Just keep swimming: Increasing resilience of STEM preservice teachers during COVID-19

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ABSTRACT

A substantial achievement gap between K-12 English learners (ELs) and non-ELs in science, technology, engineering, and mathematics (STEM) content areas exists, as indicated by national assessments of student outcomes. Considering the expected steady increase in students who are ELs in the U.S., determining methods for addressing this achievement gap is of immediate concern. Research has indicated this gap may be exacerbated by lack of adequate teacher preparation, specifically in STEM fields, to effectively teach students who are culturally and linguistically diverse (CLD). Founded in previous research about effective teacher preparation, the current case study pilots and reports on a model of early STEM preservice teacher training that integrates: knowledge of language development for ELs, early experiences with CLD learners, and professional development activities that guide the implementation of STEM pedagogical methods. Five STEM preservice teachers participated in a year-long supplemental training program focused on adapting STEM instruction for ELs. Components of the supplemental program included: (a) coursework extending teacher knowledge of EL language development, (b) fieldwork providing early exposure to research-based teaching experiences with EL students, and (c) professional development guiding the creation of hands-on STEM curriculum for diverse learners. Five secondary preservice teachers experienced increases in self-efficacy, growth in STEM instructional practices, and greater motivation for teaching in high-need schools. Results will inform educational models for improving STEM-EL teaching, thereby addressing a crucial need to serve the growing national population of underserved students.

Keywords: Noyce scholars, STEM education, teacher development, English learners, program evaluation, self-efficacy

INTRODUCTION

Now more than ever, science, technology, engineering, and mathematics (STEM) is a source of inspirational discoveries and transformative technological advances that impact many aspects of modern life. A report written by the Committee of STEM Education of the National Science & Technology Council for the Executive Office of the President (2018), indicates that both global and personal success in a 21st century economy is dependent on being a technology capable individual who is able to utilize digital devices and apply STEM process skills such as evidence-based reasoning. STEM literacy is defined as having the "ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and to innovate to solve them" (National Academies of Sciences, Engineering, and Medicine, 2007; Zollman, 2012).

The need for a greater number of students to develop high standards of STEM knowledge and have opportunities to participate in building STEM literacy through learning opportunities so that they can succeed in STEM content areas at the college level has become pressing (National Academies of Sciences, Engineering, and Medicine, 2007). According to a new analysis by the U.S. Bureau of Labor Statistics, occupations in STEM fields are expected to grow 8.0 percent between 2019 and 2029, which is significant when compared with the 3.7 percent projected for all other occupations (Zilberman & Ice, 2021). The Education Commission of the States (2017) also projected that future STEM demand would be even higher in states with denser populations such as California (estimated 15%, between 2017 and 2029). Additionally, basic STEM literacy skills are required in the majority of STEM jobs in the global workforce and due to its interdisciplinary nature will be used regularly in at least 20% of all jobs with a minimum level of STEM capability needed simply to be an informed citizen (Peterson, 2017). However, recent research has indicated that due to the COVID-19 pandemic resulting in unprecedented amounts of STEM-oriented communication with the public, as well as, number of work related fields impacted by this still ongoing global event it is predicted that the growth in need for STEM literacy and relevant STEM education will now effect an even greater number of interdisciplinary career fields than current estimates are able to predict (Braund, 2021; Zilberman & Ice, 2021).

Despite this steady increase in demand, only 20% of graduating high school students have been found to be adequately prepared to pursue STEM coursework at the college level; this percentage of students is even lower when traditionally marginalized or underrepresented groups are considered (i.e., people of color, women, English learners, etc.; Education Commission of the States, 2017; Espinosa, 2011; National Academies of Sciences, Engineering, and Medicine, 2018; NSF & NCSES, 2021; Landivar, 2013). In examining the reasons why students, particularly those from underrepresented backgrounds, veer away from careers in STEM, extensive research has focused on both extrinsic factors (i.e., socio-economic status, access to learning opportunities, classroom teaching strategies, educational policies and inequities, etc.), as well as intrinsic factors (i.e., interest and learning behavior linked to self-efficacy issues, perceived social expectations and stereotypes, etc.; Blackburn, 2017; Buxton, 2006; Holmes et al., 2018; National Research Council, 2011, 2013; Taningco et al., 2008; U.S. Department of Education, 2013).

Findings suggest that the gap between the number of students who express interest in STEM degree programs and the number who actually enter them, is often driven by prior-to-college experiences in middle school and high school classroom settings (Wang, 2013;

Ocumpaugh et al., 2016). Lack of quality STEM experiences in K-12 not only impacts student level of skill readiness but feelings of self-efficacy and sense of belonging (Rainey et al., 2018; Wang, 2013). Self-efficacy can be defined as how you think (self-concept) and how you feel (self-esteem) about yourself as related to a specific topic or skill (Strayhorn, 2012). Attribution theory indicates that it is these lists of beliefs about yourself that influence your motivation and behavior (Weiner, 1985). Student's sense of self-efficacy for STEM topics in school significantly shapes their reactions to success and failure in class and influences the quality of their cognitive performance, this then impacts their feelings of belonging and willingness to persist in these subject fields (Dweck, 1986; Good et al., 2012; Rodriguez & Blaney, 2020). An example is a study conducted by Sax and colleagues (2015), women's low math self-concept was a predictor of STEM major selection with low math self-concept in high school reducing the likelihood that they would select STEM majors in biological sciences, computer science, engineering, math/statistics, and physical sciences upon pursuing higher education. While LaForce and colleagues (2017) large survey of 10,437 U.S. college students enrolled in 336 calculus undergraduate classes that explored student beliefs about their science and math found that a greater sense of mathematics identity predicted greater student interest in pursuing STEM careers when compared with non-STEM careers in physical and computer sciences, engineering, and mathematics, or future STEM teaching. Similarly in a study that considered STEM barriers for Latinx students, low self-efficacy and poor pre-college STEM curriculum experiences and achievement were among the significant influences in student's decisions to select STEM degrees in secondary and postsecondary educational settings (Taningco et al., 2008). This has important implications for fostering equitable learning pathways and the need to enhance K-12 STEM education experiences particularly when considering the acknowledged gender and underrepresented minority (URM) gap in STEM disciplines (Espinosa, 2011; Wang, 2013; Whittaker & Montgomery, 2012) even as the K-12 student population grows more diverse.

