new teachers would end in the public housing area of town, where the principal would introduce teachers to parents.

At Granite, not only did teachers have students who were the children of students they taught in the past, but some also had students working in one of the local businesses that they frequent. As noted above, some of these relationships were leveraged to foster internship opportunities for students, and one teacher described this network created by the school in the local community as a “lineage.” It appeared that this extra layer of community attachment contributed to the close-knit feeling both teachers and administrators had working for their school.

For those teachers who grew up in or near the district they are now employed in, relationships were also essential. One of the experienced teachers at Hickory Island explained it this way:

> I’ve been a part of this community for most of my life. I was away for six years or so. But coming back, I have a connection to the area. I think that also helps with having a connection with the students. I understand where they come from, even if they’re from a completely different background than myself. I know what it’s like to live here where it’s crazy in the summer and you have to work a bunch of jobs and then it’s completely dead in the wintertime.

A similar sentiment was also made by one of Hickory’s novice teachers:

> The kids are, even kids that I don’t have, they’ll come talk to me. You’re part of that group and that’s kind of how Hickory is. A lot of the teachers around here went to school here and they went to school with the parents of the kids that are here, and there’s a lot of kids that they’re the second generation, third generation of people who went to Hickory High School,
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and the teacher that retired this past month with like 35 years, 
they saw multiple generations of Hickory people coming in and 
coming and going. So it’s a great small-knit community and 
you get a lot of support from the town.

In almost all of our cases, the current science teacher population included 
former students, and every school had administrators who highly valued 
their graduates who returned as teachers. Indeed, administrators 
indicated a strong preference on the part of schools to hire teachers 
who either had graduated from the district or who were otherwise local in 
some way. The empirical data that led to the selection of the sites seemed 
to bear out the notion that these high teacher retention districts hired 
such teachers, consistent with the findings of Reininger (2012). Though 
no districts we include in this chapter had an explicit “grow your own” 
program (Gist et al., 2019), many used informal links and networks to 
recruit teachers who had grown up in the district.

The Role of Assets in the Organization

Using the teacher embeddedness framework as a tool for understanding 
teacher retention allows us to look at those “things” teachers describe 
as influential in their decision to remain in their school or district and 
sometimes within the field as a whole. Throughout our analysis, there 
were several assets within the organization that seemed to cut across the 
cases, such as monetary assets (including adequate salary and classroom 
resources), as well as less tangible assets, such as teacher autonomy.

At Chestnut, salary appeared to be one of the driving forces for teacher 
retention. One teacher shared that although teachers were happy with 
many aspects of their district, “most of us would probably leave if we 
could be guaranteed our salary and security elsewhere.” According to 
another teacher at Chestnut School District, “the salary scale is better 
than surrounding districts.” At Granite County Technical School, teachers 
expressed that the salary was also a factor for remaining at their school. 
Because GCTS receives students from several sending districts in the
county, it pays teachers an amount close to the average salary of teachers in those sending districts.

For example, one of the novice science teachers at Granite explained to us that they felt their pay was fair, and the option to leave the district for a private school, where the salary would most likely decrease but the student population would be different, was unappealing. She also explained that she had no plans to leave to go to a district that pays more:

*I personally live in a quote “wealthier” district and my mom has always been like, “Why don’t you look there?” And I just say, “You know what? I don’t want to have to deal with those politics and our pay is almost as good. I’d rather keep our platform that we have in this school than go to another school for just a little more money.”*

For this teacher, a slight increase in salary would not offset the cost of what she might lose if she chose to leave GCTS. One of these assets was the existence of adequate materials for teaching; unlike many others in the teaching profession (Ingersoll & Collins, 2018), teachers at Granite County did not feel pressure to pay for materials out of their own pocket. “We get almost everything we want to order,” one science teacher noted. The department chair, who is charged with ordering supplies, told us:

*I’ve never disapproved of anyone, I never said, no we don’t have money for this, or no, you can’t have that. So, I mean, that’s a nice perk. Like pretty much everything you want to try, you know, as long as you can prove that it’s good for kids or it’s going to help you, you know if you’re teaching that, you can pretty much get it.*

Administrative support was cited by teachers as one of their reasons for retention in their districts. Such support often takes the form of providing adequate classroom supplies, particularly for science teachers, who typically need to order more supplies than do other teachers in the building. At Hickory Island, science teachers were allocated a higher
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annual budget for supplies and materials than were teachers in other departments. According to an administrator there, “I give them a ton of money to say ‘Spend it on labs’—where everybody else just gets $200 for materials, I give them close to $1,200: $200, for, you know, your pens, your markers, your notebooks, and then here’s $1,000—spend it on materials, chemicals.” Being provided with the materials they need, teachers felt valued and also inevitably experienced greater feelings of accomplishment during their classroom lessons.

Outside of monetary assets, teachers across all cases discussed how important it was for them to have ownership over what they did in their classrooms, and that it was a significant factor in their retention. In the retention literature, this is commonly referred to as teacher autonomy (Ingersoll et al., 2016). One of the retained teachers at Hickory Island School District explained, “I basically have control over my own classroom, so I can teach the science the way I want to teach you the science, and nobody tells me any different.” Similarly, a retained teacher listed his reasons for staying at Granite County Technical School. He said, “I think it’s a lot of the stuff that we spoke about—flexibility, freedom to teach the way that you want to teach.” A retained teacher in Mulberry School District stated, “There’s a healthy balance of the vision from up top, but also I still feel free enough to try new things in the classroom.” An administrator at Birch Charter School noted that teachers in his school chose to stay because of the “ownership over the curriculum and the freedom to do what you want.” Teacher autonomy, wherever it appeared in our case studies, was clearly a valued asset by retained teachers.
The Role of Assets in the Community

For many, the community in which their school was located afforded them several assets. One particular asset that came up repeatedly across cases was the value that many teachers placed on their commuting distance between home and school. For one teacher at Chestnut School District who was recently widowed, a short commute was more than just a luxury. She explained, “My children were growing up and I put them in a school near me. I turned down other jobs that were farther away. I chose the job that put me closest to my children.” Other teachers at Chestnut felt the same way, telling us they stay because they live in the town, some as close as “five minutes from here.”

For teachers at Hickory Island School District, living near their school meant they were in close proximity to the beach, which they valued highly. According to one teacher:

\[I \text{ mean we’re two blocks, three blocks from the beach so when you, you know, when you grew up in an environment where, you know, you worked on the boardwalk at nighttime and you were at the beach all day, I mean who doesn’t want that lifestyle, right? Like that’s number one.}\]

At other schools, some teachers chose to remain teaching in their community despite their commute. One of the school’s most experienced science teachers stated, “I fell in love with Birch City when I started here. I love diversity.” This particular teacher was willing to commute 80 miles from her home (in a much less diverse community) to Birch Charter School. She explained, “I don’t mind doing it because I love what I’m doing. And I love the school and the area.”
Discussion

Our purpose for looking at teacher retention through the lens of the theory of teacher embeddedness was to provide a deeper understanding of why science teachers remain in their positions. Not only does teacher embeddedness help describe why teachers stay, but this analysis reveals implications for the design of potential supports for teachers.

Our findings suggest that using educational resources to work on a teacher’s sense of fit within the district is a worthwhile use of professional time in schools. For example, explicitly dealing with how individuals can enact their personal interests and goals within their work may involve discussing personal goals, thinking through career aspirations, and conducting value affirmations (Borman, 2017). Issues impacting fit, such as the presence or absence of racial microaggressions (Mawhinney & Rinke, 2019) and the accumulating effects of standardized testing and punitive teacher evaluation systems (Dunn, 2020), and other forms of erosion of teacher autonomy, need continued attention. While we did not hear about these particular issues from the teachers we interviewed, it is important to remember that we interviewed in districts where teachers were choosing to stay.

In schools, relationships are built through shared experiences and classrooms, through scheduled or opportunistic personal interactions, and in the context of the daily operations of the school in a myriad of ways. Like any relationship, links are nurtured and grow over time, and a key ingredient is the development of trust (Bryk & Schneider, 2002). Therefore, fostering the ability and capacity of teachers to establish new links and sustain existing ones becomes an important avenue for retention efforts. Novice teachers may be particularly vulnerable to the dissolution of links, and unless forms of interaction and communication are established that permit existing links to persist and new ones to flourish, it is reasonable to predict that this component of teacher embeddedness will be weakened. Novice secondary science teachers
in small schools—where they may be the only teacher for a particular subject—may have even fewer possibilities for subject-specific links for support within their own school.

Given the importance of links in teacher retention, the implication is that the ability to maintain social relationships is key and ought to be nurtured in new ways. For example, multiple teachers across the districts interviewed in this study referenced the use of common resources, such as lesson and unit plans located in a shared online folder, as one strategy for supporting new science teachers in their departments. An administrator would be well served to be aware of such a resource—even if they themselves do not access it—in order to encourage participation so that novice teachers continue to benefit from these collegial links.

As we discussed briefly in the section regarding fit, the science teachers we interviewed highly valued collaborating with each other. Overburdened teachers with little time to co-plan or collaborate with colleagues built into their day may be less likely to develop the links necessary to sustain themselves professionally. Facilitating the creation of new pathways for link formation both within the organization and in the community would seem to be a worthwhile component of the effort to retain teachers (Shirrell, 2021; Zavelevsky & Lishchinsky, 2020).

With regard to assets, certainly equitable funding for schools remains a critical issue, and the adequacy of resources for teaching ought not to be taken for granted (Baker, 2018). If teachers feel that they do not have adequate resources to do their jobs, their embeddedness is likely to be weakened. Recognizing that time is also a resource that can be reallocated is important as well.

Fit, links, and assets are all interlocking components for retained teachers and are found both within the organization of the school and district and in the wider community. This was exemplified by one Mulberry science teacher, who offered the following justification for his remaining in the district for so long:
First of all, there are a lot of opportunities for progress, for self-growth, that is important to me. They are again a very collaborative and supportive administrative team. That pay is also good relative to other comparable schools. I’m able to, at this point—initially, no—but at this point I’m able to use my skills to assist teachers. So that’s actually one of the main reasons that the position is really appealing. The district is really appealing because I’m able to offer a lot of recommendations to supervisors and principals that are even outside of my school. So that kind of interaction and the intellectual stimulation is part of the reason that I have stayed here.

Limitations

We recognize several limitations on our study. First, the selection of the districts was intended to provide us with the very best examples of where teachers were being retained. However, in order to be selected, a district had to have hired—and retained—novice science teachers during the period of our study (2007–2018). In order to have hired a new science teacher, the districts had to have had an opening, either through attrition or through the addition of a new position. This means that districts that did not have an opening in this time period were not included for selection, although—or perhaps because—they may, in fact, have been doing the best at retaining their science teachers. Thinking another way, it is possible that the districts that did have openings, and were therefore selected (when they succeeded in retaining new hires) had issues related to retention that caused these openings. However, it is equally likely that the openings were caused by normal retirements or teachers leaving for reasons outside of the district’s control (such as moving for a partner’s job change or another reason, as mentioned previously).
One other limitation is that the interviews took place during the 2019–2020 and 2020–2021 school years. Many of the novice teachers we interviewed were not teaching in these districts during our study years, and even some of the administrators and retained teachers were not (yet) in these districts during the period of our study. However, there were some cases when the retained teachers in our interviews were, in fact, the novices retained during the period of study, and other retained teachers had been there since before such time. In addition to the individuals, the policies in place during our study years are not necessarily in place during our interviews. In focusing primarily on the issue of teacher retention, we ground our study in the assumption that if the districts were good at retaining novice teachers during the 2007–2018 time period, then they remain effective at doing so now, but we realize this may not always be the case. As is true with much case study work, our findings illuminate the particulars of the specific context while refining broader understandings of the phenomenon under study.

Interviews for three of the six cases mentioned in this chapter took place in the schools, before the closure of schools due to the COVID-19 pandemic. Interviews for the other three districts were conducted online during in-person school closures. Therefore, we did not always have the opportunity to get a feel for the school, and perhaps missed some important cues that would have been apparent had we visited in person. However, in some cases, online interviewing made scheduling interviews (and rescheduling, when necessary) easier on both the research team and the teachers. Still, teachers may have felt a certain level of screen fatigue (in addition to general pandemic weariness) after so much online teaching, especially since we interviewed them during or immediately following their teaching day.
Conclusion

The theory of teacher embeddedness holds great promise as a theoretical framework, and we suggest that it may have great utility beyond its use as a predictor of turnover and may even serve to guide the creation of mentoring and induction programs for teachers. We argue that new insights regarding a teacher’s decision to stay in their current position may be elicited using this framework, as demonstrated here by using teacher embeddedness to analyze issues of teacher retention.

