## Title
Examining the Effects of Undergraduate STEM Education and Teacher Education on Preservice Science and Mathematics Teacher Readiness and Teacher Performance Assessment (edTPA) Scores



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**Publication Date**
2018

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA

Santa Barbara

# Examining the Effects of Undergraduate STEM Education and Teacher Education on Preservice Science and Mathematics Teacher Readiness and Teacher Performance Assessment (edTPA) Scores

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Education

by

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ACKNOWLEDGEMENTS

I would like to express my thanks to my committee, Julie A. Bianchini, Danielle B. Harlow, Karen Nylund-Gibson, and Nancy Collins. Special thanks to my faculty advisors, Julie A. Bianchini and Danielle B. Harlow for being such great mentors throughout my time in graduate school. Thanks to everyone in the CTPSE and STELLER research teams, and special thanks to the SMTRI research team members who helped collect and score survey data to make my dissertation possible.

I want to dedicate this dissertation to my family, especially to my wife, Hawook, who always has complete confidence in me.

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Moon, S. (2004). Research on how to graft science education of China into ICT-using education of Korea. Suwon, Korea; Gyeonggi Provincial Office of Education.

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# ABSTRACT

Examining the Effects of Undergraduate STEM Education and Teacher Education on Preservice Secondary Science and Mathematics Teacher Readiness and Teacher Performance Assessment (edTPA) Scores

by

Sungmin Moon

In this study, the effects of teacher education on preservice secondary science and mathematics teacher readiness (defined as an understanding of how to implement current standards, how to teach English learners, and the belief teachers have about their abilities and skills as educators) and teacher performance assessment (edTPA) scores were examined. Its purpose was to provide insight into ways to better prepare teachers to teach their discipline in reform-based ways to all students. To do so, a subset of preservice teachers (teacher candidates) enrolled in a teacher education program at one of six California public universities participated. To determine teacher readiness, participants completed a survey, composed of both five-point Likert scale questions and open-ended response questions, at the beginning and end of their program. Their responses to both surveys were scored based on a rubric used in previous, related studies. The scores were compared between preservice teachers who had completed undergraduate STEM education programs and those who had not at the beginning of their teacher education programs. The scores were then analyzed for significant changes in teacher readiness between the beginning and end of the program using repeated measures analysis. The scores were also analyzed for differences among participants attending fifth-year, post-baccalaureate teacher education programs and an experimental undergraduate program. Further teacher performance assessment (edTPA) scores were analyzed to determine possible associations with teacher readiness using canonical correlation analysis. Undergraduate STEM education programs were effective in developing standards-based instruction. Fifth-year, post-baccalaureate teacher education programs were effective in developing language, literacy, and EL instruction, whereas an experimental undergraduate teacher education program was not. Both undergraduate STEM education programs and teacher education programs were not very effective in developing teacher efficacy. Findings suggest that teacher educators and curriculum developers involved in undergraduate STEM education programs should consider how to address and include the topic of language, literacy, and EL instructions in their programs. Teacher educators involved in teacher education programs should consider how to improve preservice teachers' understanding of standards-based instruction through their programs as well.

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Students in the United States have fallen below the average in international competitions and tests in mathematics and science. For example, 2012 results from the Program for International Student Assessment [PISA] (Organization for Economic Co-operation and Development, or OECD, 2012) revealed that 15-year-old students' performance in the U.S. ranked 27$^{th}$ in mathematics out of 34 countries: US students scored 13 points lower than the OECD mean score of 494. PISA and other similar studies (e.g., The Trends in International Mathematics and Science Study, or TIMSS) have provided consistent evidence that students in the U.S. are falling steadily behind their counterparts in East Asia and the European Union.

On the 2015 National Assessment of Educational Progress (NAEP, 2016), the only nationally standardized test in the U.S., just 24 percent of California fourth and eighth graders tested proficient in science. The average score of fourth- and eighth-grade students in California was 140 and 143 respectively. Even though California's fourth-grade scores rose 4 points from 2009, their last measurement, and California's eighth-grade scores rose 3 points from 2011, their last test, these scores are still well below the average. Fourth graders scored 13 points below the national average (153) and eighth graders scored 10 points below the national average (153). California fourth-graders ranked third to last, and eighth graders fifth to last, just above Hawaii, Alabama, New Mexico and Mississippi. New Hampshire, with 51 percent proficient, topped the fourth-grade list, and Utah, with 50 percent proficient, topped the eight-grade list. The science results were in line with

California’s mathematics and English NAEP scores, which were released previously, and for which, California also fell among the lower-scoring group of states.

Not only are U.S. students’ test scores low, many of the nation's most talented students in science, technology, engineering, and mathematics (STEM) are not entering these academic fields, or are leaving at some point during their post-academic careers (National Science Foundation, 2006a; 2006b; 2006c; 2008). The number of engineering degrees awarded since 1985 has decreased 20% domestically (Froschauer, 2006). This has ultimately resulted in the decline of scientific literacy among our citizenry. All of this has occurred at an inopportune time when our society is becoming increasingly dependent on advanced technologies.

## Statement of Problem

Low achievement in science and mathematics has been attributed to a number of challenges, including a lack of instruction appropriate for English learners (Bravo, Solis, & Mosqueda, 2011), a rapidly growing student population in US schools, and a shortage of qualified teachers (Darling-Hammond, 2000; Harris & Sass, 2011; Rice, 2003; Stronge, Ward, Tucker, & Hindman, 2007).  A quality teacher has been found to be highly influential in promoting student interest in a discipline (Christidou, 2011). A teacher’s ability to create a classroom environment that encourages students to engage in science or mathematics affects the interests and attitudes that students hold about these disciplines (Talton & Simpson, 1986). Students need to feel encouraged to explore and ask questions to develop interests in science or mathematics.

The country is experiencing a severe teacher shortage with no sign of improvement. According to recent data (ACT, 2015), fewer high school graduates are interested in pursuing education majors and fewer college students are pursuing teaching careers (see Table 1) than four years ago.

Table 1

*Trends of Student Interest in Education Majors*: *2010 - 2014*

| | | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| | Percent (%) | 7 | 6 | 6 | 5 | 5 |
| Nation | *N* Count | 106,478 | 103,932 | 94,458 | 91,186 | 89,192 |

*Note.* Between 2010 and 2014, the percent of all ACT-tested graduates who expressed an interest in education majors decreased by 2% (ACT, 2015).

California's teacher shortage is worsening, with many districts struggling to find enough qualified teachers to fill vacancies. According to a recent statewide survey in California (Podolsky & Sutcher, 2016) of 211 school districts in the California School Boards Association's Delegate Assembly, approximately 75 percent of districts indicated having a shortage of qualified teachers for the 2016 – 2017 school year, with the greatest needs for those seeking special education teachers, mathematics teachers, and science teachers (see Figure 1). Further, teacher shortages are concentrated in districts serving California's most vulnerable student populations, with 83 percent of districts with the largest concentration of English Learners (ELs) reporting having shortages, compared to 64 percent of districts with the fewest. Districts reported a variety of methods for addressing their shortages. About 55 percent of vacancies were filled by teachers with emergency or temporary credentials, 24 percent were filled with long-term substitutes, 17 percent left the position vacant, 9 percent increased class sizes because of too few teachers, and 8 percent cancelled courses (Podolsky, & Sutcher, 2016).