English Learners & STEM

Over the past two decades, English learners have continued to be a consistently growing proportion of school-age K-12 students in the United States (U.S.). In 2017, there were far more English Learner students in U.S. public schools (5.0 million students) compared to the year 2000 (3.8 million students) (Tolbert et al., 2014; Bialik, 2018; U.S. Census Bureau, 2010). English Learners (ELs) is a broad term for a heterogenous student group, from diverse backgrounds, cultures, ethnicities, but who speak a home language other than English (Bialik et al., 2018) and have varied English proficiency levels as they attend public K-12 school. Currently, California, where the present study was conducted, has the highest percentage of EL students in the United States (19.2%; NCES, 2019b) with Spanish being the most common (Bialik, 2018), but certainly not the only home language option. By 2025, it is estimated that linguistically diverse students will be the largest growing category of all K-12 students with one in four students in the United States being from a household that is multilingual (Stoddart & Mosqueda, 2015). However, despite being among the fastest growing category of students, ELs have yet to attain the same level of academic success as their English-proficient peers, particularly in the topic areas of science and mathematics from elementary school through high school as indicated on National Assessment of Educational Progress (NAEP) reports on student outcomes across fourth, eighth, and twelfth grades (NCES, 2015; NCES, 2019a). Thus, addressing this achievement gap in this growing category of students has received growing attention, especially when considering the

STEM content areas have been identified as being of increasing critical importance for all future student achievement and career opportunities in the expanding global community (Bravo & Cervetti, 2014).

In an effort to support the pedagogical needs of ELs, studies have suggested providing academic and linguistic support and searching for experimental and applied methods for increasing science achievement on par with English-proficient peers (Estrella et. al, 2018; Bravo & Cervetti, 2014; Garza et al., 2018; Hoffman & Zollman, 2016; Suh et al., 2020). This would indicate that adapting STEM pedagogical methods in order to improve the student experience and, thus, reduce this achievement and self-efficacy gap is one area of immediate concern. Research indicates historically marginalized students lack support in developing interest in STEM topics and lack a sense of belonging during STEM class activities and interactions (Rodriguez & Blaney, 2020; Burt et al., 2020). Contributing to this, teachers lack training to teach STEM topics to diverse populations, including EL students (Espinosa, 2011; Estrada et al., 2016; Cervetti et al., 2015). Improved teacher training would contribute to all students being better prepared for STEM college coursework and more inclined to pursue future careers in STEM, especially those students who historically are at greater risk for exiting the STEM pipeline (Irby et al. 2020; August et al., 2009).

Lack of Teacher Preparation

One reason for this achievement gap and low self-efficacy in K-12 STEM students including may be the lack of adequate preparation that K-12 STEM teachers receive on how to effectively teach students who are culturally and linguistically diverse (CLD). There has been a call for addressing how universities prepare and train preservice K-12 STEM teachers in existing teacher preparation programs (Avery & Meyer, 2012; Darling-Hammon et al., 2002; Eick, 2009; Kelly, 2000). Preservice teachers can be defined as “undergraduate or graduate students enrolled in a teacher education program” at a higher education institution who are taking courses and completing “supervised field-based teaching experiences with the support and mentorship of university faculty and K-12 cooperating teachers” in order to prepare them to become teachers in the K-12 setting (IGI Global, n.d.). In 2012, the National Research Council called for preservice teachers to be given experiences that help them understand how to generate supportive instructional conditions in STEM as well as other critical areas (NRC, 2012, p. 255-256). Yet, extensive reporting by STEM teachers and preservice teachers indicate a lack of professional development opportunities to develop best practices and pedagogical skills to adequately prepare them to meet STEM learner needs (August & Shanahan, 2010; Ballantyne et al., 2007; Tolbert et al., 2014; Janzen, 2008). Further, according to Besterman and colleagues’ (2018) large survey analysis (559,000+) of STEM teachers using the Schools and Staffing Survey (SASS), more than half of all STEM teachers indicated having taught courses with ELs. Yet, less than 25 percent of all STEM teachers reported participating in any EL specific professional development activities, with no teachers receiving more than eight hours of EL-specific professional development training (Besterman et al., 2018).

It is evident in the research that many K-12 teachers feel inadequately prepared to teach STEM content to EL students (Cervetti et al., 2015; Estrella et al., 2018; Gandara et al., 2005). As a result many STEM K-12 teachers report ongoing self-efficacy issues in teaching their students (Beauchamp & Thomas, 2009; Carrier at al., 2017; Gunning & Mensah, 2011; Menon & Sadler, 2016, 2018; Settlage et al., 2009). Research suggests that in addition to factors such as personal background and STEM school experiences when teachers were students themselves, teacher training substantially influences how preservice teachers position themselves as future teachers of STEM topics (Kier & Lee, 2017). In a recent study, Menon (2020) found that teacher training, in the form of rigorous science methods courses and field experiences, significantly contributed to feelings of self-efficacy and the development of their science teacher identity. Further, in STEM education research, self-efficacy is often used as a predictor of academic and career outcomes in undergraduate students such as a student's interest in STEM and persistence and completion of related degrees. It has predicted involvement in both student motivation to pursue STEM careers and also in related fields such as STEM teaching, suggesting that changing teacher mindset (e.g., self-efficacy and beliefs about STEM) directly impacts the way they teach and how students perform in STEM topics (Muenks et al., 2020).