Acknowledgments

The authors would like to express our gratitude to the teachers and administrators whose voices and experiences have contributed to this project, as well as to the district administrations and school boards whose consent made this research possible.
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CHAPTER 7

How Early-Career Science Teachers Negotiate Their Beliefs and Practices During an Online Induction Program
How Early-Career Science Teachers Negotiate Their Beliefs and Practices During an Online Induction Program

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Early-career science teachers work to negotiate between the reform-based theories presented in their preservice licensure program and the realities of the classroom. When they do so, their beliefs about science teaching and their classroom practices don’t necessarily evolve in tandem.
ABSTRACT

Prior research has reported that, in the absence of high-quality, science-specific induction support, science teachers’ beliefs and classroom practices are consolidated into teacher-centered, didactic practices as they are socialized into the classroom (Luft et al., 2003; Simmons et al., 1999). This study presents findings from A Study on Promoting Reflective and Equitable Practice Through Science Induction (PREPScI), an NSF Noyce Track 4 project focused on developing a strong empirical understanding of effective induction support for early-career secondary science teachers working in high-need schools. A primary goal of this project is to explore how participating teachers’ reform-based beliefs and practices change through their first year in an induction program.

An explanatory sequential mixed-methods design (Creswell, 2014) was used to assess how 16 beginning science teachers who participated in our online induction program understood and enacted reform-based strategies within their K–12 classrooms. Quantitative analysis of changes in teacher responses to the Beliefs About Reformed Science Teaching and Learning instrument (BARSTL; Sampson, Enderle, & Grooms, 2013) over the span of one academic year revealed statistically significant changes in beliefs related to Lesson Design and Implementation and The Nature of the Science Curriculum. Similar analysis of observational data from the Reformed Teaching Observation Protocol (RTOP; Sawada et al., 2002) over the same span of time revealed no statistically significant changes over the academic year but suggested some evidence for an increase in reformed practices related to Student/Teacher Relationships. Qualitative analysis of Teacher Beliefs Interviews (TBIs; Luft & Roehrig, 2007) conducted with these teachers served to contextualize and explain findings from the BARSTL and RTOP. The three themes resulting from this analysis are making learning meaningful, agency in planning, and listening to student conversations. These findings illustrate how our early-career science teachers negotiated between the reform-based theories presented in their preservice licensure program and the realities of the classroom.
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Background and Purpose

The National Research Council (2010) noted that “there is very little systematic research about current practice in the preparation of . . . science teachers” (p. 177). However, an area of increasing research, particularly within science education, explores the role of teacher induction programs, which have been shown to alleviate job dissatisfaction by mentoring and supporting beginning teachers (Keese et al., 2022; Kutsyuruba et al., 2019; Smith & Ingersoll, 2004).

Indeed, the number of induction programs has greatly increased, with over 90% of beginning teachers reporting some form of support as of 5 years ago (Ingersoll, 2012; Ronfeldt & McQueen, 2017) and more than half of all states in the United States requiring some type of induction for beginning teachers (Putman & Walsh, 2021). Ronfeldt & McQueen (2017) observed that teachers who participated in induction were less likely to migrate between schools or leave teaching in the first 5 years, and this effect became more pronounced as the number of induction supports increased.

A singular focus on retention, however, misses the critical opportunity to provide a bridge from teacher preparation to practice (Feiman-Nemser, 2001). Within K–12 science education, teacher effectiveness is aligned with the implementation of reform-based teaching practices advocated for within science policy documents (e.g., NGSS Lead States, 2013; NRC, 2012) as these practices are associated with improved student achievement and interest in science (e.g., Kang & Keinonen, 2018). In the absence of high-quality, science-specific induction support, science
teachers’ beliefs and classroom practices are often consolidated into teacher-centered, didactic practices as they are socialized into the classroom (Luft et al., 2003; Simmons et al., 1999). Therefore, the induction experience is a critical juncture for the development of teachers, as it “is a time when science teachers’ practices and cognitive modes are conceptualized, constructed, and crystallized” (Luft, 2007, p. 533), and “[s]upport for newly qualified teachers will ultimately impact their retention and their instructional effectiveness” (Luft et al., 2003, p. 95).

This chapter reports on a study that was conducted to examine the reform-based beliefs and practices of secondary science teachers working in high-need schools. These teachers participated in A Study on Promoting Reflective and Equitable Practice Through Science Induction (PREPSci), an NSF Noyce Track 4 project focused on developing a strong empirical understanding of effective induction support for beginning science teachers. Participants interacted with one another and with their instructor through online graduate courses at a large Midwestern university as described by Roehrig et al. (2015). A primary goal of the project was to investigate induction strategies that positively shape the professional growth of beginning secondary science teachers. Of particular importance is the desire to prevent teachers from reverting to teacher-centered practices and to instead develop their capacities for reform-based science instruction.

This study aims to answer the following research questions:

**RQ1:** How do new science teachers’ beliefs about reformed teaching change through their first year in a science teacher induction program?

**RQ2:** How do new science teachers’ reform-based practices change through their first year in a science teacher induction program?

**RQ3:** What relationship, if any, exists between new science teachers’ beliefs and practices regarding reformed instruction?
Literature Review

Reform movements in science education call for a shift away from traditional, didactic approaches toward constructivist approaches that focus on student comprehension (e.g., NGSS Lead States, 2013, NRC, 2012). In K–12 science classrooms, a primary goal of these reforms is that students “actively engage in scientific and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields” (NRC, 2012, p. 8). This kind of learning has been referred to as inquiry or inquiry-based learning by many science education researchers and policy makers (NRC, 2000; Windschitl, 2003) and more recently as three-dimensional learning within the Next Generation Science Standards (NGSS Lead States, 2013). In order to prepare science teachers for these reform-based science practices, induction programs should move beyond general topics (such as lesson planning and classroom management) and include science-specific support (such as creating inquiry-based lessons and laboratory investigations; Heredia & Yu, 2015; Luft et al., 2011; Shwartz & Dori, 2016). A major initiative of science teacher induction programs, therefore, has been to develop their candidates’ capacities for reformed instruction. Luft et al. (2003) observed that beginning teachers who participated in comprehensive, science-specific induction programs “experienced fewer constraints, and were more likely to implement inquiry-based instruction in their classrooms than did secondary science teachers receiving general induction support or no formal induction support” (p. 78). In a later study, Luft et al. (2011) explored the beliefs and instructional practices of beginning secondary science teachers during their first 2 years of teaching and found that science teachers who participated in science-specific induction supports (including web-based mentoring) engaged their students in more interactive, student-centered activities compared to beginning teachers in programs that were not science-specific. Research has also shown that participation in a comprehensive
induction program has a positive effect on classroom practices (Ingersoll & Strong, 2011). Induction programs provide new teachers with a unique opportunity to receive support from their university instructors during their first formative years (Hamilton et al., 2022; Zugelder, 2019); these instructors are able “to actually ‘be there’ when new graduates encounter institutional and sociocultural challenges at their schools” (Rodriguez, 2015).

One very important factor when exploring the enactment of reform-based practices, particularly within the context of an induction program, is an understanding of teacher beliefs related to their teaching practice. The beliefs that teachers hold influence their perceptions and judgments, and these in turn impact what takes place in the classroom (Pajares, 1992; Richardson, 1996). We have known for some time that even novice teachers are capable of reformed beliefs (Simmons et al., 1999; Windschitl, 2003); however, beginning teachers are particularly vulnerable to belief change through socialization into the profession by their more experienced peers (Tschannen-Moran & Hoy, 2007). It is therefore important to explore the beliefs of teachers who are participating in an induction program; such teachers are at a critical juncture on their path to becoming master teachers and require unique and specialized support (Luft et al., 2003).

In a seminal study, Simmons et al. (1999) investigated the relationship between secondary science and mathematics teachers’ beliefs and their classroom practices over the span of 3 years. This study found that beginning teachers held a range of beliefs, from teacher-centered to student-centered, with teachers describing their practice as being far more student-centered than their observed practices were in reality; however, in the absence of any induction support, by the third year of teaching, the majority of teachers’ beliefs and practices converged in a teacher-centered direction (Simmons et al., 1999). Induction programs hope to intervene and support beginning teachers in maintaining their student-centered beliefs developed through their preservice programs (Rimm-Kaufman et al., 2006) as they encounter the reality shock of
their first year of teaching when beliefs are shown to revert to more teacher-centered orientations (Hong, 2010; Voss & Kunter, 2020). Wang et al. (2008) suggest that the initial beliefs of beginning teachers may mediate the influence of any reform-minded induction or other professional development programs. However, research suggests that induction support can promote student-centered beliefs (e.g., Luft et al., 2011; Kleickmann et al., 2016; Voss & Kunter, 2020). For example, Luft et al. (2011) observed that the beliefs of beginning teachers who were supported through a science-specific induction program became more reform-oriented and student-centered; however, over the second year, their beliefs became more teacher-centered. It is important to note that changes in a beginning teacher’s beliefs may not necessarily lead to changes in their classroom practices (Navy et al., 2021). Jones and Leagon (2014) observed that, although recent studies have begun to explore the relationship between science teachers’ epistemic beliefs and their capacities for planning and teaching with inquiry, there is still a need to understand how science teacher beliefs change over time and how those beliefs relate to planning and teaching more generally.

Context plays an important mediating role in understanding changes in beliefs and practices for beginning teachers (Voss & Kunter, 2020) as well as understanding teacher retention. High-need schools present a particularly complex contest for beginning teachers, as these schools (particularly in urban areas) experience significantly more issues with teacher retention than suburban schools (Morettini, 2016). External factors have been shown to have a large impact on urban teacher retention (Jacob, 2007); however, positive administrative and collegial support can positively impact urban teacher retention (Geiger & Pivovarova, 2018; Mansfield, Beltman, & Price, 2014; Newberry & Allsop, 2017). Most beginning teachers will experience a period of disillusionment and associated reversion to more traditional beliefs (Moir, 1990). While beliefs may rebound with positive collegial support, beginning teachers in urban schools without positive support will fall “prey to the stereotypes and deficit thinking that is part of the air they breathe in urban public schools”
(Picower, 2007, p. 16), and their beliefs will become traditional and teacher-centered (French, 2020). Mentoring and systematic induction support are critical in helping to support the incoming reform-based and social justice-oriented beliefs of beginning teachers in urban schools (Marco-Bujosa et al., 2020).

We contend that beginning science teachers who participate in a science-specific induction program will experience a positive impact on their professional growth and ability to engage in reform-based science instruction. Since the literature above suggests an important relationship between teacher beliefs and practices (particularly among beginning science teachers), this study investigated that relationship for beginning science teachers who participated in our induction program.

Research Design and Methods

This study features an explanatory sequential mixed-methods design (Creswell, 2014) that incorporates both quantitative and qualitative measures. In our design, results from the qualitative data related to RQ3 will be used to explain results from the quantitative data that support RQ1 and RQ2. This process will be described in more detail below.

Context

Our induction program is housed at a large Midwestern university, and it is the predominant pathway for educators who wish to complete the MEd program. This study is contextualized within the PREPScI project, which focused on improving the induction experiences of beginning secondary science teachers working in high-need schools. Students enter the MEd program as a cohort and complete a yearlong licensure program that includes a three-course science methods sequence, coursework on the nature of science and extensive school-based practica, in addition to
foundations coursework. Following completion of this licensure program, teachers are required to take an additional nine credits in order to receive their MEd. These nine credits currently include an online induction course, a face-to-face course on equity and social justice, and an online action research course. The online induction course is in its 12th year of operation and has served over 200 teachers during this period.

**Induction Activities**
Within the online induction course, teachers engage in several tasks that serve as a bridge between the induction community and the teachers’ classroom. These tasks are summarized below and described in greater detail in Roehrig et al. (2015). Through our design-based research approach, we have continually modified these induction activities to best support teachers’ professional growth and develop reflective, reform-based practices (McFadden et al., 2014; Ellis et al., 2017).

**Reflective Journals.** The Reflective Journals are used as a place for teachers to process their experiences as they negotiate their interactions with their students, both within and beyond the classroom. “The journal provides a window into the emotional well-being of each beginning teacher and the ability to provide ‘just in time’ mentoring and advice” (Roehrig et al., 2015). Since the Reflective Journal is shared only with the induction facilitator, we find many teachers are more willing to discuss challenging or sensitive subjects through this medium (as opposed to through other tasks that include their peers).

**Topical Response Forums.** The Topical Responses take the form of threaded forum discussions around a prompt that the induction facilitator provides. These prompts may be selected based on commonly known challenges that beginning teachers face, or they may be generated in response to issues that the participating teachers share within the program. “The role of the facilitator in this setting is initially to determine an open-ended topic for discussion that both addresses beginning teachers’ concerns and pushes their thinking” (Roehrig et al., 2015).
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**Venture-Vexation Discussions.** The Venture-Vexation activity is adapted from the work of Johnston and Settlage (2008), who proposed a structured discussion protocol that allows participants to share either a *venture* (an opportunity to explore new approaches to curriculum and/or teaching strategies) or a *vexation* (an opportunity to reflect on a challenging situation and elicit feedback from peers). Although the highly structured sequence of this approach (where individuals have designated times when they are allowed to speak) may seem somewhat contrived in a face-to-face discussion, our instructors find that it lends itself well to an asynchronous discussion in an online induction environment.