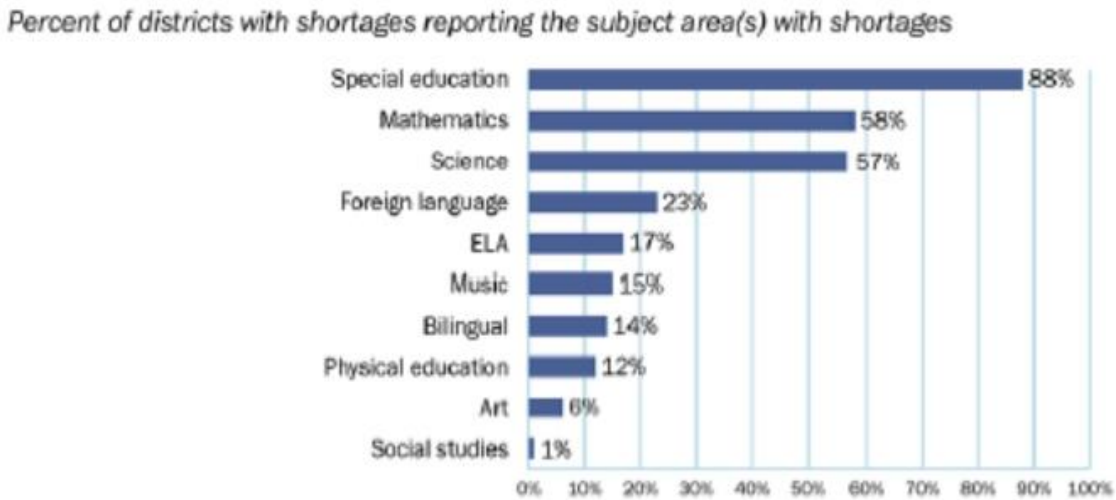



*Figure 1.* Teacher shortages by subject area (Copyright 2016 Podolsky & Sutcher).

English learners (ELs) account for more than 9 percent of the students currently enrolled in K-12 classrooms in the U.S. (National Center for Education Statistics, 2016). The highest concentrations of ELs are found in the six traditional immigrant-destination states: California, Texas, New York, Florida, Illinois, and New Jersey. In California, 2.7 million students or 43 percent of the state's public school enrollment speak a language other than English at home and 1.4 million students or 22 percent of students are designated as ELs (California Department of Education, 2014). The majority of California's ELs are native-born. National estimates reveal that 82 percent of current EL students in grades K-5 are native-born, but this percentage drops to 55 percent in grades 6-12 (Migration Policy Institute, 2012). Therefore, many older EL students are likely to be foreign-born. Although many ELs need to gain proficiency in English, that does not necessarily mean they are less capable. According to the US Census Bureau's 2011 American Community Survey (ACS), one in three immigrants has obtained a college degree. Nationwide, immigrants accounted for 16 percent of the 58.8 million college-educated population and approximately 28 percent of college-educated immigrants were limited English proficient. Furthermore, the immigrants who have recently come to the US are the most highly educated in history. A new Pew Research Center analysis of U.S. Census Bureau data (2015) shows that 40 percent of immigrants arriving in the US in the past five years had completed at least a bachelor's degree (see Figure 2). ELs in K–12 classrooms are not less capable than their native-born peers, but they may be perceived to be less capable because of their developing English proficiency. In this regard, when planning and designing curriculum and instruction for ELs, teachers need to consider what kinds of content will be appropriate to their intellectual capacity and how to engage them in learning practices, such as performing cognitively demanding tasks in science or mathematics.

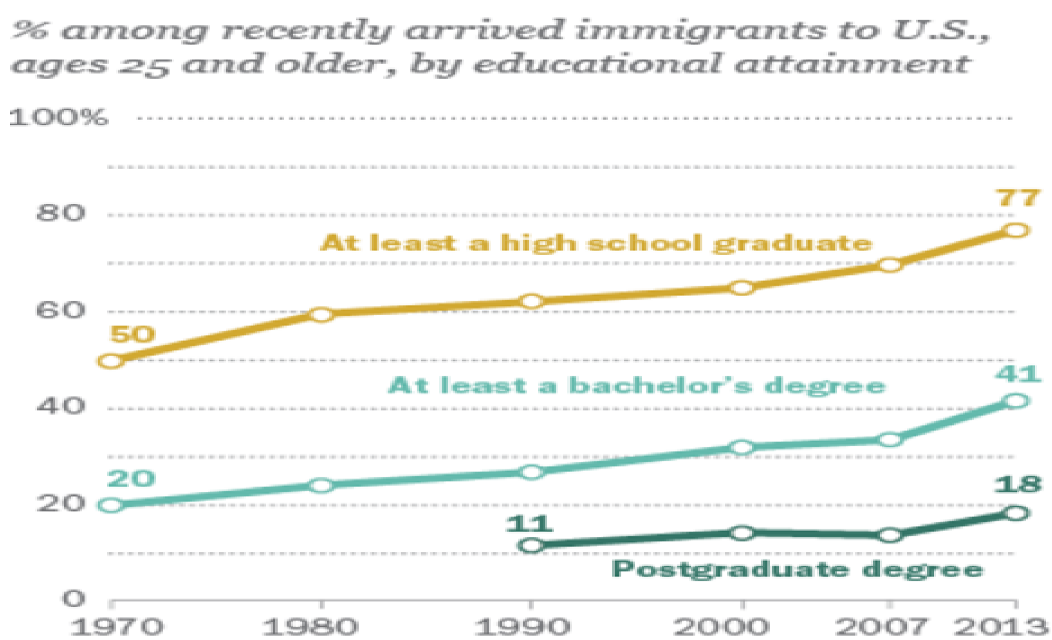



*Figure 2.* Today's newly arrived immigrants are more educated than ever (Copyright 2015 Pew Research Center).

## Purpose and Rationale

In 2012, the National Research Council (NRC) released *A Framework for K–12 Science Education* to guide the development of a new set of national standards in science, the *Next Generation Science Standards* [*NGSS*] (NGSS Lead States, 2013). *A Framework for K-12 Science Education* refines what it means to promote the learning of science by moving away from prior approaches that emphasized detailed facts or loosely defined inquiry to a three-dimensional view of science and engineering practices, crosscutting concepts, and disciplinary core ideas (Lee, Quinn, & Valdés, 2013). California adopted the *NGSS* as its state science education standards. Similarly, in mathematics education, California adopted a revised version of the *Common Core State Standards* [CCSS] – *Mathematics* (Common Core State Standards Initiative, 2010) in August 2010, replacing the 1997 state mathematics academic standards.