Evidence-based Preservice Teacher Programming

Research suggests that in order to better prepare teachers to teach EL students, preservice teacher training should integrate the following components: (a) how to incorporate language and literacy into STEM instruction, (b) fieldwork experiences that provide experience with diverse learners, and (c) professional development (PD) activities (Bravo et al., 2014; Hoffman et al., 2021; Lee et al., 2008; Stoddart et al., 2002; Suh et al., 2020).

STEM instruction generally contains abstract concepts, complex vocabulary, and multi-step problems, making it more difficult for EL students to interpret STEM content (Bravo & Cervetti, 2014; Buxton, 2006). It is theorized that EL students have greater difficulty with rigorous subject matter, such as science and mathematics, because academic language proficiency requires dedication of significantly more cognitive energy to interpreting the relevance of content (Lucas et al., 2008; National Academies of Sciences, Engineering, and Medicine, 2018; Orosco et al., 2013; Unruh & McKellar, 2017). Given this, it is important to raise teacher's understanding of EL student learning needs especially in light of research that indicates that teachers' instructional knowledge and pedagogical skill training have a significant impact on EL students' STEM achievement outcomes (Estrella et al., 2018; Heller et al., 2012). For example, Bravo and Cervetti's (2014) found that EL students receiving curriculum formatting science literacy and language support strategies during STEM class instruction outperformed ELs in the comparison group in science understanding and science vocabulary, although not in science-based reading proficiency. Another example is to provide students with explicit vocabulary instruction on specialized words relating to the STEM lesson (National Academies of Sciences, Engineering, and Medicine, 2018). Vocabulary strategies that teachers can integrate into instruction include the use of word walls, mnemonic aids, sentence stems, and graphic organizers (Hoffman et al., 2016; Jackson & Durham, 2016; Lefever-Davis & Pearman, 2015). Another strategy involves utilizing inquiry-based instruction, which involves relating science or mathematics content to real life events, asking questions, incorporating hands-on activities into instruction, and using visual representations (Cole & Wasbrun-Moses, 2010; Estrella et al., 2018; Rodriguez & Bethel, 1983; Stoddart et al., 2002). Even in instances where no significant differences were detected between science and vocabulary learning, correlation analyses still indicated close associations between teacher strategy usage and EL student learning outcomes (Cervetti et al., 2015). These findings indicate that providing teachers with training and resources on specific strategies that can be used to integrate general literacy development into

STEM instruction will help teachers adequately support EL student learning, which in turn will increase student academic achievement in STEM fields (Lee et al., 2008).

Community partnerships and fieldwork opportunities that provide exposure to a diverse population of students is another important aspect of teacher training. Research suggests that practical experience with diverse populations and language minority students are necessary in order to develop culturally responsive instructional skills (Garcia et al., 2010; Hieneke et al., 2013). Garcia and colleagues (2010) argue that teacher preparation programs should seek out partnerships with school districts with a high population of EL students in order to provide preservice teachers with exposure to the language, culture, and learning processes of language minority students. Supporting this, Bravo and colleagues (2014) found that preservice teachers whose methods courses and practicum experiences involved culturally and linguistically diverse experiences were more likely to integrate literacy into science instruction and provide scaffolds for students.

Lastly, professional development is an important cornerstone of teacher training at the preservice and in-service levels. Not only should teachers receive professional development training on teaching STEM content, but they should also be provided with professional development related to supporting diverse students, including ELs. In one study, Nadelson and colleagues (2013) provided a three-day professional development training on inquiry-based STEM curriculum and found that participating teachers experienced increases in confidence for teaching STEM, self-efficacy for STEM teaching, and positive perceptions of STEM content following the PD activities. In another study, Lee and colleagues (2008) implemented a series of five teacher training workshops focused on science and mathematics education, linguistic and cultural considerations, incorporating English language and literacy development into lessons, implementing hands-on activities, and addressing common learning challenges. Data suggested that increased teacher training through professional development workshops improved EL student state testing scores in the areas of science and mathematics.

Implications of COVID-19

The coronavirus (COVID-19) global pandemic gravely impacted the education system at both the K-12 and university levels. As of March 2020 thirteen countries closed down schools, impacting over 290 million students nationwide (UNESCO, 2020). With schools shut down, school districts immediately had to transition from brick and mortar schooling to online or distance learning. Universities and colleges followed suit and transitioned to synchronous and/or asynchronous remote instruction. Teacher credential students were uniquely impacted by the school closures in that it not only impacted their coursework, but it also ceased their fieldwork experiences (Quezada et al., 2020). As a result, teacher credential programs had to promptly change or adapt their pedagogical methodologies, instructional formats, technologies, observation and assessment practices, supervision, and fieldwork opportunities.

Purpose of the Present Study

The present case study pilots and reports on a model of early STEM preservice teacher training that integrates: (a) knowledge of language development for ELs, (b) early experiences with CLD learners, and (c) professional development activities that guide the implementation of STEM pedagogical methods. Given the unforeseen circumstances of COVID-19, this training program was implemented in the in-person setting for five months and in the virtual setting for four months. All participants in this study were awarded the Robert Noyce Scholarship. Specific research questions guiding the study included:

(1) At the conclusion of the program, will scholars demonstrate a greater understanding of STEM content standards and pedagogical practices?
(2) At the conclusion of the program, will scholars demonstrate a greater sense of self-efficacy in providing STEM instruction to ELs?
(3) Will scholars demonstrate an increased motivation for working in high-need schools with students from diverse backgrounds?

METHOD

Participants

Five STEM preservice secondary teachers were awarded the National Science Foundation (NSF) Robert Noyce Scholarship and participated in a year-long supplemental pilot training program focused on adapting STEM instruction for ELs. All participants were between the ages of 20 and 22, had a Bachelor's of Science degree in either biology, chemistry, physics, or mathematics, and were enrolled in a one-year single subject teaching credential program with a dual Master's of Education degree. Participant demographic information can be found in Table 1.

To maintain confidentiality, participant responses were not tracked by name but rather by identification number. Within this manuscript, participants have been given aliases for readability.