**Professional Development Inquiries (PDIs).** The PDI is based on Danielson’s (2007) Framework for Teaching and provides teachers with opportunities to self-evaluate, identify areas for instructional growth, implement strategies aligned with their goals for growth, and reflect on their actions using classroom video of their implementation. In our induction program, each PDI cycle lasts for approximately 8 weeks, which is intended to allow teachers to take meaningful steps toward improving their teaching practice in one of five instructional domains: *communicating clearly and accurately, using questioning and discussion techniques, engaging students in learning, providing feedback to students, and demonstrating flexibility and responsiveness.*

**Participants**

This study considers three cohorts of science teachers who participated in their first year of classroom teaching. Cohorts ranged in size from 11 to 20 teachers each, and 23 out of the 47 course participants volunteered to participate in the study. The participants in this study included 16 of these 23 teachers across three cohorts and were selected based on the completeness of the data. As described earlier, each cohort completed a yearlong initial licensure program, and this group of teachers practiced in both middle school (6th–8th grades) and high school (9th–12th grades) science classrooms. The middle school science teachers taught primarily life science and earth science, while the high school teachers taught
primarily physical science, biology, chemistry, and physics, with some engineering and AP courses also represented. These teachers taught in Midwestern school districts ranging from large, high-need metropolitan environments to sparsely populated rural areas during their enrollment in the induction program.

Data Sources
This study draws upon three data sources, with each one addressing a specific research question related to teachers’ beliefs, practices, or the relationship between beliefs and practices. Data was collected from each of these data sources at regular intervals throughout the academic year roughly corresponding to the beginning (Oct/Nov/Dec), middle (Jan/Feb/Mar), and end (Apr/May) of the academic year. These data sources are described in detail below.

Beliefs About Reformed Science Teaching and Learning Questionnaire
Each of these teachers completed the BARSTL questionnaire, an instrument that is used to assess teachers’ beliefs about science teaching and learning (Sampson et al., 2013). The developers of the instrument demonstrated the construct validity of the 32 Likert-type BARSTL items and the content validity of the four instrument subscales (How People Learn About Science, Lesson Design and Implementation, Characteristics of Teachers and the Learning Environment, and The Nature of the Science Curriculum) via a panel of experts. The internal consistency and reliability of the instrument was demonstrated by split-half coefficient and coefficient alpha values of 0.77 and 0.80, respectively (Sampson, Enderle, & Grooms, 2013). This instrument was used to assess teachers’ beliefs about reformed instruction in support of RQ1.
Reformed Teaching Observation Protocol

After the teachers completed the BARSTL questionnaire, they were observed in their classrooms. The Reformed Teaching Observation Protocol (RTOP; Sawada et al. 2002) was used to collect direct evidence of reform-based practices in the teachers’ classrooms. The 25 Likert-type items on the RTOP are organized into five subscales: (a) Lesson Plan and Implementation, (b) Content: Procedural Knowledge, (c) Content: Propositional Knowledge, (d) Classroom Culture, and (e) Student/Teacher Relationships. The reliability of the instrument was demonstrated by computing Cronbach’s alpha for the instrument as a whole (\( \alpha = 0.97 \)) and for each of the five subscales (0.80 ≤ \( \alpha \) ≤ 0.93; Sawada et al. 2002). This instrument was used to assess the degree of reform-based instruction that was observed by the authors in support of RQ2.

Teacher Beliefs Interview

In addition to the self-reported and observational data described above, the first author conducted semistructured interviews using the Teacher Beliefs Interview (TBI) protocol (Luft & Roehrig, 2007), an instrument designed to elicit teacher beliefs about traditional and reform-based teaching. The instrument is composed of seven questions that elicit responses regarding teachers’ beliefs and practices related to reformed teaching. The developers established the reliability and validity of the instrument via an internal consistencies survey (with a Cronbach alpha coefficient of 0.70) and the comparison of multiple interview reviews and interview data, respectively (Luft & Roehrig, 2007). This instrument was used to explore the relationship between teachers’ beliefs and practices regarding reformed instruction in support of RQ3.
Data Analysis

**Research Question 1**

Each teacher’s responses to the 4-point Likert-type items on the BARSTL questionnaire were summed for each of the four subscales and for the questionnaire in total. This was done for teacher responses corresponding to the first observation (Oct/Nov/Dec), second observation (Jan/Feb/Mar), and third observation (Apr/May). The mean differences of both the BARSTL questionnaire subscales and the total BARSTL score across the three administrations of the survey were analyzed using the Friedman rank-sum test (Friedman, 1937), a nonparametric test used to detect distributional differences in a single treatment group over time.

**Research Question 2**

Similarly, the authors’ ratings for the 5-point Likert-type items on the RTOP were summed for each of the five subscales and for the instrument in total. This was done for data from the first observation (Oct/Nov/Dec), second observation (Jan/Feb/Mar), and third observation (Apr/May) of each teacher. The mean differences of both the RTOP questionnaire subscales and the total RTOP score across the three observations were also analyzed using the Friedman rank-sum test.

**Research Question 3**

Transcripts from the TBIs were openly coded by the first and third authors, both of whom are former K–12 science teachers. Simultaneously, the same transcripts were independently read by the second author (a former K–12 teacher who did not teach science), who generated research memos and conducted a preliminary thematic analysis (Miles & Huberman, 1994). Once the transcripts had been coded and memoed, the first and second authors met to compare the codes and memos. Areas of commonality between the codes and the memos were identified as emergent themes, and the codebook was updated to indicate which codes were most germane to these themes. Lastly, the first and second
authors reviewed all transcript text corresponding to this subset of codes in an effort to refine the emergent themes into those presented later in this manuscript.

It is important to note that the thematic analysis for RQ 3 is informed by the results of the BARSTL and RTOP analysis, which correspond to RQ 1 and 2, respectively. This is consistent with our explanatory sequential mixed-methods design (Creswell, 2014), where the qualitative data serve to illuminate and contextualize the relationship between teachers’ beliefs and practices regarding reformed teaching as indicated by the quantitative data from the BARSTL and RTOP.

Findings

The findings of this study will be presented separately by research question. These findings will be synthesized in the following sections.

RQ1: Beliefs About Reformed Teaching

Friedman rank-sum analysis of the 16 teachers’ BARSTL questionnaire responses from the beginning, middle, and end of the academic year revealed statistically significant differences in a number of BARSTL subscales during these teachers’ first year in our induction program. TABLE 1 illustrates the results of our Friedman rank-sum analysis.

In particular, statistically significant differences were observed for the Lesson Design and Implementation and The Nature of the Science Curriculum subscales. A post hoc Nemenyi multiple comparison test revealed that the greatest differences occurred between the middle (Jan/Feb/Mar) and final (Apr/May) questionnaires for both subscales ($p = .10$ and $p = .07$, respectively), and these differences were found to be statistically significant at the $\alpha = .10$ level. It is worth noting that questionnaire responses related to Lesson Design and Implementation
first decreased from Oct/Nov/Dec to Jan/Feb/Mar and then increased between Jan/Feb/Mar and Apr/May, while responses related to *The Nature of the Science Curriculum* exhibited the reverse trend, increasing from Oct/Nov/Dec to Jan/Feb/Mar and then decreasing between Jan/Feb/Mar and Apr/May.

### TABLE 1

**Friedman Rank-Sum Analysis of BARSTL Data**

<table>
<thead>
<tr>
<th>BARSTL Score</th>
<th>M_{Oct/Nov/Dec} (SD)</th>
<th>M_{Jan/Feb/Mar} (SD)</th>
<th>M_{Apr/May} (SD)</th>
<th>(\chi^2)</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>How People Learn About Science</td>
<td>21.88 (1.31)</td>
<td>21.88 (2.19)</td>
<td>22.19 (1.76)</td>
<td>0.44</td>
<td>2</td>
<td>0.80</td>
</tr>
<tr>
<td>Lesson Design and Implementation</td>
<td>21.19 (1.42)</td>
<td>20.75 (1.13)</td>
<td>21.62 (1.63)</td>
<td>6.95</td>
<td>2</td>
<td>0.03**</td>
</tr>
<tr>
<td>Characteristics of Teachers and the Learning Environment</td>
<td>21.06 (1.84)</td>
<td>21.19 (1.97)</td>
<td>21.44 (1.21)</td>
<td>0.13</td>
<td>2</td>
<td>0.94</td>
</tr>
<tr>
<td>The Nature of the Science Curriculum</td>
<td>21.75 (1.24)</td>
<td>22.06 (2.14)</td>
<td>21.19 (1.38)</td>
<td>7.57</td>
<td>2</td>
<td>0.02**</td>
</tr>
<tr>
<td>Total</td>
<td>85.88 (3.88)</td>
<td>85.88 (5.14)</td>
<td>86.44 (4.19)</td>
<td>0.14</td>
<td>2</td>
<td>0.93</td>
</tr>
</tbody>
</table>

*\(p < .10\),  **\(p < .05\),  ***\(p < .01\)

**RQ2: Reformed Teaching Practices**

Friedman rank-sum analysis of the 16 teachers’ total RTOP scores from the beginning, middle, and end of the year revealed no statistically significant differences during these teachers’ first year in our induction program. **TABLE 2** illustrates the results of the Friedman rank-sum analysis.
TABLE 2

Friedman Rank-Sum Analysis of RTOP Data

<table>
<thead>
<tr>
<th>RTOP Score</th>
<th>$M_{\text{Oct/Nov/Dec}}$ (SD)</th>
<th>$M_{\text{Jan/Feb/Mar}}$ (SD)</th>
<th>$M_{\text{Apr/May}}$ (SD)</th>
<th>$\chi^2$</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson Plan and Implementation</td>
<td>9.44 (3.85)</td>
<td>8.44 (4.66)</td>
<td>10.50 (4.53)</td>
<td>1.54</td>
<td>2</td>
<td>0.46</td>
</tr>
<tr>
<td>Content: Procedural Knowledge</td>
<td>11.75 (2.82)</td>
<td>11.06 (3.51)</td>
<td>11.44 (3.27)</td>
<td>1.20</td>
<td>2</td>
<td>0.59</td>
</tr>
<tr>
<td>Content: Propositional Knowledge</td>
<td>8.06 (3.99)</td>
<td>7.88 (5.02)</td>
<td>7.88 (4.60)</td>
<td>0.03</td>
<td>2</td>
<td>0.98</td>
</tr>
<tr>
<td>Classroom Culture</td>
<td>9.12 (3.70)</td>
<td>9.06 (4.64)</td>
<td>10.62 (3.83)</td>
<td>0.97</td>
<td>2</td>
<td>0.62</td>
</tr>
<tr>
<td>Student/Teacher Relationships</td>
<td>10.88 (3.48)</td>
<td>12.12 (4.26)</td>
<td>13.31 (3.05)</td>
<td>4.27</td>
<td>2</td>
<td>0.12</td>
</tr>
<tr>
<td>Total</td>
<td>49.25 (15.02)</td>
<td>48.56 (20.53)</td>
<td>53.75 (16.49)</td>
<td>1.39</td>
<td>2</td>
<td>0.50</td>
</tr>
</tbody>
</table>

* $p < .10$, ** $p < .05$, *** $p < .01$

Although this analysis revealed no statistically significant differences in mean scores for any of the five RTOP subscales, it is notable that mean scores on the Student/Teacher Relationships subscale steadily increased with each observation over the academic year. This subscale includes statements that describe student/teacher relationships as “more egalitarian with teachers supporting initiatives that are coming from the students” (Sawada et al., 2002, p. 246). No other subscale exhibited this positive linear trend, with most subscales exhibiting a “U” shape instead, decreasing from Oct/Nov/Dec to Jan/Feb/Mar and then increasing again between Jan/Feb/Mar and Apr/May.

RQ3: The Relationship Between Beliefs and Practices Regarding Reformed Teaching

Our thematic analysis of the TBI transcripts was informed by the broad categories of Lesson Design and Implementation, The Nature of the
Science Curriculum and Student/Teacher Relationships, as our analysis of the BARSTL and RTOP data indicated that our teachers exhibited the greatest changes in their beliefs and practices in these areas. The themes presented below serve to illustrate (and possibly explain) the trends in teacher beliefs and practice that we observed in our quantitative data. All names listed below are pseudonyms.

**Making Learning Meaningful**

Across a number of TBI interview questions, our teachers shared their views on what makes learning meaningful in a science classroom and what steps the teacher can take in order to create conditions for meaningful learning. Codes related to this theme include hands-on/kinesthetic, student engagement, and learning is relevant to students. Across these interviews, we observed a distinct evolution in how our teachers described what meaningful learning is and what role students play in planning for such learning.