To help recruit and better prepare beginning science and mathematics teachers in California, a group of public universities launched undergraduate STEM education programs in 2005. This program seeks to motivate talented undergraduates to explore careers as science or mathematics teachers by providing special coursework and field experiences in K-12 classrooms while they complete their undergraduate degrees. For students who opt to consider teaching, the program offers a coherent sequence of courses in science or mathematics education. This sequence is designed to provide an early introduction to a practical experience in K-12 classrooms within a science or mathematics context. Students take on a variety of roles in classrooms, from observing to assisting with teaching. These experiences provide the participants direct contact with K-12 students and also give them a sense of responsibility and purpose. Participants develop scientific thinking and mathematical reasoning skills, and learn research and evaluation methods.

In California, with the exception of experimental teaching credential programs, teacher education programs (TEPs) are administered at the post-baccalaureate level. For five of the universities participating in this study, the teacher education programs were a one-year, post-baccalaureate program (2 summers and one academic year). Preservice teachers have the option to earn both a California teacher credential and a master’s degree. The TEPs provide the knowledge and experience in university and school classrooms needed to begin a teaching career. The credential programs are an accelerated 13-month full-time program, beginning in summer and concluding the following summer. Partnerships with local schools provide preservice teachers with opportunities to become involved in all aspects of school life. University supervisors assigned to a school campus work closely with cooperating teachers to mentor teacher candidates. Strong collegial relationships enhance professional growth. Learning to teach is developmental in nature, and reflection is supported by strong professional relationships among the candidates and faculty. Program faculty bring a variety of expertise through their roles as professors of education, clinical faculty, practicing teachers, and school administrators. Candidates may only pursue a master’s degree if also pursuing a California teacher credential in the TEP. The master’s degree is only and always an addition to the teacher credential. Furthermore, successful completion of all state and institutional requirements for a credential is a prerequisite for granting the master’s degree. As a graduate degree, the degree demands a special commitment to independent, scholarly work outside of fieldwork, class meetings, and assignments.

The TEPs provide preparation for teaching English language learners in a regular classroom setting because the program aims to prepare teachers for California's culturally and linguistically diverse children and youth. Course includes methods of teaching a second language and developing academic literacy in all discipline areas. Through a combination of coursework, classroom placements and research projects, preservice teachers learn to integrate theoretical perspectives with teaching practice to be informed, articulate, analytical leaders of educational reform within schools and the communities.

One of the programs participating in the study was an experimental teacher education program, where undergraduates who have completed the undergraduate STEM (science, technology, engineering, and mathematics) education minor program and have declared a major in a STEM field are eligible to apply for the credential program, which supports them to get a mathematics or science secondary school teaching credential and begin teaching middle or high school after graduation. Students admitted to the credential program engage in student teaching and enroll concurrently in the final STEM education minor course, *Apprentice Teaching*. This program is unusual in the state of California in that it grants credentials concurrent with undergraduate education. This allows preservice teachers to enter the classroom earlier, and with less expense, than they would have with a post-baccalaureate credential. Admission to the credential program is restricted to students who are STEM majors.

## Research Questions

This research examined if and how undergraduate STEM education programs and teacher education programs contributed to facilitating science and mathematics teacher readiness and improving teacher performance assessment (edTPA) scores. Teacher readiness was defined as how well preservice teachers were aware of and prepared for (1) the implementation of the *NGSS* science and engineering practices or the CCSS mathematical practices (i.e., standards-based instruction); (2) the facilitation of language and literacy development for all students, including English learners (i.e., language, literacy, and EL instruction); and (3) the belief that teachers have about their abilities and skills as educators (i.e., teacher efficacy). Teacher readiness was compared between preservice teachers (teacher candidates) who had completed undergraduate STEM education programs and those who had not at the beginning of their teacher education program. I investigated whether there was a significant change (increase) in the levels of teacher readiness between the beginning and end of the program among preservice teachers enrolled in their teacher education program and whether the change over time differed between participants attending fifth-year programs (at the graduate level) and an experimental undergraduate program (at the undergraduate level) and between those who had completed undergraduate STEM education programs and those who had not. Further, I determined how teacher readiness was associated with teacher performance assessment (edTPA) scores. I posed the following three sets of research questions:

1. Were there significant differences in the levels of teacher readiness (teacher efficacy, standards-based instruction, and language, literacy, and EL instruction) between preservice teachers who had completed undergraduate STEM education programs and those who had not at the beginning of their teacher education program?

2. Was there a significant change (increase) in the levels of teacher readiness between the beginning and end of the program among preservice teachers enrolled in their teacher education program?
    a. Did the change over time differ between preservice teachers attending fifth-year programs (at the graduate level) and an experimental undergraduate program (at the undergraduate level)?
    b. Did the change over time differ between preservice teachers who had completed undergraduate STEM education programs and those who had not?
3. Were there significant correlations between teacher readiness (as determined by the post-survey) and their edTPA scores? Or what set of the teacher readiness construct best predicted their edTPA scores?

# Chapter II: Literature Review and Conceptual Framework

## Overview

There has been a fair amount of research on how to prepare preservice teachers to become qualified teachers to meet the needs of the new era. My research study builds on three previous research efforts. One, it draws on a model of science teacher quality for cultivating 21$^{st}$ century skills. This model was presented by Windschitl (2009), suggesting that the learning goals of 21$^{st}$ century skills can be achieved in the context of scientific inquiry or project-based learning. Two, it draws on an instructional framework, *the Secondary Science Teaching with English Language and Literacy Acquisition* (SSTELLA) Framework (Tolbert, Stoddart, Lyon, & Solis, 2014), which built on the prior research project, *Effective Science Teaching for English Language Learners* (ESTELL), which was developed with the primary goal of restructuring  elementary science methods courses and focuses on engaging novice elementary teachers in personal learning experiences of science through integrated science content and science methods lessons (Stoddart et al., 2010). The SSTELLA framework was designed to prepare teachers to effectively integrate science, language, and literacy instruction for ELs by promoting the productive use of science language in authentic contexts, whereby "students are supported in using multiple resources and strategies for learning science and developing English" (Lee et al., 2013, p. 229). Finally, a survey on teachers' efficacy about effective pedagogy for ELs administered to preservice teachers at the onset and again at the completion of their teacher education program (Bravo, Solis, & Mosqueda, 2011) informed the overall structure of my research study.

## Literature Review

Windschitl (2009) presented a model of science teacher quality for cultivating 21st century skills, suggesting that the learning goals of 21st century skills can be achieved in the context of scientific inquiry or project-based learning. This requires ambitious teaching practices as follows: (1) deep interconnected content knowledge, or ability to “see” big ideas in curriculum and understand how to teach these as big ideas; (2) ability to engage students in specialized classroom discourses aligned with reform goals; (3) understanding the full range of assessment strategies, purposes and contexts within which they should be used; and (4) understanding how to learn from one’s practice. While implementing ambitious teaching practices, it is important to consider the following challenges as research tells us: (1) content knowledge is very important, and is related to student learning (Magnusson et al., 1992); and (2) preservice teachers come into preparation with deeply engrained theories about what counts as good teaching and what counts as learning. These theories can be resistant to change and may filter out the learning of new approaches to science instruction, unless teacher educators surface these theories and work actively to counter them.