Recruitment

This is the first year of a multi-year study with the NSF Noyce Program. The first cohort consisted of five participants who were recruited from a California four-year university credential program's pool of applicants. Applicants, consisting of STEM undergraduate students at the participating university and incoming STEM transfer students from local community colleges, were all sent announcements and flyers at the start of the school year about the recruitment opportunity. Students who were interested in this opportunity were asked to submit an application consisting of two essays, a transcript, evidence of test scores, two references, and a resume listing relevant experience with K-12 students.

The first wave of applicant screening required applicants to first meet the minimum admission requirements for the participating university's credential program which included the following: (a) expected completion of a Baccalaureate degree from an accredited institution in a STEM field by start of program, (b) a minimum 3.0 GPA based on the last 90 quarter units in the baccalaureate program, (c) a passing score on the California Basic Educational Skills Test (CBEST) or equivalent, and (d) a passing score on the California Subject Examinations for Teachers (CSET) in their subject of interest.

The study's participants were then recruited after a second review of those qualified applicants. Selected participants were those who indicated exemplary undergraduate classroom performance in all of the following areas: (a) a stated interest in teaching in low performing schools with a high percentage of EL students, (b) completion of either an undergraduate

Mathematics Education course or an undergraduate Introduction to Science Pedagogy course in addition to their baccalaureate requirements, (c) completion of at least two undergraduate education courses focused on diversity or special needs in the classroom, and (d) completion of 60 hours of classroom observation, mentoring, or tutoring within the community.

Compensation

The Robert Noyce Scholarship Program is a federally-funded program through the NSF that provides grants to institutions of higher education in the United States. The grants are used to award scholarships to students in STEM fields who are interested in pursuing a career teaching science or mathematics in the K-12 setting; scholarship recipients will be referred to as scholars throughout this paper. Upon program completion, scholars must commit to teaching in a high needs school district for two years (NSF, 2005).

As part of the Robert Noyce Scholarship Program, tuition scholarships of at least $10,000 were provided to each of the five participating preservice teachers. The scholarship funds were allocated to provide each participant with coverage of the teaching credential program tuition for one year not including housing, books, or lab fees.

Program Overview

Similar to the other STEM preservice teachers in their cohort, all scholars were enrolled in the one-year single subject teaching credential program with a dual Master's of Education degree at a major four-year university in California. However, scholars also received additional training opportunities focused on adapting STEM instruction for diverse students. Components of the supplemental program included: (a) coursework that extended student STEM curriculum implementation and knowledge of language development for English Learners in the STEM setting, (b) fieldwork opportunities that provided students with early exposure to research-based learning/teaching experiences working with EL students in STEM topics, and (c) hands-on professional development workshops that provided further guidance in the development of appropriate science/math pedagogy for diverse learners. All program activities began at the first day of entry into the credential program and concluded at the end of the year-long post-baccalaureate credential program.

Coursework

Scholars followed the traditional course sequence for single subject preservice teachers in the university's one-year teaching credential program. Coursework for the single-subject science participants was oriented toward the Next Generation Science Standards (NGSS) for science instruction at the secondary level, whereas the coursework for the single-subject mathematics participants was directed towards the Common Core State Standards in Mathematics (CCSS-Math) for math instruction at the secondary level. In addition, the Common Core Standards in English Language Arts (CCSS-ELA) and the California English Language Development (ELD) Standards for ELs are incorporated into instruction for all preservice teachers in order to highlight the importance of the interrelatedness of disciplines.

Fieldwork

All scholars were placed in the same high-need school district for their fieldwork placement (600 supervised student teaching hours total for the year). Of the 20,141 students within the participating district, 77% were Hispanic, 13% African American, 5% White, 3% Other, and 2% Asian. Among these students, 84% were eligible for free or reduced lunch and 20% were classified as an EL, mirroring California's overall EL percentage (California Department of Education, 2020). Not only was this district selected because it provided scholars fieldwork experience working with a diverse student population, but also because it placed an emphasis on developing and implementing non-traditional approaches to STEM learning for EL students.

The district's non-traditional approach to STEM learning is contextual and integrated with other skills including English language competency. The curriculum is aligned to state standards in all four core areas (i.e., English language arts, mathematics, science, and social science). However, instead of cataloging learning into traditional divided subjects, teachers emphasize integration of subject matter into a matrix of four abilities locally entitled "the 4C's": Creativity, Collaboration, Communication and Critical Thinking. The participating district has also embraced the California ELD standards and has structured its professional development model to explore research-based instructional strategies and to establish collaborative teacher environments for group discussions to accelerate language development through meaningful and grade-level appropriate training. Given this, in-service teachers within the district have received extensive training on EL practices and have demonstrated a commitment to incorporating flexible learning spaces and instructional technology designed with ELs in mind. Through their novel teaching strategies, the district has the 4th highest graduation rate (93%) out of the 23 districts in the county (California Department of Education, 2020).

Professional Development

Scholars were given the opportunity to participate in several professional development activities facilitated by the university teaching credential program and the California Science Project (CSP). The teaching credential programming included: three education teaching performance assessment (edTPA) workshops, a restorative justice workshop, and a mock interview/resume critique workshop. The CSP programming included three NGSS single subject science workshops focused on how to deliver engaging STEM pedagogy.

Scholars were also given the opportunity to participate in three specific EL professional development programs through their fieldwork school district, which were designed to provide integrated EL-NGSS/Common Core training. First, scholars participated in a 3-day Summer Institute, which focused on deepening teachers' understanding of how ELs produce language relating to STEM content and exposing teachers to the best instructional practices for EL students. Second, scholars participated in a one-day district-wide EL Professional Development Day focused on the best practices of integrating English language maturation across STEM content areas. Lastly, several professional development sessions were provided throughout the school year to all in-service and preservice teachers.

Data Sources

Besides demographic information, three types of data were collected to develop a deeper understanding of scholars' pedagogical understanding and reflections as part of this pilot programming: interviews, surveys, and classroom observations.