In her first interview, Farah expressed a belief in “varying up the structure of your classroom so [you] reach different styles of learners” through hands-on and interactive activities. This approach to learning was supported in the teachers’ preservice licensure program, and Farah remained consistent in her desire for “hands-on stuff” and “creating different ways for student learning” throughout the year. For example, in her second interview, she expressed anxiety over keeping students “engaged.” Although she explained that she gave “very traditional assessments right now,” such as “Friday quizzes,” she also expressed that she is “really into student centered learning.” Although she enacted traditional practices in her classroom, this suggests a move toward more reformed beliefs. She reflected these reformed beliefs in her third interview when she stated that students “need to be doing something and thinking about the information themselves” and “relating it back to something in the real world.” Like many of her peers, Farah spoke at length about the importance of understanding student interests and using those interests in planning for learning.
In his first interview, Henry expressed a view of students as “kinesthetic learners” that was shared by a number of teachers. Although a “learning styles” approach to teaching was not advanced in these teachers’ preservice licensure program, teachers like Henry invoked these ideas in their first interviews when describing how to make learning meaningful for their students. In his second interview, Henry discussed a focus on learning activities that students would find engaging or interesting: He wanted to keep students “engaged” and “hanging on to every word.” By the second interview, Henry and others began to articulate what “hands-on” learning could look like beyond “not lecturing.” However, while we viewed the teachers’ focus on student engagement as generally positive, we could not determine how student engagement and student learning were connected, as students could be engaged in an activity while learning little about science. By the final interview, Henry discussed the importance of considering real-world applications when planning for learning. Henry explained his desire to teach concepts that his students “can use for the rest of their lives” (Interview 3).

While teachers like Farah and Henry slowly developed their perspectives on how to make learning meaningful for their students, Kevin developed his perspectives more quickly than his peers. In his first interview, he stated he wanted “students to experience everything that they’re learning” while also reiterating the desire for “a really hands-on classroom”—a view that was similar to those of his peers (like Farah and Henry). However, in his second interview, Kevin began attending to students as individuals, stating that he wanted to “understand who they are and get an idea of things that they might enjoy.” He expressed a desire to focus on things “that have a real-life impact” for students, demonstrating a shift toward leveraging content that is relevant to students’ lives when planning for learning. Many of his peers expressed similar perspectives by the end of the year, but Kevin was unique in arriving at this view as early as the second interview. Kevin continued to express these sentiments in his final interview and further solidified his reformed beliefs that, when planning for learning, “it varies almost student to student.” Overall, these final
interviews demonstrated a shift toward focusing on information that is relevant to students’ lives when planning for learning.

**Exercising Agency in Planning**

We learned through the TBIs that many of our teachers did not exercise a high degree of agency in designing the curriculum that they were teaching in their classrooms. Some of the codes related to this theme were consulting/imitating, freedom with restrictions, and prioritizing what is important. These codes primarily surfaced in teacher responses to the question, “In the school setting, how do you decide what to teach and what not to teach?” From her very first interview, Whitney described an environment in which her classroom learning experiences were predetermined by district mandates and standardized testing. “They have a set curriculum,” she explained, suggesting little opportunity to exercise agency in planning her curriculum. As the year progressed, she began to identify areas where she could demonstrate some agency within this rigid environment. For example, although her senior colleague “has it all mapped out” when it comes to the curriculum unit and lessons, she felt that she was able to “change it up a little bit” when she implemented these lessons in her classroom. By her third interview, Whitney grew even more confident in her ability to exercise agency in her classroom planning. Although her materials were still “dictated by the district” or provided to her by a senior colleague, she affirmed that “how I cover them is up to me” and that she would “change an assignment there that better fits for me.”

Like Whitney, Wanda explained throughout her interviews that she used material “from the other physics teacher” when planning for learning, repeating a version of this phrase in each interview. For our novice teachers, the decision to adopt another teacher’s approach (in whole or in part) may be due to convenience, district requirements, and/or their insecurity with crafting lessons. Yet, despite leaning on colleagues for course material and planning, Wanda demonstrated a strong arc over the course of the year toward exercising greater agency over her planning. By the second interview, she noted that if “I really want to talk about
this certain aspect, I will just add it in to my own class,” whether or not the other physics teacher chose to do the same. In her final interview, she affirmed confidence in her ability to exercise agency in planning, stating, “I do decide what I want to focus on a little bit more” than she had earlier in the year.

Like his peers, Kevin consistently described an environment in which he was “tied” and “limited” by district testing requirements. In his first interview, he shared that this rigidity made him feel that he was “not prepared to come up with all of my own stuff.” Yet, by his second interview, Kevin expressed increased confidence in his ability to exercise agency within this framework, explaining, “I’m tied in terms of covering all the topics for that test, but when it comes down to what I do to talk about those individual topics, I have a lot of freedom to choose what I want to talk about.” He reiterated this “freedom in terms of deciding what I want to talk about” in his third interview, demonstrating a sense of autonomy in aspects of his lessons that other teachers exhibited by the end of the year as well. In summary, these teachers eventually discovered ways to exercise greater agency when planning for learning, even in districts with rigid content or testing requirements. This realization opens up the possibility for them to bring their future teaching practices into greater alignment with their reformed beliefs about teaching—something that many of them did not deem possible at the beginning of the academic year.
How Early-Career Science Teachers Negotiate Their Beliefs and Practices During an Online Induction Program

Listening to Student Conversations

When our teachers responded to the TBI question “How do you know when learning is occurring in your classroom?” many of them placed a strong emphasis on the importance of conversations with and among students in evaluating student understanding. Some of the codes related to this theme were listening to students, understanding students’ knowledge, and formative assessment.

In his first interview, Henry espoused somewhat traditional views on how to gauge student learning, stating, “I judge on where I feel they are at or what they have learned based on how well they answer my questions.” Although we interpreted this strategy as being more traditional than reformed, Henry did provide evidence to suggest his interest in engaging students in conversations about their learning: “At some point, I know that most of them [get] it just through discussion. I can openly ask them.” In his second interview, Henry revealed that he knows students are learning about a given topic “if they can have an engaging discussion about it and start to use some terms.” This suggests that Henry valued students’ ability to participate in discussions that include scientific language. While it is unclear if these “engaging” discussions are more student-centered than a sequence of questions and answers, he adhered to his belief in his final interview as well, saying that when “they . . . engage in discussion a little bit better afterwards, I feel that’s when they learn.”

During his interviews, Randall emphasized not only the value that he placed on listening in to student conversations, but why this information was valuable to him as a teacher. In his first interview, he suggested that “the active exchange of ideas” represented “active learning taking place. . . . A student having an 'A' in my class doesn’t tell me very much.” In his second interview, Randall described how he would listen for evidence of “kids reflecting on what they’re doing and not just doing something for the sake of doing it.” As he progressed through the academic year, Randall became increasingly adamant about the importance of student metacognition. By the third interview, Randall claimed, “Seeing students
really get it is when they actually evaluate what they’ve done and when they take a step back and have some metacognitive opportunities . . . without me giving some sort of test or something.” For Randall, student conversations served as a window into their metacognition, and listening to these conversations was essential to gain an understanding of when learning was occurring in his classroom.

In his first interview, Kevin demonstrated his belief that “listening to students’ conversations” and to “the language that students use” gave him indicators of learning taking place. In fact, he seemed to grow more confident in these beliefs as the year progressed, stating, for example, that “listening to conversations, what students are talking about with each other—that’s the biggest thing” in his second interview. Kevin also suggested that students’ behavior, including their “facial expressions” or their engagement in their work, were indicators of whether learning was taking place. In his final interview, he again referenced “listening in on conversation” multiple times and shared how this allowed him to overhear a student’s lightbulb moment, when “all of a sudden they get the answer and they’re like, ‘Hah, I got it.’” Taken together, these responses suggest that Kevin values student conversation, expression, and engagement as formative assessments.

Liu began the year with traditional views of student learning, noting in her first interview that she used quizzes “every Friday” and “formatives” to assess learning. However, she also mentioned student “attitude” as an indicator of understanding, a belief that she elaborated upon in her second interview: “If they’re feeling really happy to understand it and they’re telling another student what the answer is and they’re able to articulate and explain their thinking . . . I think that’s one really good sign.” This suggests a progression away from more traditional views of learning toward ones that attend to students’ attitudes and language. Liu continues this progression in her third interview when she refers to “asking questions,” being “able to sit there and explain to another student” and “using the words” of the discipline as indicators of learning
and understanding. Overall, Liu’s responses suggest her beliefs about indicators of student learning became more reformed throughout the school year. To summarize, even teachers who initially held traditional views of assessing students’ learning began to adopt new approaches that valued student conversations and nonverbal communication.

Discussion and Synthesis

In this section, we provide a synthesis of the quantitative and qualitative findings that comprise this study and summarize the key ideas and implications generated by this work. After reviewing the teachers’ questionnaire responses, classroom observations, and interview transcripts, we begin to see a picture of how our early-career teachers negotiate their beliefs about science teaching and learning within the constraints of the classroom. The BARSTL and RTOP data suggest that our teachers’ beliefs and practices (respectively) occupy a somewhat narrow range from traditional and teacher-centered to inquiry-driven and student-centered. This range in both beliefs and practices is similar to what Simmons et al. (1999) observed with their early-career science and mathematics teachers, but the relationship between our teachers’ beliefs and practices is best understood through teacher responses to the TBI. While teachers may not have consistently engaged in reform-based teaching practices that were commensurate with their reformed beliefs, the interview transcripts reveal how they tried to negotiate between the reformed theories presented in their preservice licensure program and the realities of the classroom.

Our understanding of this nuanced process of negotiation (particularly during the preservice to in-service transition) builds upon prior research in science teacher education and teacher education in general. Ryan (1986) described the transition from preservice teacher to in-service teacher as a fantasy stage followed by a survival stage, where the
aspirational optimism experienced in preservice courses and student teaching gives way to the pressures associated with the first year of teaching and the professional and personal doubts that result from those pressures (e.g., Moir, 1990; Picower, 2007; French, 2020). Indeed, our teachers experienced challenges in their first year of teaching that they did not anticipate (for example, the lack of agency they were afforded in planning for instruction) and exhibited the “wobbling” beliefs related to teaching and learning that Simmons et al. (1999) observed among their first-year teachers. In the following sections, we describe the areas of success and areas of challenge evidenced by our findings.

One of the more positive findings from the observation and interview data is our teachers’ increasing attention to building relationships with their students through conversations. Listening to students and engaging them in conversation served at least two purposes for our teachers: It allowed them to formatively assess student understanding in ways that a worksheet or quiz could not, and it opened up the opportunity for them to understand student interests and incorporate those interests when planning for learning. The greatest evidence of these practices occurred only toward the end of the academic year, suggesting that many of these teachers were slow to adopt them. However, the time it took for our teachers to enact these practices in their classrooms was significantly shorter than the 2 to 3 years that Simmons et al. (1999) observed among their beginning teachers. Our findings therefore support the claims of Luft et al. (2011) that beginning teachers who receive support through an online, science-specific induction program are more likely to engage their students in more interactive activities. For induction leaders, this underscores the importance of supporting their teachers in building these relationships with students and leveraging student conversations at the very beginning of the teachers’ participation in the induction program; this could create the opportunity for teachers to enact these practices even earlier in their first year instead of only toward the end.
Perhaps unsurprisingly, a number of our teachers named external constraints as the primary impediments to enacting more reformed lessons in their classroom, particularly when it came to planning the curriculum. To be sure, initiatives like districtwide pacing guides and high-stakes state testing impose notable constraints on how a teacher plans curriculum and delivers instruction. Thankfully, by the end of the academic year, even our teachers who operated in such districts found ways to exercise a modicum of agency over their lessons, and those who originally imitated or duplicated the approach of a more senior colleague began planning more independently. Wang et al. (2008) noted the importance of the teachers’ school context in any induction experience, and this observation was certainly supported in our findings. While an induction leader could encourage their teachers to exercise as much agency as possible, this may not be practicable in all cases, as there may in fact be an upper limit on how much freedom the teacher has in bringing more reformed instructional experiences to their classroom. A more measured approach may be found in understanding what the “decision-making units” are at the teachers’ school (for example, a professional learning community or a science department) and then exploring how the induction program could complement (or even augment) the way that the teacher engages in instructional decision-making within that unit. This is in line with the suggestions of Wang et al. (2008) to consider the situated context of induction mentorship and the various interactions that can take place among the teacher, their mentor(s) and their school context(s).

Limitations
This study had a small number of limitations. The first is that our beginning teachers were compensated for their participation in the induction program. It is possible that teachers who volunteer to participate in an induction program and receive compensation for their participation may be more motivated to reflect on their teaching practice and effect change in their classrooms than are teachers who do not volunteer or receive compensation. A second limitation is that all of our participants
in the induction program matriculated from the same teacher licensure program. Although we perceive this as a strength of our induction design, not all induction program leaders may be able to rely on their participants sharing common preservice experiences as our teachers did.