An instructional framework, *the Secondary Science Teaching with English Language and Literacy Acquisition* (SSTELLA) Framework (Tolbert, Stoddart, Lyon, & Solis, 2014), was developed to help secondary science teachers teach science to English learners (ELs), who are the fastest growing sector of the school-age population but have the least access to the core academic curriculum (Genesee, Lindholm-Leary, Saunders, & Christian, 2005; Janzen, 2008; U.S. Census Bureau, 2010). The SSTELLA framework

(Tolbert, Stoddart, Lyon, & Solis, 2014) reflected principles from the Science Framework (NGSS Lead States, 2013) and was designed to prepare teachers to effectively integrate science, language, and literacy instruction for ELs by promoting the productive use of science language in authentic contexts. ELs' achievement in science and literacy has lagged behind that of mainstream students for over 30 years (Lee & Luyxk, 2006; National Center for Education Statistics [NCES], 2011; Rodriguez, 2010). Further, gaps in achievement are larger for secondary students when compared to elementary school students (NCES, 2011). Although this gap continues to widen, current teacher education programs are not likely to provide adequate educational opportunities to deal with this issue for preservice teachers (Ballantyne, Sanderman, & Levy, 2008; Darling-Hammond, 2006; Gandara, Maxwell- Jolly, & Driscoll, 2005). Instructional strategies about how to teach ELs science or mathematics have been rarely offered to science or mathematics preservice teachers through their coursework. Therefore, new science or mathematics teachers start their teaching career with a limited knowledge about how to teach ELs science or mathematics. The challenge for teacher education programs is to prepare preservice teachers to teach ELs by integrating science or mathematics instruction with the development of English language and literacy (Tolbert, Stoddart, Lyon, & Solis, 2014). Topics about language and literacy development, or cultural and linguistic diversity have been presented in separate courses which focus was on social conditions rather than on science or mathematics (Trent et al., 2008). To fill the gap between teacher education programs and the needs of the educational field, teacher education programs need to try harder to develop and offer courses which integrate the development of academic language and literacy with the teaching of science or mathematics content (Tolbert, Stoddart, Lyon, & Solis, 2014).

Prior to the SSTELLA Framework, a research project, *Effective Science Teaching for English Language Learners* (ESTELL), was carried out to restructure elementary science methods courses to engage novice elementary teachers in personal learning experiences of science through integrated science content and science methods lessons (Stoddart et al., 2010). The ESTELL project focused on improving the science teaching and learning of K-6 linguistic minority students who are currently underserved in education. The goal of the ESTELL project was to design, implement, and evaluate a comprehensive, integrated model of preservice elementary science teacher education by adapting a model of linguistically and culturally responsive ESTELL pedagogy that significantly improves the achievement of ELs. Their research identified five areas of teaching practice that promote the achievement of ELs: (1) Language and Literacy (LL), or teacher use of authentic science literacy tasks to support science learning and teacher use of science discourse patterns and science vocabulary; (2) Contextualization (C), or teacher elicitation of student expertise from home/community (culture) or local (environmental/natural surrounding) understandings of science-related phenomena in classroom science lessons; (3) Collaborative Inquiry (CI), or student-led participation in science activities with a shared goal resulting in a material or symbolic product used for or an outcome of scientific processes; (4) Instructional Conversation (IC), or teacher initiation of conversation that requires student scientific reasoning and dialogue; and (5) Complex Thinking (CT), or teacher elicitation and modeling of complex reasoning of science concepts. The SSTELLA Framework is considered an extension of the ESTELL Framework (Stoddart, Bravo, Solis, Mosqueda, & Rodriguez, 2011).

These frameworks reflect the reciprocal and synergistic relationships among science, language, and literacy. Lee, Quinn, and Valdés (2013) examined intersections between the learning of science and the learning of language. They identified key features of the language of the science classroom as engaging students in the NGSS language-intensive science and engineering practices (i.e., developing and using model; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information). Contemporary research on language in science learning and teaching highlights what students and teachers *do* with language as they engage in science inquiry and discourse practices (Carlsen, 2007; Kelly, 2007). This way both science learning and language learning are promoted. The NGSS science and engineering practices are presented as a representation of what students must do to learn and understand science in ways that are similar to what scientists do in the real world. In particular, engagement in the language-intensive practices promotes both scientific sense-making and language development. For example, students must read, write, view, and visually represent their ideas as they develop models and explanations. They speak and listen as they present their ideas or engage in argumentation with others to refine their ideas and reach shared conclusions. Teachers implementing these practices need an understanding both of the practices and strategies to include all students regardless of their English proficiency and of the classroom culture of discourse that must be developed and supported even though a model or explanation proposed by ELs turns out to be a flawed use of language. Such engagement can provide an opportunity to learn both science and language for ELs.

The same article (Lee, Quinn, & Valdés, 2013) introduced the term *language of the science classroom* that includes the registers (i.e., styles of talk) used in the science classroom by teachers and students as they participate in academic tasks and activities in oral or written forms. They argued that language of the science classroom is grounded in everyday language but moves toward the disciplinary language of science as the grade level advances. For example, academic language of science can be used when teachers or students are describing models, constructing arguments, or providing written or oral explanations of a phenomenon or system. Students can also improve discipline-specific written language by reading lab manuals, searching for internet materials, reading science articles, writing class assignments, or even reading syllabi. However, it is still unclear how much the implementation of *language of science classroom* can contribute to the development of both language and science for students (including ELs).

Bravo, Solís, and Mosqueda (2011) conducted a survey on teachers' efficacy about effective pedagogy for ELs. They administered a total of 105 preservice teachers at the onset and again at the completion of their teacher education program. They presented five instructional practices to measure as follows: (1) language and literacy in science; (2) contextualization; (3) facilitating collaborative inquiry; (4) promoting science talk; and (5) promoting scientific reasoning. Out of these five instructional practices, there was no statistically significant change between pre-survey and post-survey results on language and literacy in science and promoting science talk. The research team also observed the teacher candidates teaching a science lesson, using a researcher-created observational protocol. They proposed a total of six criteria to evaluate teachers' efficacy about effective pedagogy for ELs as follows: (1) facilitating collaborative inquiry; (2) promoting science talk; (3) literacy in science; (4) scaffolding and language development; (5) contextualization; and (6) promoting scientific reasoning and inquiry. Each observation was scored on a 4-point scale (not present: 0, introducing: 1, implementing: 2, and elaborating: 3). Results showed that with the exception of two instructional practice areas (i.e., facilitating collaborative inquiry and contextualizing science activity), teacher candidates implemented all other four instructional practices at the introductory level (ranging from 1.15 – 1.37), suggesting that teacher candidates were using but not explaining science discourse patterns to students while giving limited to no follow-up (promoting science talk), offering some basic science literacy tasks with no explicit instruction on science tools while providing limited instruction on key vocabulary (literacy in science), providing implicit instruction on English language structures with minimal modified scaffolding for ELs (scaffolding and language development), and listing prior student science knowledge while leading all phases of the inquiry process (promoting scientific reasoning and inquiry).