Semi-structured Interview

Two researchers conducted interviews with each preservice teacher at the end of the program in order to obtain their unique perspectives on their experiences and progress throughout the program. The semi-structured interview consisted of 13 open-ended questions on the following topics: self-efficacy in STEM instruction, level of understanding of STEM pedagogy and methods for integrating EL practices into science and math teaching, ability to support the learning of all students, the program support system, and the impact of COVID-19. Interviews were conducted via password protected face-to-face Zoom sessions and lasted approximately one hour. With the participant's verbal consent, all interviews were recorded and transcribed. Interview notes and transcriptions for each participant were reviewed independently by the two researchers to identify areas of perceived professional growth. No significant differences in outcome interpretations between the two researchers were found. If differences had been found, a third researcher (one not involved in the interview process) had been recruited to review the interview transcripts and document their interpretations, but this was not needed. After thorough review, outcomes based on the interview data were documented and synthesized.

Job Status Survey

Job status in teaching survey information was gathered at the end of the program by email by a research project member to further address post-program motivation for working in a high-need school. This email was sent out three months after the participants had graduated from the credential program and were no longer receiving compensation from the study. Scholars were asked if they had pursued a teaching position. If not, had they applied for a teaching position and been declined? If yes, they were asked whether they signed a full time teaching contract, whether they were teaching in a single-subject STEM topic area, and what school and school district they were hired at. Researchers then looked up the information on the school site in order to determine if it was designated a high need school site.

Retrospective Survey

At the end of the one-year pilot program, a retrospective-post survey was administered online to participating scholars to assess their overall knowledge and skills in teaching. The survey asked a mixture of Likert scale and open-ended questions about their self-efficacy in developing, implementing, and assessing STEM lessons in general and specifically for EL students. Questions regarding their motivations to teach in general and in high-needs schools, which were used as an indicator for potential retention in teaching, were also asked. Scholars were also given the opportunity to provide feedback on program components, such as usefulness of and satisfaction with workshops, coursework, and mentor teaching at their fieldwork sites, and to provide open-ended suggestions for improvement. This survey was developed and administered by a third party external evaluator. Survey information was gathered at the end of the program, and results were not released to the research team until after the participants had graduated from the credential program and were no longer receiving compensation from the study.

Observation Ratings

At the end of the Fall 2019 and Winter 2020 quarters, subject matter credential program supervisors in charge of the single subject science and single subject mathematics cohorts (both participant and nonparticipant), and who were not members of the research team, conducted independent observations of each participating preservice student teacher on behalf of the credential program. Preservice teacher performance was observed in-person while preparing curriculum and teaching in the classroom setting. Based on these observations, Teacher Performance Expectation (TPE) Formative Evaluations were completed for each preservice teacher based on a 4-point Likert scale data (1 = *Novice Practice*, 2 = *Emerging Practice*, 3 = *Exploring Practice*, 4 = *Applying Practice*). Progress was assessed in the following teaching domains: (1) engaging and supporting all students in learning, (2) creating and maintaining effective learning environments, (3) understanding and organizing subject matter, (4) planning instruction and designing learning experiences for all students, (5) assessing student learning, and (6) developing as a professional educator. In order to be recommended for a preliminary teaching credential by any California credentialing program, student teachers must be evaluated and meet the requirements of proficiency on these six TPE domains (Commission on Teacher Credentialing, 2016).

TPE observation data was submitted by the credential program supervisors at the end of each quarter to the university and stored in a secure password protected data system. University administrators did not give the research team access to the data for the five participating scholars until several weeks after the end of each quarter. Due to COVID-19 and movement to fully online instruction, in-person observation data was unavailable for collection in the Spring 2020 quarter as planned.

Data Analysis

Using a qualitative approach to this case study, findings from the interviews, observations, and surveys were analyzed and summarized to present snapshots of each participant's pattern of growth throughout the pilot program (Hancock & Algozzine, 2017). Survey data analyses relied on Microsoft Excel, version 16.51, to obtain averages across survey responses. Three major themes of growth were identified for analysis and patterns in performance were evaluated: (1) confidence in STEM instruction, (2) self-efficacy in EL practices, and (3) interest in serving in high-needs schools. Each participant is presented as an individual case description (Hancock & Algozzine, 2017).

RESULTS

Program Effectiveness

All scholars (a) completed all required coursework, (b) completed 600 hours of fieldwork, and (c) attended program PD activities. After participating in the pilot intervention program, all scholars demonstrated significant growth in their teaching abilities in the area of STEM education across all six TPE domains of the classroom observation report rubric. Further, the scholars indicated they would use skills and strategies learned in the program to create a learning environment for all students, including EL students. All scholars also reported they had greater motivation to teach in high needs schools after having participated in the supplemental program. Two of the scholars also indicated they were motivated to participate in the supplemental programming because of the program's stated goals of helping motivate and prepare students to teach in high needs schools.

Student 1

STEM Instruction

Interview data suggested that prior to starting this program, Anthony rated his confidence in teaching math to students as a three out of ten. He explained that coming into the program, he was not confident or comfortable teaching math due a lack of experience with teaching. He stated "I knew what a class looked like, but not how to teach in one". By the conclusion of the program, Anthony demonstrated substantial growth and rated his confidence level with math instruction as an eight out of ten because he learned a lot throughout the program and now feels comfortable in the teaching role.

Observation data indicated that Anthony improved in all six teaching performance domains throughout the program (see Figure 1).

EL Practices

Interview data suggested that at the start of the program, Anthony had minimal confidence in his ability to adapt instruction for EL students, and therefore rated his abilities as a one out of ten. However, by the end of the intervention program Anthony reported that his confidence level had increased to a six out of ten. He explained that the program provided him with a substantial amount of knowledge of what EL strategies can be incorporated into curriculum instruction, but he acknowledged that he still needed more practice with incorporating them into his teaching.

A survey on self-efficacy in teaching STEM for EL students demonstrated that on average Anthony rated himself as having slight skills in adapting instruction for ELs before the program began (M = 1.29). After the program, Anthony's ratings of his abilities increased (M = 2.86) demonstrating growth in this domain (see Table 2).