Conclusions

While our findings concur with Windschitl (2003) and others suggesting that beginning science teachers are capable of reformed beliefs, a growing number of studies have demonstrated that the beliefs and practices of science teachers do not necessarily move in tandem (Jones & Leagon, 2014). For our first-year science teachers participating in the induction program, their beliefs about the challenges of lesson design and implementation, the nature of the science curriculum, and developing relationships with their students shifted as they navigated the complexities of the classroom. This allowed the teachers to develop their capacities for making learning meaningful, exercising agency in planning and listening to student conversations, all within their very first year of teaching. Our science teachers will likely continue to negotiate the relationship between their beliefs and practice as they progress through the induction program and become more experienced teachers. This places a renewed emphasis on the work that we as induction designers do to design and redesign experiences that will enable our beginning science teachers to survive and thrive during their first years of classroom teaching. It is our sincere hope that other science teacher educators and researchers will continue to explore ways to support their science teachers’ developing beliefs and practices as they embark on their first years in the classroom.
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References


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CHAPTER 8

Viewing STEM Teacher Leadership Through a Communities-of-Practice Lens
These communities became more than the sum of their parts, providing Master Teaching Fellows (MTFs) with a supportive foundation from which to take risks and engage in new leadership activities. When Noyce projects provided opportunities for MTFs to lead outside their classrooms—often framing it as a responsibility in this space—this intentionally positioned MTFs as leaders who crossed the typical boundaries that keep teachers in school-centered bubbles that do not interact outside those bubbles.
ABSTRACT

In this chapter, we share findings from the collaborative Noyce teacher leadership project, and how communities of practice can provide a lens to view the development and support of teacher leadership activities and identities. With eight Track 3 Noyce projects collaborating to collect and analyze data related to Master Teaching Fellows’ (MTFs) teacher leadership trajectories and influences, we share findings from a variety of contexts. The research reported here centers on the following questions: 1) What are the key features of the Noyce communities of practice, and how do they impact the professional identities of the MTFs? and 2) What are the boundary objects and what are the natures of the border crossings that affect the transfer of meanings and practices between the MTFs’ Noyce and school external communities of practice (CoPs)? This chapter provides a series of vignettes to explore these questions in the context of different Noyce Track 3 MTF projects. The communities of practice allowed MTFs to grow together into professional identities as teacher leaders, and then to use the external Noyce communities of practice to in turn develop and strengthen their internal school communities of practice. This type of boundary crossing, bringing information from one community to another (including bridging research-practice gaps), became a central feature of the work of the MTFs. The chapter concludes with recommendations to various stakeholders for how they can best develop and support teacher leaders.
Introduction

Teacher leadership has the potential to value teachers and offer them more agency (Allen, 2018), increase professional satisfaction and teacher retention (Dauksas & White, 2010), and support educational change and improve the academic achievement of K–12 students (Margolis & Huggins, 2012), making it a worthwhile area of focus in educational research.

Nonetheless, significant gaps have been identified in the field’s understanding of teacher leadership. Two well-known reviews of that research—York-Barr and Duke (2004) and Wenner and Campbell (2018)—both noted the lack of a consensus definition of teacher leadership and no widely adopted theoretical frameworks in this area.

Part of the challenge of defining or theorizing about teacher leadership is that it encompasses such a broad array of contexts and activities. As such, any definition or framework would either be so general as to have limited utility or fail to capture key aspects of teacher leadership—or both. As an example, consider the definition of teacher leader proposed by Wenner and Campbell (2018): “Teachers who maintain K–12 classroom-based teaching responsibilities, while also taking on leadership responsibilities outside of the classroom” (p. 7). This definition is fairly general, taking precautions not to say anything too specific about what teachers might do that would merit them being labeled as leaders. Nonetheless, it does not include a form of teacher leadership we observed in one of the following programs where teachers spend 1 to 3 years in a full-time leadership role before returning to the classroom. Our definition that obviates this issue is that a teacher leader has an identity as a teacher and as a leader; is seen as such by others in their school community;

Viewing STEM Teacher Leadership Through a Communities-of-Practice Lens
and uses their knowledge of effective practice, and of the educational system, to not only empower others but also bring about improvements that lead to better teaching and learning.

Smylie and Eckert (2018) and Campbell et al. (2019) have put forth frameworks to model certain features of teacher leadership. They are complementary in that Smylie and Eckert’s framework describes organizational structures associated with teacher leader development, and Campbell et al.’s framework illuminates how teacher leaders engage in their work in relation to social structures. While valuable contributions to the field, these frameworks only describe aspects of teacher leadership internal to the school system. Our research involves a multi-site study of eight Noyce Track 3 programs that developed and supported MTFs as teacher leaders. A crucial concern of our work is that all eight programs function as external training grounds for teacher leaders. Put another way, all eight programs serve as external communities of practice (CoPs)—external to the MTFs’ school CoPs. This distinction allows us to explore the following issues: (1) What are the key features of the Noyce CoPs, and how do they impact the professional identities of the MTFs? and (2) What are the boundary objects and what are the natures of the border crossings that affect the transfer of meanings and practices between the MTFs’ Noyce and school CoPs? In answering these questions, we will provide clear recommendations to various stakeholders for how they can best develop and support teacher leaders so as to achieve the potential outcomes outlined in the opening sentence.
Background

Teacher Leadership: Investigating the Persistence and Trajectories of Noyce Master Teaching Fellows (hereafter, simply T-Lead) is a Track 4 collaborative research project that began its work in the summer of 2018. Its goal is to examine the influences of teacher leadership development and support on the persistence and professional trajectories of MTFs in eight Noyce programs across the country. These programs, which run 5 to 7 years, all focused on teachers within STEM areas (mathematics, science, mathematics and science, or integrated STEM) and engaged between 14 and 33 MTFs. The programs served a mixture of rural and urban areas and often drew their participating teachers (the MTFs) from multiple school districts. Depending on when the program started, teachers may have been required to have a master’s degree in either education or a STEM discipline in order to participate. Older programs—including programs that had been completed by the time of the initial T-Lead data collection—were required by the funding agency to select teachers with a master’s degree.

For the T-Lead project, 3 years of data collection have occurred. In year 1 we collected data about the program itself (including proposal and report documents, and principal investigator interviews) and data from the MTFs (including initial interviews and both a leadership and social network analysis (SNA) survey). In year 2 we focused on individual case studies, selecting MTFs who represented different professional trajectories (e.g., staying in teaching or leaving the profession). The selected MTFs were interviewed, along with four or five colleagues and administrators with whom they worked. In year 3 we repeated the MTF data collection (interviews and surveys) conducted in year 1 to gain a longitudinal sense of all the MTFs’ experiences, with some modifications to the protocols. For this chapter, we draw upon the interview data collected in years 1 and 2 and present a set of case studies of each MTF project, with the
experiences of one or two MTFs highlighted as exemplars within each project to tell the story of each project’s impacts.

The interview data for the MTFs across the eight sites were analyzed by T-Lead research teams using a codebook created by the T-Lead PIs. The codebook had six domains (e.g., PROFESSIONAL IDENTITY) and 15 codes (e.g., Becoming under PROFESSIONAL IDENTITY). Coding teams worked to obtain inter-rater reliability values of 80% or better before members coded independently, but still often discussed codes until reaching consensus. Teams then transferred critical insights from the coded data into interview summary tables (one for each program site), where they could archive quotes and descriptions related to the T-Lead research questions so as to distill the data down. For year 2, a similar coding and analysis process was undertaken. The codebook was modified to match the new interview protocols utilized in year 2 and the summary table allowed members to present key data for the MTF and their particular colleagues and administrators collectively. The insights from the interview data that we present below were largely drawn from the years 1–2 summary tables.

For the SNA data, we used a network survey that was modified from Polizzi et al. (2019) and Polizzi et al. (2021). MTFs self-reported on contacts in their teaching network (related to teaching and leadership), whether contacts were in the same school/district/state/nation, how frequently and in what direction interactions occurred, and whether contacts interacted with each other. This information about primary and secondary ties allowed the calculation of multiple network characteristics that could be compared across programs. Characteristics included brokerage roles, or whether MTFs bridged contacts who would not otherwise be connected inside, outside, or spanning their local school. The process was repeated separately for contacts in their leadership networks (related to school improvement). See Polizzi et al. (2021) for network variable descriptions and examples.
Relevant Literature

York-Barr and Duke’s (2004) concern about the lack of teacher leadership frameworks has been addressed in recent years by efforts to describe teacher leadership in the form of competencies, standards, and frameworks. An example of a document in this arena created by a national organization is the Teacher Leader Skills Framework (Center for Strengthening the Teaching Profession, 2021), which characterizes the knowledge and skills, dispositions, and roles and opportunities representative of teacher leadership (all viewed through an equity lens). State-level teacher leadership documents also exist, such as those in Kentucky (Kentucky Department of Education, 2021) and Ohio (Ohio Department of Education, 2021).

While varying in their perspectives on teacher leadership, all the aforementioned documents are connected by their practitioner viewpoint. Berg and Zoellick (2019) effectively bridged the research-practice gap by collecting data from 70 researchers and practitioners to develop a concept web of teacher leader descriptors, which suggested four critical domains that could be used to define teacher leadership: legitimacy, support, objective, and method. This web included critical aspects of teacher leadership that are not necessarily found in the national and state documents, such as the notion of spheres of influence and the inclusion of identity.

Criswell et al. (2018) considered some of those same aspects in creating their conceptual framework for teacher leadership. This model incorporated the notion of spheres of influence in essence by identifying four metaphors that represented different possible instantiations of teacher leadership: effective practitioner, learning partner, productive scholar, and policy voice. Further, these authors suggested four interrelated components that can support individuals in functioning as teacher leaders: professional identity, professional vision, adaptive
expertise, and system sensitivity. Their model is designed to link the actions of teacher leaders with the capacities that must be developed to best execute those actions.

Both Berg and Zoellick’s (2019) and Criswell et al.’s (2018) frameworks emphasized theoretical constructs critical to the nature of teacher leadership; neither gave attention to the organizational or social aspects of this area. Given that teacher leadership is embedded in educational organizations and that it involves social interactions with colleagues, administrators, etc., it is important to consider frameworks that highlight these concerns. One such framework is that of Smylie and Eckert (2018), who offered “a conceptual-theoretical model to guide the practice of teacher leadership development” (p. 556). Their model has eight components: five focused on organizational features associated with leadership development (Principal Development, Principal Support for Teacher Leadership Development, Initial Capacity for Teacher Leadership, Leadership Work Design, and Development Activities and Experiences), and three centered on what these features produce (Teacher Leader Capacity, Teacher Leadership Practice, and Teacher Leadership Outcomes).

Campbell et al.’s (2018) Community-of-Practice (CoP) framework minimizes the structural features influencing teacher leadership to foreground social and practice-based features. Borrowing from Carlone and Johnson’s (2007) tripartite model of identity formation, Campbell et al. described practice in terms of competence, performance, and recognition. They proceeded to identify the key competencies and performances demonstrated by teacher leaders in their study, thus connecting their framework to some of the national and state frameworks. Where they went beyond those frameworks is in describing three CoPs internal to school systems—teacher, teacher leader, and school leader—that intersect to impact the teacher leaders’ views of competence, performance, and recognition; these intersections, in turn, influence the teachers’ identity formation.
The social-organizational foci of Smylie and Eckert’s (2019) and Campbell et al.’s (2018) frameworks are important contributions to our understanding of teacher leadership. However, both emphasize features internal to the school systems, while efforts like the Noyce Master Teaching Fellow program (National Science Foundation, 2021) involve the development of teacher leaders by organizations that are external to school systems. This sets up a social-organizational dynamic in which the teacher-leader development CoP can function independent of the school CoPs. There are some potentially valuable affordances to this, such as giving the teachers a different perspective on the meanings and practices that are shared across the school and external-group CoPs. There are also some potentially formidable constraints from this, such as there being significant resistance by school CoPs to the transfer of meanings and practices from the external-group CoPs. The nature of these interactions between school CoPs and external-group CoPs has yet to be given substantive attention in the teacher leadership literature, and this chapter attempts to address that gap.

When the teacher-leader development CoPs operate independently of the school CoPs, this creates the conditions for both the work of boundary crossings (Wenger-Trayner & Wenger-Trayner, 2015) and the formation of boundary objects (Star & Griesemer, 1989; Wenger, 1998). As Akkerman and Baker (2011) describe it, boundary crossings usually represent “a person’s transitions and interactions across different sites” (p. 133, citing Suchman, 1994). Applied to CoPs, this would involve social and cultural movement across the boundaries of practices, meanings, and identities generated by the ways different CoPs function. This often occurs when individuals operate as participants in multiple intersecting CoPs. Wenger (1998) defined boundary objects as “artifacts, documents, terms, concepts, and other forms of reification around which CoPs can organize their interconnections” (p. 105). Thus, these boundary objects can link together CoPs if participants within the CoPs can recognize their potential to do so. Star (2010) makes an important point that a boundary object is material not in the sense of being a concrete entity, but in the
sense of being a focal point of human activity: “Its materiality derives from action, not from a sense of prefabricated stuff or ‘thing’-ness” (p. 603).

Before moving to what we have learned related to the two questions asked in the Introduction, we do want to discuss a significant sub-component of exploring those questions from a CoP viewpoint: A critical way in which participants in a CoP are affected by their participation is through the CoP’s influence on their identity (Wenger, 1998). For the purposes of this chapter, we will focus on MTFs’ professional identity—one’s sense of oneself, in conjunction with how others see oneself, related to one’s role in a field of work (Ewan, 1988; Paterson et al., 2002). As Collay (2016) notes, “Teachers must recognize the conditions that influence professional identity as they transit leadership roles and be proactive in managing those conditions” (p. 141). Hanuscin et al. (2011) determined that teachers had their strongest sense of a teacher leader identity when they engaged in practices related to preservice teacher education and school or district curriculum work (p. 6). Later, Sinha and Hanuscin (2017) used case studies to show that teachers developed their most robust leadership identity when there was overlap and synergy between their leadership views, leadership practices, and identity. The insights from studies like these would be extended by recognizing identity as embedded in the CoP activities of teacher leaders and considering the impact of an external-group CoP on identity.