## Conceptual Framework

My research study examined if and how undergraduate STEM education programs and teacher education programs contributed to facilitating science and mathematics teacher readiness and improving teacher performance assessment (edTPA) scores. Teacher readiness was defined as how well preservice teachers were aware of and prepared for (1) the implementation of the *NGSS* science and engineering practices or the *CCSS* mathematical practices (i.e., standards-based instruction); (2) the facilitation of language and literacy development for all students, including English learners (i.e., language, literacy, and EL instruction); and (3) the belief that teachers have about their abilities and skills as educators (i.e., teacher efficacy).

**Reform-Based Instruction**

In 2012, the National Research Council (NRC) released *A Framework for K–12 Science Education* to guide the development of a new set of national standards in science, the *Next Generation Science Standards* [*NGSS*] (NGSS Lead States, 2013). *A Framework for K-12 Science Education* refines what it means to promote the learning of science by moving away from prior approaches that emphasized detailed facts or loosely defined inquiry to a three-dimensional view of science and engineering practices, crosscutting concepts, and disciplinary core ideas (Lee, Quinn, & Valdés, 2013). California adopted the *NGSS* as its state science education standards. Similarly, in mathematics education, California adopted a revised version of the *Common Core State Standards – Mathematics* (Common Core State Standards Initiative, 2010) in August 2010, replacing the 1997 state mathematics academic standards.

Both sets of standards include eight disciplinary practices that teachers are asked to engage their students in. In science, which includes engineering practices as well, the eight science and engineering practices are as follows: (1) asking questions (for science) and defining problems (for engineering); (2) developing and using models; (3) planning and carrying out investigations; (4) analyzing and interpreting data; (5) using mathematics and computational thinking; (6) constructing explanations (for science) and designing solutions (for engineering); (7) engaging in argument from evidence; and (8) obtaining, evaluating and communicating information. The *Framework* presents the following rationale for why the practices are important.

> Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Engaging in the practices of engineering likewise helps students understand the work of engineers, as well as the links between engineering and science. Participation in these practices also helps students form an understanding of the crosscutting concepts and disciplinary ideas of science and engineering; moreover, it makes students' knowledge more meaningful and embeds it more deeply into their worldview. (p. 42)

The mathematical practices (MP) standards describe expertise that mathematics educators at all levels should seek to develop in their students as follows: (1) make sense of problems and persevere in solving them; (2) reason abstractly and quantitatively; (3) construct viable arguments and critique the reasoning of others; (4) model with mathematics; (5) use appropriate tools strategically; (6) attend to precision; (7) look for and make use of structure; and (8) look for and express regularity in repeated reasoning. These MP standards are designed to be connected to the standards of mathematical content. These connections are essential to support the development of students' broader mathematical understanding because students who lack understanding of a topic may rely heavily on procedures (Common Core State Standards Initiative, 2010a, 2010b).

To effectively implement the new standards in science and mathematics education, then, teacher knowledge of the *NGSS* science and engineering practices or the *CCSS* mathematical practices is considered essential. Desimone (2009) demonstrated that a teacher's instructional practice can impact student interest and achievement more than advanced degrees or teaching experience. Identifying a core set of science and mathematics teaching practices may be one key approach to improving science and mathematics education.

**Effective EL Instruction**

Given the changing demographics of the US student population, science and mathematics teachers need a deep understanding not only of how to implement the recent standards, but also of how to teach ELs. Indeed, in California, where this study was conducted, 2.7 million students or 43 percent of the state's public school enrollment speak a language other than English at home and 1.4 million students or 22 percent of students are designated as ELs (California Department of Education, 2014).

Integrating the teaching of science content with the development of English language and literacy through contextualized science inquiry has been consistently shown to increase ELs' achievement in both science and the development of academic language and literacy (Bravo & Garcia, 2004; Echevarria, Vogt, & Short, 2004; Hart & Lee, 2003; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008; Rivet & Krajcik, 2008; Rosebery & Warren, 2008; Stoddart, 2005; Stoddart, Pinal, Latzke, & Canaday, 2002). The advances in teaching science and English language and literacy to ELs are consonant with the discourse about the development of NGSS for science, as well as CCSS for mathematics. The NGSS represents a major shift from scientific literacy as decontextualized content toward scientific literacy as the integrated use of science language with science content to resonate with what scientists do in the real world, such as planning investigations, developing models, or arguing from evidence (Tolbert, Stoddart, Lyon, & Solis, 2014). As science classrooms incorporate the language-intensive science and engineering practices described in the Framework and NGSS, all students experience richer language learning environments as well as richer science learning environments (Lee, Quinn, & Valdés, 2013). Teachers can support their students through classroom practices that make explicit the features of the disciplinary language of science, so that students can build linguistic awareness using the disciplinary language for challenging tasks (Fang & Schleppegrell, 2008).

Aguirre, Zavala, and Katanyoutanant (2012) collected data from 40 preservice mathematics teachers who were taking a mathematics methods course at an urban university in the Pacific Northwest region of the United States to investigate their thoughts about a culturally responsive mathematics teaching (CRMT) tool. The CRMT tool is made up of eight dimensions that approximate the categories of mathematics thinking, language, culture, and social justice: Intellectual Support (IS), Depth of Knowledge and Student Understanding (DofK & SU), Mathematical Analysis (MA), Mathematics Discourse and Communication (MD & C), Student Engagement (SE), Academic Language Support for ELLs: Use of L1 (ALS:A) and Use of ESL Scaffolding Strategies (ALS:B), Funds of Knowledge, Culture, and Community Support (CFoK), and Use of Critical Knowledge, Power, and Social Justice (CMSJ). Findings revealed that preservice mathematics teachers felt very confident that they could or did address important dimensions of children's mathematical thinking within their lessons, including an emphasis on analysis, discourse, and student engagement. However, preservice mathematics teachers showed substantial variabilities in responses related to the categories associated with language, cultural funds of knowledge and critical mathematics/social justice. There was a range of teacher receptivity and resistance that are consequential to improving their lessons from a culturally responsive standpoint. Their study suggests that preservice mathematics teachers will need additional support to attend to and integrate these constructs into their practice.