Service in High-Need Schools

Anthony reported that he greatly enjoyed working within a high-needs school and was very interested in working at one in the future. Survey data also indicated that he viewed working at a high-needs school as a way for him to make a positive, worthwhile contribution to society. He noted that he was grateful for the "opportunities the program offered to become more involved in my observation site", which was a high-need school.

Student 2

STEM Instruction

Before the program started, Adam felt fairly comfortable with science instruction due to his fieldwork experiences as an undergraduate. In an interview, he rated his confidence level as a six and explained that observing teachers during fieldwork gave him a solid understanding of how he would want to teach science. Throughout the program, his confidence in his ability to teach science continued to increase and he rated himself as an eight out of ten at the conclusion of the program. He stated that he didn't rate himself higher because he felt that there is always room for improvement. Adam explained that the focus on how to incorporate the Next Generation Science Standards (NGSS) into lesson planning was the most helpful aspect of the program.

Observation data indicated that Adam made progress in four out of six teaching performance domains throughout the program. Adam's performance remained stable throughout the course of the program in two of the domains: (1) creating and maintaining effective environments for student learning and (2) planning and designing instruction (see Figure 2).

EL Practices

In an interview, Adam explained that prior to the program he did not have a lot of experience or exposure to EL students, therefore he rated himself as a four out of ten. By the conclusion of the program, he felt more comfortable with integrating EL strategies into instruction and rated himself as a seven out of ten. Adam stated "through this program, I learned that there are diverse learners with diverse needs and I need to make accommodations for different students. Understanding how to differentiate instruction is very helpful". However, he explained that his confidence in his abilities to integrate these strategies into instruction would have been higher if he had more opportunities to conduct in-person practice.

A survey on self-efficacy in teaching STEM for EL students demonstrated that on average Adam rated himself as having slight skills in adapting instruction for ELs before the program (M = 2.14). After the program, Adam's ratings of his abilities substantially increased (M = 4.00) demonstrating growth in this domain (see Table 3).

Service in High-Need Schools

Survey data indicated that Adam believes that working within a high-needs school will be professionally engaging and that he is now interested in working at a school like this. Prior to completing fieldwork within a high-needs district, Adam reported that he did not believe working with a high-need population would make a difference. His views, however, changed after completing the program and he now sees value in working within a high-needs school.

Student 3

STEM Instruction

In regard to his confidence with math instruction prior to the program, Bill explained in an interview that he “felt confident with the material but didn’t yet feel confident delivering it”. Given this, he rated himself as a five out of ten in this domain. By the conclusion of the program, he rated himself as a nine out of ten because he felt extremely comfortable delivering math content to students, yet still stated that there was room for improvement.

Observation data indicated that throughout the program Bill’s performance remained stable in five out of six teaching performance domains. He did demonstrate improvement in one domain, understanding and organizing subject matter for student learning (see Figure 3).

EL Practices

Interview data indicated that before starting the program Bill claimed that he did not know of any strategies for ELs other than direct translation. Given this, he rated his abilities as a three out of ten. Throughout the program, he demonstrated growth in regard to learning and applying EL strategies and therefore rated himself as an eight out of ten by program end.

A survey on self-efficacy in teaching STEM for EL students demonstrated that on average Bill rated himself as having slight skills in adapting instruction for ELs before the program (M = 1.00). After the program, Bill’s ratings of his abilities increased (M = 3.57) demonstrating growth in this domain (see Table 4).

Service in High-Need Schools

Bill is now very interested in working within a high-needs school and views that opportunity as a long-term career path. Survey data indicated that he believes working with high-needs schools will be professionally engaging. He reported that he finds great enjoyment from serving high-need students and is confident that he will succeed as a teacher in such a school.

Student 4

STEM Instruction

Interview data suggested that before the program started, Emily felt fairly confident in her abilities to facilitate science instruction because of her fieldwork experiences as an undergraduate. She rated her confidence level as a five and explained that during fieldwork she was able to teach a couple of lessons in the classroom and this provided her with a solid background upon entering the program. Throughout the program, her confidence in her ability to teach science improved and she rated herself as an eight out of ten at the conclusion of the program. Emily stated that “I progressed a lot from where I started and where I am now, but I feel there’s so much more I feel I still need to learn and could improve on”. She also noted that a core component in her training that was most influential was learning how to incorporate Next Generation Science Standards (NGSS) into her instructional practices.

Observation data indicated that Emily made progress in four out of six teaching performance domains throughout the program. Emily's performance remained stable throughout the course of the program in two of the domains: (1) engaging and supporting all students in learning and (2) planning and designing instruction (see Figure 4).

EL Practices

In an interview, Emily explained that at the start of the program she was only aware of two strategies to support EL students, the use of visuals and direct translation. She rated her confidence in integrating practices to support ELs as a two out of ten because she stated that she needed to learn many more strategies in order to adequately support these students. By the end of the program, she rated herself as an eight because she indicated that she had learned how to incorporate EL strategies (i.e., culturally relevant pedagogy, including multiple perspectives into instruction, emphasis on vocabulary instruction) into STEM lesson planning. She stated that she did not give herself a higher score because "there is always room for improvement and to continue to learn how to better support my students".

A survey on self-efficacy in teaching STEM for EL students demonstrated that on average Emily rated herself as having slight skills in adapting instruction for ELs before the program ($M = 1.71$). After the program, Emily's ratings of her abilities substantially increased ($M = 4.00$) demonstrating growth in this domain (see Table 5).

Service in High-Need Schools

Emily reported that she has greatly enjoyed working within a high-needs school and is now very interested in working at one. Survey data also indicated that working within a high-needs school is well suited to Emily's abilities. She explained that: "I was motivated to apply for the program because of the school [fieldwork] placement this program would offer, where it would most likely be a high-needs school. I wanted to see what it was like working at a high needs school and it was a great experience that has made me want to work in a Title I or high needs school".