The following sections provide vignettes to illustrate how CoPs impact teacher leadership as well as teacher leader identities and professional networks; all program and teacher names are pseudonyms. Each vignette provides the context of the particular Noyce program, the features of that program’s CoP identified as critical to its functioning, and the significance of these features in the MTFs’ teacher leadership development.
TL-PACT: Developing Identity and Shaping Networks

Context
The Teacher Leadership for Physics and Chemistry Teachers (TL-PACT) program operated out of a large Southeastern university from 2010 to 2017. The program focused on recruiting chemistry and physics teachers—16 across two cohorts—who showed leadership potential but had not necessarily functioned or been seen as teacher leaders; i.e., TL-PACT was geared toward developing teacher leaders. MTFs in the program were taken through a teacher leadership endorsement in their first 2 years, then assisted in internalizing their teacher leader identity through activities in the remaining 5 years, such as through designing and hosting a local conference to share best teaching practices and forming their own professional learning communities to address a broader educational issue. We present a case study of John, a member of the first TL-PACT cohort, because it illustrates several key aspects of this program that influenced the MTFs' teacher leader identity formation and networking efforts.

Features
When John, a physics teacher with a biology degree and 7 years of teaching experience, joined the Noyce program, he was “sick” of what he was doing as a classroom teacher and “wanted to throw it away and start over.” Limited content knowledge, few opportunities for advancement, and unsatisfying relationships with colleagues led to frustration. One of his “biggest challenges . . . was not knowing enough,” because he “didn’t have a ton of physics background,” John said. For financial reasons, John contemplated advancing through the administrative route, but was not “really excited about going to be an assistant principal”—the only pathway to advancement he could identify. Another challenge for
him was isolation in the school. He said, “I’m a physics teacher in high school and nobody knows what I’m doing.” Engaging in TL-PACT experiences gave John a sense of belonging that allowed him to imagine himself as a teacher leader and align his perspectives of leadership with those of his peers. John actively participated in Noyce experiences: the leadership certification courses, science pedagogy sessions, peer mentoring, collaborative conference presentations, and professional learning communities. Role models (program facilitators, the leadership certification trainer and several nationally recognized teacher leaders) who participated in the Noyce experiences were critical components of the program. They served as experts and provided the MTFs with inspiration and feedback while modeling the actions of teacher leaders. The exchanges with the nationally recognized teacher leaders particularly resonated with John: “The speakers came in, and to hear their story and how they were promoting science through their job was awesome.” This statement describes the inspiration that these role models provided John. However, their stories, particularly the descriptions of how they developed into teacher leaders, had a deeper impact: they allowed him to envision what it could look like for him to develop into a teacher leader. Markus and Nurius (1986) described this envisioning as identifying possible selves, which represent “the ideal selves that we would very much like to become. They are also the selves we could become, and the selves we are afraid of becoming” (p. 954).

In relation to the issue of isolation, the TL-PACT CoP provided mechanisms for John to augment his professional network. As he noted, his network expanded to “probably 10 times what it was before” by connecting with content and pedagogy experts on social media. He said, “I follow this person on Twitter, because I met the guy. [Knowing these people] opened a lot of doors for us.” This expansion supported John in overcoming some of that sense of isolation that had existed before his participation in TL-PACT. Through explicit attention to the way the MTFs developed their
networks (described as follows), John was able to build a collaborative and generative community around him.

In his school, John enacted teacher leadership by becoming a member of the teacher advisory board, which allowed him to become an advocate for his colleagues. He also revamped the district’s curriculum and conducted physics training for teachers inside and outside the district. John’s actions as a teacher leader reflected the activities of the role models who spoke about working with teachers. Over time, John stopped looking to external role models and identified role models within his TL-PACT peers. He described this in response to a question in year 2 about how he was navigating the challenges posed by the COVID-19 pandemic: “I can ask myself, ‘How would Mark [a TL-PACT peer] handle that?’"

Toward the end of and after the program, John’s images for possible selves as a teacher leader were being formed from his peers in the program. Thus, John’s TL-PACT network had maximized his self-efficacy by creating visions of selves that could address the challenges with which he and his fellow teachers were confronted. Through the TL-PACT program, John and his peers internalized these visions as part of their evolving teacher leader identity. This transformation began with experts as the role models, but as the MTFs advanced their pedagogical content, and leadership knowledge and skills, they became one another’s role models.

During the TL-PACT project, MTFs completed an online network survey in advance of a professional learning activity. During the activity, the MTFs were shown the networks generated from the survey, discussed the affordances and constraints of different network structures, and described the educational contexts in which MTFs found different networks were applicable. MTFs contemplated visually closed, dense networks with many ties between contacts, and how that could lead to collaborative, affirming, and even redundant environments in education. MTFs also contemplated visually open, less-dense networks with fewer ties between contacts, and how that could lead to new perspectives, control of information, and power of individuals. Discussions of how the
networks related to education settings were not focused on the MTFs’ classrooms, but moved to teacher leadership topics including recruiting and staffing, working in interdisciplinary groups, spearheading school initiatives, and participating in professional organizations. MTFs voiced value in both open and closed network structures, and their network maps reflected local dense areas as well as more open areas that included contacts outside their schools in other states and regions. MTFs were encouraged to examine and reflect on their network maps and consider how to continue to build their networks to achieve leadership goals. John was, in general, more interested in increasing contacts outside of his school, as he had a sense that it was more important for him to impact the system at a broader level.

Significance
There are three critical aspects of this vignette to highlight. First is the role model’s influence in developing John’s initial identity as a teacher leader, his possible self. The possible self reflects the identity of who we “want to become” (Markus & Nurius, 1986, p. 954). An important element of how this happened was having nationally recognized teacher leaders tell their stories—and the MTFs seeing features of those stories that were similar to their own experiences. Through this mechanism, TL-PACT assisted John in developing a vision of himself as a teacher leader. Second, as John faced challenges in his school, he used his TL-PACT peers as role models to inform his enactment of a provisional self (Ibarra, 1999), supporting the continued growth of his leadership identity. Ibarra explains such provisional selves as “temporary solutions people use to bridge the gap between their current capacities and self-conceptions and the representations they hold about what attitudes and behaviors are expected in the new role” (p. 765). Third, the explicit discussion of the MTFs’ social networks as they existed, and the comparison of the network features to their envisioned leadership goals, guided future efforts in building their networks. This process allowed the MTFs to take their images of their possible selves and determine the best pathway to
actualize those images as they experimented with provisional selves. In John’s case, he could see how to further develop his network in a way that supported his goal of impacting the broader educational system. This also allowed John to more meaningfully engage in boundary crossings across diverse CoPs (like K–12 and higher education communities, both of which were represented in his networks).

UP Program: Leadership Development Through NGSS-Aligned Teaching and Action Research

Context
The Noyce program at an Upper Midwest University (hereafter referred to as UP program) attracted 20 STEM teachers (19 middle school and one high school). All teach science and/or integrated STEM courses. The goal of the project was to develop teacher leaders who could be an impetus for reform across the region. Of the 20 participants, 12 already had a master’s degree in education (cohort 1) and immediately started to develop leadership skills and capacity through coursework, participation in professional learning communities (PLCs) and other leadership-building activities. The remaining eight did not have a master’s degree in education (cohort 2) and spent the first 2 1/2 years of the program completing required coursework and a thesis to earn a master’s degree in education before focusing on leadership development and being integrated into activities with cohort 1. Primary goals of the project were to strengthen participants’ pedagogical and content knowledge related to the Next Generation Science Standards (NGSS); strengthen participants’ leadership skills; and facilitate leadership to be subsequent agents of change in their schools, their districts and throughout the region. To
highlight important program features that supported these outcomes, Lacey’s story follows.

Features
At the start of the UP program, 16 of the 19 middle school teacher participants utilized a particular state curriculum, an NGSS-aligned, problem-based curriculum for middle-school students. Lacey was one of the three middle-school teachers not using the curriculum at the outset of the project. Lacey teaches at a high-need urban school with approximately 450 seventh- and eighth-grade students. The school community is ethnically homogeneous with the dominant race being Black (67.3%), followed by Hispanic (19.2%), White (non-Hispanic) (12.1%), and Hawaiian (1.1%). Men make up 53.2% of the students. The students face many challenges. Nearly 93% of students are economically disadvantaged and qualify for free/reduced-price lunches.

Lacey admitted that she taught her seventh-grade science students using teacher-centered methods from a textbook. She was encouraged to implement one or more state curriculum units with her students to support student engagement in science and engineering practices and student-centered instruction. However, she expressed the belief that her typically low-achieving students could not learn via reforms-based instruction. Rather, her students needed simple, direct instruction.

A cornerstone of the UP program is the State’s Teacher Leader Preparation Standards with particular emphasis on participants (a) accessing and using research to improve practice and (b) facilitating improvements in instruction and student learning. The UP leaders supported Lacey in developing an action research project to either confirm or challenge her beliefs. As a result of this classroom-based inquiry, Lacey realized that her students were more engaged during instruction and were capable of successfully participating in student-centered instruction despite their traditional low achievement (Gonczi et al., in press). Lacey subsequently helped pilot new NGSS-aligned lessons in her STEM classes.
and worked in a PLC group whose goal was to develop these plans for broader implementation.

**Significance**

Two program components were critical in supporting the described change and growth thus far. First, it was important that the vast majority of project participants used the same curriculum that reflected reform-based curriculum, and the few who did not were challenged to justify why they did not through action-based research. The curriculum provided a concrete representation of reform-based teaching that provided a common denominator for the participants to share. This allowed many participants to enter the program with a common vision and provided opportunities for action research to help those without that vision grow. The action research that Lacey embarked upon not only allowed her to improve her instruction but also provided opportunities for her to demonstrate leadership outside of her school and district. She shared what she had done first at the Midwest Noyce Conference in 2019 and then subsequently prepared and submitted a manuscript to a peer-reviewed journal. The curriculum-focused CoP that provided a gel for many participants at first supported new leadership skill development and gave teachers the ability to expand into new CoPs both within and outside the UP program.
RMSN: Leadership Development Through Project-Based Learning

Context
The Rural Math and Science Noyce (RMSN) Master Teacher program, situated in a Southeastern state, provided teacher leadership training for 20 rural mathematics and science MTFs at the secondary level for 7 years. Ten of the MTFs taught mathematics (six middle school and four high school), and 10 taught science (four middle school and six high school). Three were men, and 17 were women. Twelve were Caucasian, and eight were African American. At the time of their applications to the program, all the MTFs’ schools were designated Title I schools and had an average of 77% of students on free/reduced cost lunch programs. The average number of students at each school was 500 (range 193–1,255).

Features
The RMSN program worked to develop MTFs’ content knowledge, pedagogical practices and leadership skills through professional development workshops in the summer and academic year. Using project-based learning (PBL) as a pedagogy of focus, the program provided a common language to talk about student-centered teaching. The RMSN program was purposely designed with professional development interactions to gradually support MTFs’ PBL skills and build their teacher leadership identities. Thus, after MTFs developed and implemented their own PBL unit the first summer with their students, the second-year summer institute required them to develop a PBL state conference presentation. The next year’s summer institute focused on the teachers sharing their PBL units and other pedagogical skills at a regional conference. Finally, MTFs presented at a national conference. Thus, this sequence of teacher leadership competence and support started with MTFs making local presentations to their program peers,
planning, and implementing a regional conference, and finally presenting at a national conference.

**Significance**

The 7-year duration of the RMSN program, along with its focus on rural secondary science and mathematics teachers, has developed a strong CoP among MTFs and program leaders. The teachers describe the program as their “Noyce family,” and they have supported one another during our planned sessions and through informal communication (e.g., phone calls, email, Facebook). MTFs identified the common context of rural high-poverty schools as important for reducing their isolation and connecting them through shared student problems and experiences (Lotter et al., 2020). In the following vignette, we provide an example of how the Noyce CoP impacted the teacher leader identity and skills of one MTF.

Jackie, a high school mathematics teacher, reluctantly applied for the program on the persistent prodding of her science teacher peer. Jackie grew up in the small community where she now teaches; she is committed to strengthening the schools in her community. Her initial CoP was the rural community in which she lived and taught. When the program began, Jackie became part of her second CoP, the Noyce community. She spoke of the value of the relationships in this Noyce CoP: “One of the most amazing things is the relationships with the other teachers and you know that in itself is powerful because now I feel like I have teachers on the outside who I can call on.” As the program continued, those feelings of community only deepened. With the program’s initial deep dive into PBL, Jackie’s first task was to develop a PBL unit. Given her belief that students in her community needed a better understanding of financial literacy, Jackie developed a unit exploring credit card use. The MTFs worked together to design and critique one another’s units. This first joint enterprise of developing a rich, inquiry-based learning challenge helped her continue to develop the Noyce CoP. Further, as part of a university methods course, secondary mathematics preservice teachers visited
Jackie’s rural school. Their visit allowed Jackie to share one lesson from her PBL unit with preservice teachers, thereby allowing her to serve as a teacher educator. Speaking about the impact of presenting at a national conference after presenting locally, Jackie stated, “That was a big thing as a teacher leader because here you are presenting to other teachers and they are asking you questions and they’re saying, I’m from this state, and you just see that openness and how much of a teacher leader you are with other people looking to you.” In each instance, Jackie was able to cross boundaries into new CoPs using ideas learned from the RMSN CoP. Moreover, she was able to expand her sphere of influence, sharing her work and expertise with a wider community.