How to include ELs in learning context and support them regardless of their levels of English proficiency has been discussed for a long time and greatly advanced among educators and researchers (Lacelle-Peterson & Rivera, 1994). As the NGSS and CCSSM incorporate language-intensive practices, science and mathematics teachers need to attend to the development of academic language and literacy along with science or mathematics content for ELs. There have been attempts to integrate the teaching of language and the teaching of science or mathematics in previous decades. For example, content-based language instruction was introduced to counter traditional "content-less" language instruction which focused more on forms and minimized the importance of meaningful and authentic use in the acquisition of language (Brinton's work, 1989, as cited in Lee, Quinn, & Valdés, 2013). However, content-based language instruction was designed to be taught by language specialists, not by content specialists, which resulted in inadequate content teaching. So, this approach gained only limited success. Content-based language instruction was then replaced with "sheltered" instruction. Sheltered instruction is designed to provide ELs with the same high quality, academically challenging content that native English speakers receive (Hansen-Thomas, 2008). Sheltered classes can be team-taught by an English as a Second Language (ESL) teacher and a content-area teacher or taught by a content-area specialist trained in sheltered instruction. Content-area teachers, however, are often directed at the study and practice of forms and language items such as vocabulary, phrases, or sentence frames, which leads to very limited effect (Lee, Quinn, & Valdés, 2013). Current language instruction is moving toward experiential approaches or task-based instruction, where language-in-use environments are created. In this environment, appropriate contexts and experiences are provided and the opportunities for language development are offered instead of teaching them as discrete language skills. Students engage in classroom discourse using the disciplinary language of science or mathematics while implementing the NGSS science practices or the CCSS mathematics practices (Lee, Quinn, & Valdés, 2013).

My research study reported here was framed by four key principles of effective EL instruction in science and mathematics (Roberts, Bianchini, Lee, Hough, & Carpenter, 2017, pp. 79-96). One principle, *identifying academic language demands and supports for ELs* (Aguirre & Bunch, 2012), asks preservice teachers to attend to the language demands present in each lesson. A second principle, *providing students with cognitively demanding work* (Berk & Windschitl, 2015), asks that ELs have the opportunity to engage in complex, reform-based tasks that are often reserved only for non-EL students (Iddings, 2005). A third principle, *providing students with opportunities for rich language and literacy exposure and practice* (Lee, Quinn, & Valdés, 2013), attends to the importance of preservice science and mathematics teachers offering ELs multiple opportunities to engage in academic discourse so as to advance both their English language acquisition and their content learning. Finally, a fourth principle, *building on and using students' funds of knowledge and resources* (Moll, Amanti, Neff, & Gonzalez, 1992), asks preservice teachers to use ELs' home languages as a resource for learning and to recognize the diversity of ELs' interests, experiences, and connections to the community.

**Teacher Efficacy**

Teacher efficacy is the belief that teachers have about their abilities and skills as educators (Gavora, 2010). Teacher efficacy has been shown to be an important characteristic of teachers and it has been strongly related to success in teaching. Teacher efficacy is a construct that was developed within the context of Bandura's social-cognitive theory. Bandura (1997) defined self-efficacy as the belief about one's own capabilities to organize and execute a certain task. According to Bandura's theory, four sources enhance the development of high teacher efficacy: (1) mastery teaching experiences, (2) vicarious experiences, (3) social persuasion, and (4) physiological and emotional states (Bandura's work, 1997, as cited in Gavora, 2010).

Gavora (2010) defined each of the four sources which enhance the development of high teacher efficacy. (1) Mastery teaching experiences are situations in which teachers demonstrate their own success of teaching, thus proving that they are competent teachers.

> Enacted mastery (teaching) experiences are the most influential source of efficacy information because they provide the most authentic evidence of whether one can muster whatever it takes to succeed. Success builds a robust belief in ones' personal efficacy" (Bandura, 1997, p. 80).

Whenever teachers engage in teaching activities, they interpret their results and use these interpretations to develop beliefs about their ability to engage in similar activities. If these activities are consistently successful, they tend to raise self-efficacy or, conversely, if these activities typically produce failure, self-efficacy is likely to be lowered. (2) Vicarious experience is learning from observations of other teachers' success. Observing and modeling successful teachers may generate expectations that teachers can learn from successes of colleagues, which in turn, can result in their own positive self-efficacy. In brief, teachers can learn to be effective by observing the behaviors of others being effective. (3) Social persuasion by colleagues and superiors who can teach successfully will enhance a teacher's self-efficacy as well. For example, coaching and giving encouraging feedback are commonly used actions that likely influence teacher self-efficacy positively. Essentially, emotional support fosters a teacher's belief in teaching. (4) Physiological and emotional states of teachers influence self-efficacy. For example, a teacher's excitement and enthusiasm can provide cues about anticipated teaching success. On the other hand, stress, anxiety, and other negative states can lead to negative judgments of teacher abilities and skills. A teacher who is professionally well-qualified may not be a successful teacher if personal negative or inhibiting emotional factors come into play. In general, a more narrowly defined concept of teacher confidence is less influenced by emotional factors outside the realm of teaching than is teacher self-efficacy.

# Chapter III: Methods

## Overview

For this study, a survey was administered to preservice teachers enrolled in one of six teacher education programs at research universities in California at the beginning and end of their program. The survey was composed of multiple choice questions and open-ended response questions. For multiple choice questions, survey response formats come in many forms. Survey participants were asked to use a 5-point Likert scale (*Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree*), a 5-point importance scale (*Very Important, Important, Neutral, Not Important, and Very Not Important*), or a 5-point frequency scale (*Very Frequently, Somewhat Frequently, Occasionally, Rarely, and Never Done*). Since survey data were ordinal, an Item Response Theory (IRT) was used to deal with the non-linear problems existing in the survey data. Ordinal rating scale data are not linear and cannot be immediately used for parametric statistical analysis no matter how many previously published studies have done so (Boon, Staver, & Yale, 2014).

Like any other statistical analysis, an IRT with a small sample is less precise estimates (bigger standard errors), less powerful fit analysis, and less robust estimates. If each sample were 2,000 or 3,000 participants, results might be essentially stable. However, large samples are expensive and time-consuming. Wright and Stone (1979) performed useful exploratory work using Rasch analysis with a small sample of 35 children and 18 items. The least number of participants depends on the IRT method you are using. For Rasch, it is 30 participants for dichotomies and 50 participants for polytomies (Linacre, 1994).

In most research involving a survey, unidimensionality of the construct to be measured is assumed, which means a set of items are supposed to measure the same construct. A second assumption is that the responses to an item are independent of the responses to any other items conditional on the person's location (person's response behavior). This assumption is referred to as conditional independence. A third assumption is the functional form assumption. This assumption states that the data follow the function specified by the model (De Ayala, 2013) as follows:

$$\ln\left[\frac{P(X_{ij}=1)}{P(X_{ij}=0)}\right] = \theta_j - \delta_i \text{ or } P(X_{ij}=1) = \frac{e^{(\theta_j-\delta_i)}}{1+e^{(\theta_j-\delta_i)}}$$

where, ln = natural logarithm, p = probability, $\theta_j$ = an estimate of the ability of person j, and $\delta_i$ = an estimate of the difficulty of item i.

Using the above function, survey participants' responses to an item are transformed and expressed in logit (log of the odds) unit, which converts ordinal relationship into linear relationship (Boon, Staver, & Yale, 2014).

Preservice teachers' responses to the open-ended questions were reviewed and scored by three trained researchers. Using *Facets* software (Linacre, 2017), multifaceted Rasch measurement method was then used to correct for the mixture of judges each participant received. Finally, a Rasch modeling method was used to merge the results of multiple choice questions and open-ended response questions to adjust the differences arising from the different scales multiple choice questions and open-ended response questions were measured on. In addition to the survey data, teacher performance assessment (edTPA) scores, comprised of three components - (1) planning, (2) instruction, and (3) assessment - were collected to examine how significantly teacher readiness (standards-based instruction; language, literacy and EL instruction; and teacher efficacy) and the edTPA scores correlated.