Student 5

STEM Instruction

At the beginning of the program, Paul rated his confidence level in math instruction as a seven because he had a solid understanding of math content knowledge but needed to develop pedagogical knowledge. By the conclusion of the program, his confidence in his abilities based on knowledge in this category increased to a rating of a nine.

Observation data indicated that throughout the program Paul's performance remained stable in three out of six teaching performance domains. He did demonstrate improvement in one domain, creating and maintaining effective environments for student learning. However, in the other two domains, (1) understanding and organizing subject matter for student learning and (2) planning and designing instruction, Paul received lower TPE scores in the Winter when compared to the Fall (see Figure 5).

EL Practices

In an interview, Paul explained that he did not have classroom experience or personal experience to draw on prior to the program, which led to him rating his confidence level in integrating EL strategies as a six. At the end of the program, he rated his abilities as an eight because he felt that he developed an understanding of strategies to support ELs.

A survey on self-efficacy in teaching STEM for EL students demonstrated that on average Paul rated himself as having slight skills in adapting instruction for ELs before the program (M = 2.71). After the program, Paul's ratings of his abilities substantially increased (M = 4.57) demonstrating growth in this domain (see Table 6).

Service in High-Need Schools

Paul explained that he was motivated to join the program because of the "opportunity to better attain a credential and master's degree, knowing full well that I get to serve in a high-needs school district". Survey data indicated that Paul viewed working at a high-need school as a steady, long-term career path. He also noted that he strongly believed that working within a high-needs school would help to make a difference in student lives and would enable him to make a worthwhile social contribution.

Overall Teaching Status at High-Need Schools

Job status in teaching survey information was gathered at the end of the program by email to further address indications of post-program motivation for working in a high-need school. All five participants responded to the job status in the teaching survey. Four of the five participants indicated they had signed contracts for full time teaching positions in single-subject STEM topics within a high-need public school. The fifth participant (Bill) stated that due to COVID-19, he had suspended job searching in the summer months (the three months immediately after the first year of the program), but planned to apply to single-subject teaching positions in the coming year including at high-need school; in the interim he is teaching in a high-need school as a substitute teacher.

DISCUSSION

Secondary science and mathematics teachers are often considered teachers of content, however, all K-12 STEM teachers need to be able to integrate written and oral literacy practices, and develop student processing skills in order to achieve academic success (Hoffman & Zollman, 2016; Suh et al., 2020; Tolbert et al., 2014). This is particularly true given the growing diversity and multilingual background of students entering the STEM pipeline (Estrella et al., 2018; NCES, 2019b; Stoddart & Mosqueda, 2015). For example, research has shown that teachers who are able to successfully integrate science content with the development of English language and communication skills by means of contextualizing the presented information provide better support for emergent multilingual students' in both science content and in the development of academic language and literacy (Bravo & Cervetti, 2014; Garza et al., 2018; August et al., 2009). Positive STEM learning experiences have been shown to not only increase student academic readiness but feelings of science self-efficacy and sense of belonging contributing toward the positive feeling of STEM identity across educational settings (Rainey et al., 2018; Wang, 2013). This increases the likelihood of students participating in college STEM majors and continuing on into STEM-based careers (Deshler et al., 2019; LaForce et al., 2017; Sax et al., 2015), this appears particularly impactful for supporting persistence in historically underrepresented categories of students such as EL's, Latinx, and women (LaCosse et al, 2020; Ramsey et al., 2013; Rodriguez & Blaney, 2020).

However, many K-12 STEM teachers report they feel woefully underprepared to meet this challenge (August et al., 2014; Besterman et al., 2018; García et al., 2010). Previous research suggests added STEM pedagogical training can serve as a valuable resource for improving preparation for effectively teaching students who are culturally and linguistically diverse (Hoffman & Zollman, 2016; Irby et al., 2020; Suh et al., 2020). Tolbert and colleagues' (2014) study found that this can be especially useful when such information and training is presented early in teaching careers at the preservice or novice teacher stage. To address this, the present case study explored what impact a NSF Noyce scholars pilot program had on secondary science and math teacher preparedness by means of introducing supplemental activities presented at the start of their credential program and continuing throughout the school year until completion. The supplemental activities included learning about methods for introducing language development strategies for ELs as part of STEM learning, fieldwork experiences that included opportunities to work with culturally and linguistically diverse learners, and methods for developing inclusive STEM pedagogy that utilized inquiry-based practices for developing problem solving process skills and STEM literacy. Further, this study provided the opportunity to inquire on the level of support these activities contributed toward preservice teacher's feelings of preparedness when online and during times of stress (e.g., moving to full remote instruction during the earliest phase of the COVID-19 pandemic).

The primary objective of the study was to explore the impact of the scholar program within the following three areas. Addressing the first research question on the program's impact, all STEM scholar preservice teachers expressed growth in understanding of STEM content standards and pedagogical best practices. Second, all scholars, both secondary science and mathematics, expressed a greater sense of self-efficacy and capability in adapting STEM instruction for ELs at the conclusion of the program's year. Lastly, despite stressors experienced as a result of COVID-19 and early warnings of teacher burnout and potential teacher melt as a result of K-12 teaching experiences during the pandemic (Cardoza, 2021; Loewus, 2021; Pressley, 2021), all participants voiced increased motivation for seeking careers teaching in high-needs schools. Upon program completion, scholars also expressed interest in working with students from diverse backgrounds, despite pandemic remote teaching requirements still in effect (and expected to continue into the next school year) at the time of the interview. Although viewed cautiously, since it is expected that students that would apply for a scholar program that has as stated goal of placing more highly qualified STEM teaches in high-need schools might be more motivated to do this at outset (in fact two of the participants stated this in their follow-up interview), it is noteworthy that every scholar noted an increase in the interest to teach and in these locations even after what was arguably a very difficult student teaching year and it would have been understandable to have them voice no change or hesitation in light of the COVID-19 uncertainty that has brought to the profession.