Jackie’s participation in the RMSN CoP also facilitated her teacher leadership identity growth and her retention in education:

> At least I know I got this avenue of support. They will keep pushing me. . . . It’s professional development around here, it’s people who you can talk to, it’s support that you can get that encourage you and push you and help you to make it through another day.

The RMSN CoP, with its scaffolded leadership opportunities, PBL focus as a shared instructional practice, and long-term support structures, provided Jackie with knowledge and skills that she was able to share with others across multiple CoPs to improve mathematics education and her own leadership identity.
MMN: Communities to Support Math Teacher Leaders

Context
Beginning in 2011, the Midwestern Math Noyce (MMN) program was formed in partnership among a large research university in a central, Midwestern state and three local school districts to increase the number of high-quality mathematics teachers in the state’s high-need schools. Along with other efforts, the MMN program recruited 30 mathematics teachers and instructional coaches, each dedicated to impacting mathematics teaching and learning in their schools and districts, to become Master Teacher Fellows. MTFs initially completed 24 credit hours of graduate coursework emphasizing mathematics content, pedagogy, and leadership, followed by individualized support for the MTFs as teacher leaders; these opportunities included attending conferences, writing professional publications, serving as instructors of graduate courses for teachers, and mentoring and funding for self-determined leadership projects. To explore the impacts of the MMN program, we present the story of Thomas.

Features
Thomas is a secondary mathematics teacher at a rural high school who is deeply dedicated to students and to remaining in the classroom, despite numerous offers to shift into other roles. Before joining MMN, Thomas was already operating as a leader in his school and district—he spearheaded a competitive mathematics club and designed curriculum for a new mathematics elective on problem-solving. However, he also disagreed with the school’s assessment practices and focus on procedure in their mathematics instruction, causing tension with his department chair and peers; he felt isolated and in need of resources to advance his work as a teacher and leader.
The initial graduate courses were intentionally designed to be too challenging to complete alone, forcing the MTFs to work together through problems of practice and content. In doing so, Thomas found himself belonging to a community of teachers that he did not have before. In describing the importance of connecting with his Noyce peers, he shared:

*It is very easy to become convinced that you’re alone. Isolationism is not surprising. But to be a mathematics or STEM teacher in a rural community, far away from a teacher preparation program, to be in such a remote area and find people that are like you—to know that there are other people out there with the same passion and drive and struggles.*

As Thomas continued through the program, he continued to take advantage of new opportunities that permitted him to grow his professional network and expand his sphere of influence. Looking back, Thomas described the most significant impact of his Noyce involvement was “the opportunity to network with other teachers in more situations. Sometimes it was a foot in the door to meetings and opportunities that wouldn’t have been there otherwise.” Thomas developed and taught a summer graduate course for teachers on how to teach AP statistics, allowing him to influence teacher preparation and professional development. As his community recognized his credibility as a teacher and leader, he became department head and joined his school’s advisory committee. To expand his reach, Thomas began using Twitter to share resources, experiences, and discoveries from his teaching on a wider scale, later garnering an invitation to give a plenary presentation at an international education conference in France.
Significance

Four years after the completion of the MMN program, Thomas remains in his school and continues to call upon his connections with his Noyce peers. Looking back on his accomplishments and leadership, Thomas reflected,

*Part of the reason why I’ve been able to push and poke and prod where I’m at is because I’m reminded that I’m not alone and I’m not as special as I think I am. . . . It’d be easy to fall in love with the idea of, you’re unique and special--all those things. That’s not the case. . . . We need to make sure that we’re committing our resources to programs like [MMN] that offer those types of experiences for teachers that can help them to get better.*

Thomas’s journey illustrates the impact and importance of belonging to a community of practice like that of the MMN fellows. Although Thomas’s involvement provided opportunities to establish credibility and expand his sphere of influence, Thomas’s sense of belonging to their lasting community has continued to motivate and push him to imagine new ways to enact his leadership. As Thomas and other members of the MMN community shared the leadership opportunities they found or created, the ideas were generative and led to additional leadership activities and a close sense of community.
MTL: Networking to Enhance Identity and a Boundary Object to Aid Transfer

Context

The MountainTop Leadership (MTL) program operated out of a large Southwestern university. The program was unique from other programs in the larger T-Lead project because it focused on providing opportunities for MTFs to engage in a research community external to their school or teaching community. The MTL program was designed to support established teacher leaders rather than develop them, so the participants were being guided to expand and strengthen their leadership trajectories and identities. Through this study we were able to identify (1) features of the program that provided opportunities to engage in research and (2) the influence of these features on the empowerment of the teacher leaders.

Features

While several program features were identified as being important to empowering teacher leaders, we focus on two of the more salient ones: (1) support for networking and conferencing and (2) coordination through a shared boundary object. In terms of networking and conferencing, the MTFs were positioned as researchers by being supported to attend research conferences and to expand their professional networks to include educational researchers. In these experiences, MTFs were often encouraged to collaborate with researchers, present their own work, and network with others. This support allowed the MTFs to see themselves as equals to researchers, even though teaching often is perceived as having a lower status than research. MTF Nadine reflected on this:

*I always felt like my opinion and my voice was valued and that it mattered . . . they [education researchers] were all very welcoming and open and valued what I had to say and made me feel like part of the [education research] group. (Year 2 Interview)*
Viewing STEM Teacher Leadership Through a Communities-of-Practice Lens

This produced a cycle of networking, action, and validation that reinforced the MTFs’ identities as researchers, and researcher identity became a critical component of their expanding teacher-leader identity. This cycle is a different temporal sequence for supporting teacher leaders’ growth than that identified by Drayton (2020), in which the validation came first, which led to new actions by the teacher leaders, and then, finally, further networking occurred.

One of the significant concerns of the T-Lead project is understanding when, and under what conditions, meanings and practices were transferred between school and Noyce CoPs. Given that we saw indications that the educational research practices of the MountainTop Leadership MTFs were being transferred to their schools, we searched for a mechanism in the data. We propose that the transfer occurred as the teacher leaders learned to coordinate between the two CoPs. The coordination between teaching and Noyce/research communities occurred through identification of shared boundary objects. One such boundary object identified was arguing with evidence. This boundary object was made visible during an interview with the PI of the program, who revealed that the MTL program was intentionally designed to support teacher leaders to “learn how to support claims with evidence.” The shared boundary object, arguing with evidence, was valued in both the research CoP and some of the school CoPs—and those were the ones where transfer happened more effectively. However, when this boundary object was not shared between the communities, MTFs were not only less able to transfer the practice of educational research to their school CoPs but could even experience being “othered,” as indicated by Sara:

They [peers at school] are like “your stupid little research project”... you know it basically wasn’t respected because we are not “researchers” [air quotes added by participant] really, we are teachers. So that caused a little bit of tension.

The focus of MTL on education research, including the building of strong external networks that connected the MTFs to educational researchers,
had a secondary effect that showed up in their SNA surveys. MTFs across all sites reported information on leadership networks that allowed the calculation of brokerage roles. For example, an MTF passing information between fellow contacts in their local school would be operating in a Coordinator role, if the contacts were not otherwise connected to each other without the MTF. Alternatively, an MTF acting as a conduit for information between a contact at the state level and a second contact at the national level would be operating in a Liaison role, since the contacts were not otherwise connected, and all three individuals were presumably operating in different parts of the educational system. We examined the total number of brokerage roles calculated for MTFs and what percent of those roles were Coordinator, Liaison, or any of several other defined roles. When disaggregated by program site, we found that MountainTop Leadership MTFs showed a significantly higher percentage of Liaison brokerage roles than did other sites. This finding suggests that when MountainTop Leadership MTFs broker information related to school improvement, they are primarily operating completely outside their own schools, connecting individuals from multiple organizations or spheres of influence.

**Significance**

Participation within a research CoP had substantial influence on teacher leaders’ perceptions of themselves and others’ perceptions of them as leaders (credibility). Through their participation in the research CoP, the MTFs began to see their relationships with researchers as more horizontal rather than vertical in nature (i.e., of more equal status than of lower status). This perceived horizontal nature of these relationships fostered MTFs’ sense of belonging and validated them as having ideas worth sharing with the broader educational community. Morgan illustrated this effect:

> [It] has pulled the veil away a little bit, you know. It’s not these people high up on a hill. It’s like I can present and I have things to say, and it’s important that I get my work out there.
In addition to feeling like they belonged to the research community, MTFs were also often seen as credible by their peers and colleagues in their teaching communities. We hypothesize that this was at least partially due to the shared boundary object (“arguing with evidence”) that supported not only transfer of the practice of educational research, but also transfer of the MTFs’ credibility as legitimate researchers:

*With my [curriculum] program, because I’ve done this research and had kind of successful outcomes and successful interventions, I am seen as a leader because I’ve put in the work and I’ve seen what parts of it work and how it works and tested different things in my classroom.* (Morgan, Year 2)

This sense of engaging in a legitimate intellectual practice (educational research) and being seen as an expert practitioner of it provided credibility for some of the MTFs. It also affected their professional identity by giving them a new sense of what it meant to be a professional as a teacher. Morgan illustrated this as she discussed how her experience in MTL gave her “words to what I’ve been feeling for a long time” and that her participation “professionalized teaching for me.”

Significantly, the structures of the MTL that supported the MTFs in engaging in the practice of educational research also shaped their social networks, producing networks that had them more outwardly focused on functioning as Liaisons than inwardly focused on serving as Coordinators within their own schools. Thus, their boundary crossings were tied to broader levels of the educational system and wider spheres of influence. It remains to be seen what the long-term effects of building an outwardly focused network will be on the professional identities and trajectories of the MountainTop Leadership MTFs.
UCEST: A Boundary Object Brings a New Meaning to Mentoring—and Attrition

Context
The Urban Collaboration for Excellence in STEM Teaching (UCEST) is a partnership between an urban public school district and a large Midwestern university to train and support two cohorts of STEM teachers over a 5-year term. Participants chosen for UCEST were veteran teachers with master’s degrees or higher, in content or education, and were serving or had served in a teacher leadership role within the district. The MTFs had nine to 27 years of teaching experience. The cohort consisted of 12 women and six men; eight were African American, and 10 were Caucasian. Although the MTFs were from different schools, all served in the same school district under the same teacher leadership framework. UCEST was designed to support and utilize veteran teacher leader expertise through personalized professional learning experiences such as (1) graduate STEM courses, (2) pedagogical coursework, and (3) leadership development. We share data from two MTFs in UCEST to show how mentoring, as a boundary object, informed their activities and shaped their professional identities as teacher leaders.

Features
Depending on their selected pathway, the MTFs met on campus or online as a cohort, individually or in small groups, to discuss pedagogy, receive training or work on program projects. The structured activities allowed the MTFs to reexamine the meanings for practices in which they had engaged in their school CoPs from the new perspective afforded by the UCEST CoP. One of those practices was mentoring, as most of the UCEST MTFs had mentored either new or experienced teachers in their schools. However, the opportunity to redesign the curricula for some secondary methods courses at the partner university, including STEM-focused
ones, and then to teach those courses as adjuncts, provided the MTFs the space to reconsider their ideas about mentoring. Brenda illustrates the way these opportunities affected her viewpoint:

> It made me think about how I can improve being a mentor teacher, not only to the group that I have at school but also to the preservice teachers here. It made me reevaluate what I was doing a little bit and think about some new ways of doing things that I hadn’t really thought of before—[it is valuable] anytime you get that fresh perspective. It also allowed me to see a little bit of the, maybe understand the struggle that new teachers have. . . . I wasn’t really aware of some of the curriculum that was being taught to the new teachers over at [the university] and that we’re in such close proximity.

There are two critical insights to be gleaned from Brenda’s words. The first is that this fresh perspective had the effect of generating more empathy for the new teachers in her district (“maybe understand the struggle that new teachers have”). The second is that one can see the beginnings of mentoring becoming a boundary object between the UCEST and school CoPs as Brenda displays awareness of connections in practice: “the curriculum” for training teachers that could be linked to approaches to mentoring in her district.

Several of the MTFs began to recognize a linkage between the quality of mentoring that new teachers receive and the attrition of new teachers prevalent in the district; as Brenda noted:

> We do see a lot of teacher turnover and a lot of teachers leaving the profession after the first couple of years. I always wondered why that was and didn’t really understand some of the issues until I started being a part of this program and seeing the preservice [teachers] . . . all the way through [their teacher preparation experiences].
Between the activity of developing the methods course curricula, the mutual engagement of MTFs around issues of mentoring and attrition, and the chance for a couple of MTFs to teach the methods courses, the UCEST program supported the MTFs in reformulating their view of mentoring and its role in mitigating attrition. They transferred these reformulated views back to their school CoPs. A pamphlet was created by three of the MTFs that offered suggestions for effective mentoring based on their new understanding of the practice. Unfortunately, the pandemic limited the extent to which the ideas in the pamphlet were explored, and the pamphlet itself was disseminated within the district.