## Context

This study examined preservice secondary science and mathematics teachers in one of six teacher education programs at research universities in California. Each was small in size and grouped students by cohorts. Five were fifth-year programs of approximately 13 months in length. One was part of an undergraduate program. Preservice teachers enrolled in teacher education programs were composed of those who had completed undergraduate STEM education programs and those who had not.

### Undergraduate STEM Education Programs

To help recruit and better prepare beginning science and mathematics teachers in California, a group of public universities launched undergraduate STEM education programs in 2005. This program seeks to motivate talented undergraduates to explore careers as science or mathematics teachers by providing special coursework and field experiences in K-12 classrooms while they complete their undergraduate degrees. Science, mathematics, and education faculty work together to design curricula and innovative instructional strategies to help students acquire deep mathematical and scientific knowledge, research techniques, and pedagogical skills. Coursework offered by the programs is united by a foundational course sequence that introduces students to mathematics and science teaching pedagogy; focuses on supporting all learners, in particular, those in high needs schools; and is accompanied by field work of increasing teaching responsibility in elementary, middle and high school classrooms. Program participants, *prospective teachers*, develop scientific thinking and mathematical reasoning skills, and learn research and evaluation methods in courses. Students gain early professional experiences through conferences, credential program recruitment fairs, and various network-building activities. Mentor teachers oversee student field experiences in K-12 mathematics and science classrooms. While assisting their mentor teachers, they learn how to apply these skills and methods in their teaching.

One out of the six research universities in California has an experimental undergraduate teacher credential program, where completion of their undergraduate STEM education minor program is a prerequisite for their credential program. The undergraduate STEM education minor program at this university consists of two components: (1) Introductory Course (K-8 Teaching and Inquiry-Based Lesson Design in the Science and Mathematics Classroom) and (2) Science and Mathematics Education Minor Courses (e.g., (i) Knowing and Learning in Mathematics and Science, (ii) Classroom Interactions in Science and Mathematics: A Focus on Equity and Urban Schools, (iii) Project-Based Instruction, (iv) Research Methods for Science and Mathematics K-12 Teachers, and (v) History of Science with CalTeach Perspectives Section). The objective of the introductory course is to offer an opportunity to explore teaching, foster children's natural curiosity, and inspire local K-12 students. This course includes a field placement of 1 hour per week with a cooperating teacher in a local K-6 classroom. An increased number of undergraduates are expected to achieve the skills, tools, and experiences they need to succeed in today's classroom after taking this course. As a result, a number of undergraduates are eligible for the credential program. Science and mathematics education minor courses help undergraduates prepare for a career in the modern public school classroom and build a comprehensive teaching skill set. Both introductory course and education minor courses are committed to improving K-12 mathematics and science education in the area where the school is located and across the state (see Table 2). At this university, the component of an internship program is not included in the undergraduate STEM education minor courses but included in the credential program courses, instead.

Table 2

*Structure of an Undergraduate STEM Education Minor Program as Part of the Undergraduate Teacher Credential Program*

| COMPONENTS | IMPLEMENTATION OBJECTIVES | OUTPUTS | LINKING CONSTRUCTS | PROXIMAL OUTCOME | DISTAL OUTCOME |
|---|---|---|---|---|---|
| Introductory course (seminar style classes and field placements) | To offer an opportunity to explore teaching, foster children's natural curiosity, and inspire local K-12 students | The number of undergraduates who achieved the skills, tools, and experiences | Increased skills, tools, and experiences for success in today's classroom | Increased number of prospective teachers who are eligible for the credential program | Improved K-12 mathematics and science education in the community and across the state |
| Science and mathematics education minor courses | To prepare undergraduates for a career in the modern public school classroom | The number of undergraduates who build a comprehensive teaching skill set | Increased teaching skills | | |

In the rest five universities, the undergraduate STEM education programs include the same two components as an undergraduate STEM education minor program as part of the undergraduate teacher credential program has: (1) introductory course and (2) science and mathematics education minor courses. Additionally, some universities have an internship program or a curriculum project component, too. The objective of the introductory course is to offer an opportunity to explore effective teaching methods and practices. An increased number of undergraduates are exposed to effective teaching methods and practices after taking this course. Their understanding of effective teaching is broadened and deepened. Science and mathematics education minor courses help undergraduates prepare for a career in the modern school classroom and build a comprehensive teaching skill set. Both the introductory course and education minor courses are composed of seminar style classes and field placements. The purpose of the internship program is to provide an opportunity for undergraduates to develop deeper content knowledge, communication skills, and teaching skills. A number of undergraduates develop deeper understanding of teaching in real classrooms and their understanding of teaching in the real world is increased. Some universities have a curriculum project component to give an opportunity for undergraduates to develop and present curriculum in the classroom. Undergraduates improve knowledge about curriculum development through this curriculum project. As a result of completing coursework, an internship, and/or a project, prospective teachers are eligible for a teacher credential program at the graduate level. In the long run, the number of highly qualified preservice mathematics and science teachers is expected to increase (see Table 3).

Table 3

*Structure of Undergraduate STEM Education Programs at Five of the Participating Universities (Those with Post Baccalaureate Programs)*

| COMPONENTS | IMPLEMENTATION OBJECTIVES | OUTPUTS | LINKING CONSTRUCTS | PROXIMAL OUTCOME | DISTAL OUTCOME |
|---|---|---|---|---|---|
| Introductory course (seminar style classes and field placements) | To offer an opportunity to explore effective teaching methods and practices | The number of undergraduates who were exposed to effective teaching methods and practices | Increased understanding of effective teaching methods and practices | Increased number of prospective teachers who are eligible for a teacher credential program at the | Increased number of highly qualified preservice mathematics and science teachers |
| Science and mathematics | To prepare undergraduates for | The number of undergraduates | Increased teaching skills | | |

| | | | | | |
|---|---|---|---|---|---|
| education minor courses | a career in the modern school classroom | who build a comprehensive teaching skill set | | graduate level | |
| Internship program | To provide an opportunity for undergraduates to develop deeper content knowledge, communication skills, and teaching skills | The number of undergraduates who developed deeper understanding of teaching in real classrooms | Increased understanding of teaching in the real world | | |
| Curriculum project | To give an opportunity to develop and present curriculum in the classroom | The number of undergraduates who have developed and presented curriculum | Improved knowledge about curriculum development | | |

Overall, these universities' undergraduate STEM education programs play a crucial role in facilitating the implementation of ambitious or high-leverage teaching practices and the NGSS/CCSS practices through their coursework and field placements. Although there are several classes addressing *language, literacy,* and/or *instruction of English learners*, such as 'Language, Culture and Education' or 'Innovative Practices for English Language Learners in K-12 Mathematics and Science Classrooms' offered by some universities, classes on how to teach English learners (ELs) science or mathematics or how to help students develop academic language and literacy in science or mathematics, in general, seem to be rather limited. Under the new science and mathematics standards which emphasize language use in the science and mathematics classroom through implementing science, engineering, or mathematics practices, the undergraduate STEM education programs need to be directed to addressing academic language and literacy development in science and mathematics. Furthermore, considering the K-12 student population in California where 43 percent of the state's public school enrollment speak a language other than English at home, how to teach ELs science or mathematics will be a very urgent task for teachers compared to other states in the US.