In the course of this investigation, this study explored what impact the unplanned move to remote online teaching and Noyce supplemental training might have had on scholars despite these overall positive outcomes. When asked to reflect in the end-of-year interviews about

COVID-19's influence, scholar responses overlapped the most in two areas: (1) expressing that they felt they had less opportunity to support their K-12 students because of not being able to see them in person to gauge needs and responses more accurately and (2) feeling that there were fewer opportunities to practice applying the teaching strategies they were learning in the online environment. Some scholars indicated that they felt they could have excelled further because "having those few extra months of practice [in-person] would have helped a lot to pull everything together" at the end of the year. Another indicated a similar thought but elaborated that if they had been with their students in person at the end of the year it would have allowed them to wrap-up the year better and prepare students for transition more effectively. Surprisingly, several scholars noted positive effects of completing the program online, suggesting that the situation had helped them to realize how essential communication is to teaching. One scholar stated they became "more aware" of the importance of it and that in order to be effective teacher that "my communication skills with parents needs to be stronger [too]", while another indicated that being forced to teach online encouraged them to explore more methods of communication than they might have otherwise tried, "[I found that] there are so many ways and platforms that we can communicate with our students" in order to share content and interactions.

In conclusion, the piloted case study indicates that early STEM preservice teacher training leads to STEM teachers who feel better prepared to teach and have a greater sense of self-efficacy when it comes to considering how to adapt their first year instruction to meet the needs of STEM students who are culturally and linguistically diverse. This sense of preparedness served to increase their motivation to work in high needs schools and was still resilient in the face of job stressors (i.e., COVID-19 and online instruction).

These findings have implications for improving the quality and responsiveness of STEM teaching in middle school and high school classroom settings by suggesting the importance of offering added STEM content and pedagogical training earlier in a STEM teacher's career, starting as early as the initial preservice student teacher phase and continuing for the length of the teaching credential. These findings also support the literature on incorporating not only expanded training on best practices for presenting STEM academic content, but also specific pedagogical information on how to provide linguistic support for ELs throughout this early part of training. Further, these outcomes have expected implications for increasing a STEM teacher's feelings of capability and preparedness, but also unexpected implications that such early programming could be effective when delivered both in-person and in online formats and may foster a greater sense of resilience in STEM teachers helping them respond with greater motivation to early teacher career stress.

However, there are limitations to these findings that must be acknowledged before this information can be fully generalized. Fieldwork observation data for the third time point (Spring 2020) was not collected as planned. This was due to migrating to remote learning environments during that time. Online classrooms were set up in an emergency capacity by the partner school district and video access was restricted to only critical teachers. Future planned research is expected to include time to coordinate access to any remote environments and/or resume in-person instruction. Additionally, future versions will broaden to include not only a greater number of STEM scholars but a control group (another group of early STEM student teachers in the same institution) to compare measurements of growth, motivation, self-efficacy, etc.

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APPENDIX

Table 1
Demographic Characteristics of Preservice Teachers

Characteristics	Participants (*n* = 5)
Gender	
Male	4 (20%)
Female	1 (80%)
Racial/Ethnic Background	
Chicano/Mexican American	2 (40%)
Philipino/Filipino	1 (20%)
Vietnamese	1 (20%)
Decline to State	1 (20%)
Credential Subject	
Math	3 (60%)
Science	2 (40%)

Table 2
Student 1 EL Survey

	Before Program	After Program
Ability to implement teaching practices for EL students	1	3
Ability to reflect on teaching practices to improve instruction for EL students	1	4
Ability to connect theoretical knowledge in EL training with practical experiences	1	3
Ability to engage EL students in STEM learning	1	2
Ability to create an effective environment for EL students for learning STEM	2	3
Ability to establish clear expectations for positive classroom behavior for STEM EL lessons	2	3
Ability to modify lessons to enable EL students to have access to the curriculum	1	2

Table 3
Student 2 EL Survey

	Before Program	After Program
Ability to implement teaching practices for EL students	1	4
Ability to reflect on teaching practices to improve instruction for EL students	1	4
Ability to connect theoretical knowledge in EL training with practical experiences	1	4
Ability to engage EL students in STEM learning	3	4
Ability to create an effective environment for EL students for learning STEM	3	4
Ability to establish clear expectations for positive classroom behavior for STEM EL lessons	3	4
Ability to modify lessons to enable EL students to have access to the curriculum	3	4

Table 4
Student 3 EL Survey

	Before Program	After Program
Ability to implement teaching practices for EL students	1	4
Ability to reflect on teaching practices to improve instruction for EL students	1	4
Ability to connect theoretical knowledge in EL training with practical experiences	1	4
Ability to engage EL students in STEM learning	1	2
Ability to create an effective environment for EL students for learning STEM	1	3
Ability to establish clear expectations for positive classroom behavior for STEM EL lessons	1	4
Ability to modify lessons to enable EL students to have access to the curriculum	1	4

Table 5
Student 4 EL Survey

	Before Program	After Program
Ability to implement teaching practices for EL students	2	4
Ability to reflect on teaching practices to improve instruction for EL students	2	5
Ability to connect theoretical knowledge in EL training with practical experiences	1	4
Ability to engage EL students in STEM learning	1	3
Ability to create an effective environment for EL students for learning STEM	2	4
Ability to establish clear expectations for positive classroom behavior for STEM EL lessons	2	4
Ability to modify lessons to enable EL students to have access to the curriculum	2	4

Table 6
Student 5 EL Survey

	Before Program	After Program
Ability to implement teaching practices for EL students	1	4
Ability to reflect on teaching practices to improve instruction for EL students	1	4
Ability to connect theoretical knowledge in EL training with practical experiences	1	4
Ability to engage EL students in STEM learning	4	5
Ability to create an effective environment for EL students for learning STEM	4	5
Ability to establish clear expectations for positive classroom behavior for STEM EL lessons	4	5
Ability to modify lessons to enable EL students to have access to the curriculum	4	5