The experiences in UCEST led the MTFs to reframe the meaning of mentoring to be one of active engagement with the new teachers by providing support and skills to navigate the school system all while leading by example. Mentoring as a boundary object supported this reframing and a revisiting of associated issues within the MTFs’ district. The MTFs realized that the district failed to prepare their teacher leaders with the interpersonal skills for supporting other teachers. Georgia, a science and technology teacher, highlighted this: “I really didn’t know how to help them [new teachers] and they didn’t really know how to ask.” Even though she had served as the resident educator mentor for the school district for over 10 years, she realized she lacked the training to be an effective mentor. UCEST has begun to fill in that skill gap.

There was a secondary effect of the focus on mentoring and other practices within UCEST that became visible though the SNA conducted by T-Lead. As noted in the MTL vignette, the SNA data allowed the calculation of brokerage roles. Among the different roles being analyzed were Coordinator, which is indicated by an MTF passing information between fellow contacts in their local school. By comparison, the role of Liaison is represented by the case in which an MTF acted as a conduit for information between a contact at the state level and a second contact at the national level—cases in which the MTF was connecting individuals in different parts of the educational system. We examined the total number
of brokerage roles calculated for MTFs and what percentage of those roles were Coordinator, Liaison, or any of several other defined roles. When the data were disaggregated by program, we found that UCEST MTFs showed a significantly higher percentage of Coordinator roles than did other sites ($p < .05$). Because of their concerns for mentoring and other district issues, the UCEST MTFs may be focused on bringing stakeholders together within a school where there are not dense communication networks, at the expense of extramural opportunities. This suggests boundary crossings more focused on a local sphere of influence.

Significance

The vignette provides key insights about how the use of a boundary object—mentoring in this case—can bridge intersecting practices while individuals navigate between multiple CoPs (Akkerman & Bakker, 2011). The joint enterprises of UCEST—e.g., revising the university’s curricula for the methods courses and MTFs’ serving as adjunct professors for the courses—made mentoring available as a boundary object. This partnership allowed the MTFs to develop a new conceptualization of mentoring, from one of overseeing to one of collaborative engagement, and to gain empathy for the new teachers in their district. To enact this new conceptualization, the MTFs realized a need to possess interpersonal skills that the district was not providing; UCEST has been offering the training needed for the MTFs to mentor differently. The new meaning of and way of engaging in the practice of mentoring became reified in a pamphlet created by three of the MTFs. This pamphlet has the potential to create more systemic change in mentoring—possibly the kind of transformation described by Akkerman and Baker—but the COVID-19 pandemic has interrupted the dissemination of its ideas. Our research project will be examining if that disruption of the change process was temporary or permanent.

The evolution of mentoring as a boundary object was a spontaneous process within the UCEST program. There is value, though, in similar
teacher-leader development programs planning for the formation of such boundary objects. Such intentionally formed boundary objects can support the transfer of meanings and practices across CoPs both internal and external to school systems. This would facilitate change occurring across those CoPs, in all directions. This change can include changes in the professional identities of individuals who are functioning as boundary crossers (Wenger, 1998), much like the UCEST MTFs, whose teacher leader identities have grown and been strengthened. However, the engagement of boundary objects must be undertaken thoughtfully, as there can be secondary effects that need consideration. In the case of UCEST, our SNA data indicated that the MTFs have taken on much more locally focused brokerage roles than did MTFs in other programs we have studied. This outcome may or may not be detrimental, but it is important to monitor such effects to ensure that programs like UCEST are producing their maximum positive influence on school systems.

Discussion

Each vignette reveals details of the key features of the Noyce CoPs (research question 1) and of the form of boundary objects and nature of boundary crossings relevant to the teacher-leader activities of the MTFs (research question 2). TABLE 1 provides a brief summary of the main insights presented in those vignettes. The set of Noyce projects examined are each unique, and each worked with a distinct group of MTFs to develop and/or support STEM teacher leadership. Across these varied contexts, however, all of the projects approached leadership development and support through establishing and maintaining communities of practice. What has been learned through the T-Lead research project, though, is that there are sometimes subtle and sometimes significant differences in the ways the CoPs operated, particularly in relation to the school CoPs, wherein the MTFs expended the majority of their professional efforts. For
instance, while most of the Noyce projects enhanced the professional networks of the MTFs, this occurred in different ways, something made visible by the social network analysis we conducted. As an example, the differences in the ways the networks were elaborated by the MountainTop Leadership program and the UCEST program resulted in the MountainTop Leadership MTFs adopting more Liaison roles—largely focused on linking individuals and information beyond the MTFs’ school CoPs, whereas the UCEST MTFs adopted more Coordinator roles—ones that produced more connections between individuals and information within their school district.

The different projects also featured different boundary objects: PBL in RMSN, curriculum development in UP, leading professional development for peers in MMN, arguing from evidence in MTL, and mentoring in UCEST. These boundary objects provided a focus for the improvement efforts in which the MTFs engaged as part of their Noyce activities, but also supported transfer of practices, meanings, and identities across boundaries into their school CoPs. These boundary objects and the boundary crossings they support offer mechanisms for learning across CoPs, such as the ones identified by Akkerman and Baker (2011). Specifically, we saw coordination of meanings concerning the boundary object “mentoring” occur within the UCEST program and we saw the beginning of transformation of practices via the boundary object “arguing from evidence” in the MTL program. However, there is still a great deal to be understood about how different boundary objects and their utilization affects the particular learning mechanisms across CoPs, and therefore affects the transfer of useful innovations.
# TABLE 1

## Summary of Main Insights Related to Research Questions

<table>
<thead>
<tr>
<th>Noyce Project</th>
<th>RQ1: Key Features of CoPs Within the Noyce Projects</th>
<th>RQ2: Identities of Boundary Objects and Nature of Boundary Crossings</th>
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| TL-PACT       | • Identity building through providing narratives of successful TL  
• Building possible selves and experimenting with provisional selves in a supportive CoP  
• Examining network structure in relation to leadership goals | • No boundary object was identified, but the networks supported meaningful boundary crossings for the MTFs in relation to leadership goals |
| UP            | • All participants are from rural locales  
• Most taught the jointly developed curriculum for middle school science  
• Many were working toward master’s degree in education | • Curriculum development  
• Conference presentations and publications  
• Lead district professional development and topic-specific professional learning communities |
| RMSN          | • Developing and teaching PBL curriculum  
• Rural community connections  
• Building TL identity over time with competence, recognition, and networking | • Scaffolded leadership opportunities with development and implementation of PBL units  
• Local, regional, and national presentations of PBL units  
• Professional development for teachers led by MTFs for teachers from schools |
| MMN           | • Challenging initial graduate coursework created cohort bond  
• Engaged in leading professional development for peers (cotaught graduate courses) | • Encouraged to pursue National Board Certification  
• Provided opportunities to teach graduate courses for teachers  
• Encouraged to present at conferences, get involved with regional/state/national associations |
| MTL           | • Networking and conferencing forged identity as ed researchers  
• Development of horizontal rather than vertical networks by immersion in research CoP  
• Networking, action, validation cycle further supported teacher leader as researcher identity | • Epistemological commitment of arguing from evidence as a boundary object  
• Boundary object may have supported transfer of credibility into school CoP  
• Brokerage role suggests boundary crossing at broader levels of educational system |
| UCEST         | • Joint enterprise of MTFs around development of revised methods course curricula  
• Mutual engagement around how mentoring related to districtwide issue of new teacher attrition | • Mentoring as a boundary object  
• Reification of new meaning of mentoring in pamphlet  
• Brokerage roles (coordinator) suggests work at more local level of educational system |
Conclusions and Implications

The vast majority of T-Lead MTFs are stayers—still in the schools they were in when they first became MTFs—while a small number have moved schools or shifted roles (in the same school or a different school), and under 2% have left education (all through retirement or death). Thus, the MTF programs that developed or supported teacher leaders are associated with tremendous retention as teacher leaders, along with growth of professional identities as teacher leaders, and growing spheres of influence as STEM teacher leaders. These findings align with Hanuscin’s (2011) and Sinha and Hanuscin’s (2017) findings that strong teacher leader identities are associated with school or district leadership activities aligned with leaders’ beliefs about effective teaching and learning. Noyce programs connected teachers from different schools, often statewide, and intentionally nurtured the cohorts to form a CoP. The CoPs allowed MTFs to grow together into professional identities as teacher leaders, and then to use the external Noyce CoPs to in turn develop and strengthen their internal school CoPs. This type of boundary crossing (Wenger, 1998), bringing information (including bridging research-practice gaps) from one CoP to another, became a central feature of the work of the MTFs. Explicitly identifying the boundary objects and boundary crossings aligns with Collay’s (2016) findings that teacher leaders need to be proactive in managing conditions as they transition into new leadership roles.

Key to all of the Noyce programs was beginning with professional development in STEM content and pedagogy, as well as leadership development. These features align with the Teacher Leader Skills Framework (Center for Strengthening the Teaching Profession, 2021) central domains. MTFs typically cited the additional knowledge as a factor in their growth as leaders. MTFs also discovered that once they were connected to STEM education research, they were better able to not only bridge the typical research-practice gap but also to engage in
their own action research projects. The early professional development experiences were also intentionally designed to create a CoP among the MTFs. MTFs universally felt isolated before Noyce, even those in large urban schools; Noyce programs provided them with a CoP of like-minded peers and, thus, an extended professional network. These communities became more than the sum of their parts, providing MTFs with a supportive foundation from which to take risks and engage in new leadership activities. Further, the external Noyce CoPs often led teachers to develop or strengthen local CoPs within their own schools, as they sought to lead their peers to improved STEM teaching and learning. Thus, the CoPs functioned as Campbell et al. (2018) described effective CoPs, with positive impacts on teacher leaders’ views of competence, performance, and recognition.

When Noyce programs provided opportunities for MTFs to lead outside their classrooms—often framing it as a responsibility in this space—this intentionally positioned MTFs began the programs as leaders who crossed the typical boundaries that keep teachers in school-centered bubbles so that they do not interact outside those bubbles (Wenger-Trayner & Wenger-Trayner, 2015). Most MTFs across T-Lead were full-time classroom teachers with informal leadership roles. Although most MTFs without identifying as leaders, they credited their Noyce experiences with helping them gain in leadership efficacy. Many noted that the practice of leadership came before the leadership identity. Thus, other programs seeking to develop teacher leaders may want to support the development of teacher leadership identities by providing opportunities to engage in teacher leadership activities. MTFs sometimes engaged in early leadership activities in pairs and small groups, which both fostered a sense of community and bolstered confidence among those not yet confident in their professional identities as leaders. The CoPs within the different Noyce programs helped to develop or support the MTFs’ teacher leadership identities through common goals, supports and leadership practices that were shared across the MTFs’ expanding networks and school CoPs.
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References


Viewing STEM Teacher Leadership Through a Communities-of-Practice Lens


Closing

The projects funded by the NSF’s Robert Noyce Teacher Scholarship program have always intended to utilize research-based evidence regarding the recruitment of STEM undergraduate majors and STEM teacher leaders, their preparation, their induction into teaching, and their leadership development. The recent introduction of the Noyce Research Track has added a critical element in its support of researchers to discover, study, and promote pathways for STEM teacher education using Noyce projects and participants to gather important data and generate evidence-based trends and findings.

The eight chapters in this book highlight research studies and their findings on elements of inclusive recruitment programs (Chapter 2), practices for supporting students during clinical experiences and induction (Chapters 3, 4, 6, & 7), the importance of creating supportive networks for teachers (Chapters 1, 6, & 8), and policy and funding priorities for retaining teachers in the highest-need schools (Chapter 5). While chapter authors provide recommendations specific to their research areas, we are excited to see how this research progresses and informs future STEM teacher recruitment, preparation, and retention efforts.

It may be too early to determine the impact of the Noyce Research Track on STEM teacher outcomes, effectiveness, and retention, but
we believe the findings presented in the eight chapters can be used in productive ways and inspire additional research on PreK–12 STEM teacher recruitment, effectiveness, and retention in high-need schools. The presented research in this volume aligns with extant literature to make clear that the future of America’s STEM research and innovation enterprise is dependent upon the cultivation of a larger, more diverse cadre of PreK–12 STEM teachers who are equipped with inclusive curricula and assessments, along with evidence-based pedagogies. We look forward to learning from future research funded by the Noyce Research Track and its implications on preparing and retaining excellent STEM teachers in high-need school districts.

We would like to conclude this volume by thanking the Noyce Research Track investigators and our NSF colleagues who have contributed their time and talents to this publication. We are eager to learn from the ever-growing portfolio of NSF-funded Noyce projects which we hope will expand on the work highlighted in this collection to improve the recruitment, preparation, and retention of STEM teachers in high-need school districts.