## Teacher Education Programs

In California, teacher education programs (TEPs), except experimental programs, are administered at the post-baccalaureate level. The TEPs, in general, are one-year, post-baccalaureate programs (2 summers and one academic year). Preservice teachers at the institutions under study have the option to earn both a California teacher credential and a master's degree. The TEPs provide the knowledge and experience in university and secondary school classrooms needed to begin a teaching career.

**An Experimental Undergraduate Teacher Credential Program.** One out of the six universities participating in this study has a unique undergraduate credential program. Undergraduates who have completed the undergraduate STEM education minor and have declared a major in a science, technology, engineering, or mathematics field are eligible for this credential program, which supports them to get a mathematics or science secondary school teacher credential and begin teaching middle or high school after graduation. This undergraduate credential program is unusual in the state of California in that it grants credentials concurrently with undergraduate education. This allows preservice teachers to enter the classroom sooner, and with less expense, than they would have with a typical post-baccalaureate credential. This program has two components: (1) apprentice teaching and (2) student teaching. Apprentice teaching is designed to support new preservice science and mathematics teachers in earning a credential for teaching in California secondary schools. Preservice teachers demonstrate that they have developed the skills to meet the state credentialing requirements by undertaking an inquiry project on their own teaching practice. Effective teaching methods for the science and mathematics classrooms are emphasized, including strategies for lesson planning, assessment, and English learner support. Preservice teachers enrolled in apprentice teaching work in a discussion group, called “Supervised Teaching,” which provides a safe space in which preservice teachers can “think out loud” about ideas or issues that have come up as a result of their intern or student teaching experience. This group work aims to cultivate a community of practitioners that engage in supporting all members by taking on roles of an active listener, creative problem solver, and critical friend.

According to a handbook for secondary student teaching (Robert Morris University, 2007), the purposes of student teaching are (1) to help the student teacher to make the transition from university student to the role of teacher; (2) to help the student teacher to make better application of the theories and content contained in all the professional courses, such as the differences in students’ learning, appropriate instructional strategies, and the skills needed to manage a class; (3) to give the student teacher an opportunity to demonstrate his or her competency in a real teaching situation; and (4) to further develop instructional strategies, such as preparing lesson plans, evaluating students’ learning, selecting appropriate teaching materials and media, and adapting instruction and assessment to diverse learners. Completion of student teaching is one of the most important requirements to earn a California teacher credential.

Table 4

*Structure of the Experimental Undergraduate Teacher Credential Program under Study*

| COMPONENTS | IMPLEMENTATION OBJECTIVES | OUTPUTS | LINKING CONSTRUCTS | PROXIMAL OUTCOME | DISTAL OUTCOME |
|---|---|---|---|---|---|
| Apprentice teaching | To offer an opportunity to | The number of preservice | Increased teaching skills | Increased number of | Increased number of |

| | | | | | |
|---|---|---|---|---|---|
| (including supervised teaching) | undertake an inquiry on their own teaching practices | teachers who have developed teaching practices | to meet the credentialing requirements | preservice teachers who are eligible for a teacher credential | highly qualified beginning mathematics and science teachers |
| Student teaching | To prepare student teachers to make better application of the theories and content contained in all the professional courses | The number of student teachers who demonstrated their competency in a real teaching situation | Further developed instructional strategies | | |

**Post-Baccalaureate Teacher Education Programs.** Post-baccalaureate teacher education programs are administered at the graduate school level. For the five universities in this study, the program is an accelerated 13-month full-time program (five-quarter program), beginning in summer and concluding the following summer. Preservice teachers have the option to earn both a California teacher credential and a master's degree. This program consists of three components as follows: (1) an integrated model of coursework, (2) year-long student teaching, and (3) a master's degree. An integrated model of coursework addresses classroom management, theories of teaching and learning, how to educate special-needs students, advanced teaching practices, and methods of teaching a second language and developing academic literacy in all discipline areas. Through a year-long student teaching experiences, preservice teachers further develop instructional strategies. The master's degree is designed to help preservice teachers become teacher leaders with a deep, responsible, and creative vision of students and their learning. As a graduate degree, this degree demands a special commitment to independent, scholarly work outside of fieldwork, class meetings, and assignments (see Table 5).

The overarching goal of these teacher education programs is to develop teachers who are advocates for social justice dedicated to fostering equitable and effective schooling and life opportunities for all students and to help teachers learn to integrate theoretical perspectives with teaching practices through their coursework, classroom placements, and research projects. Preservice teachers are prepared to be informed, articulate, analytical leaders of educational reform within schools and communities. Overall, the topic of language, literacy, or instruction of English learners seems to be well addressed through all the components of the post-baccalaureate teacher education programs as compared to the undergraduate STEM education programs or the experimental teacher credential program at the undergraduate school level.

Table 5

*General Structure of the Post-Baccalaureate Teacher Education Programs under Study*

| COMPONENTS | IMPLEMENTATION OBJECTIVES | OUTPUTS | LINKING CONSTRUCTS | PROXIMAL OUTCOME | DISTAL OUTCOME |
|---|---|---|---|---|---|
| Integrated model of coursework (professional preparation coursework) | To provide knowledge and experience in university and school classrooms needed to begin a teaching career | The number of preservice teachers who have developed teaching practices | Increased teaching skills to meet the credentialing requirements | Increased number of preservice teachers who are eligible for a teacher credential and a graduate degree | Increased number of highly qualified beginning mathematics and science teacher leaders |
| Year-long student teaching | To prepare student teachers to make better application of the theories and content contained in all the professional courses | The number of student teachers who demonstrated their competency in a real teaching situation | Further developed instructional strategies | | |
| Master's degree | To help preservice teachers become teacher leaders | The number of highly qualified teacher leaders | Increased independent and scholarly work | | |

## Participants

Out of 158 preservice secondary science and mathematics teachers enrolled in one of the six teacher education programs at research universities in California under study, a total of 106 participated at the beginning of their program. The response rate was initially 67%. Since 40 preservice teachers did not participate in this study at the end of the program, however, the final response rate was 42%, which was over the 20% needed for an acceptable response rate for a parametric analysis (Raykov & Marcoulides, 2012). 52 were fifth-year graduate students and 14, undergraduate teacher candidates. While all 14 undergraduates had completed STEM undergraduate programs, out of the 52 fifth-year graduate students, 29 had completed STEM undergraduate programs and 23 had not (see Table 6).

Table 6

*Total Number of Participants and Completion of Undergraduate STEM Education Programs*

| Level | Participants | Population | Percent of sample size | Undergraduate STEM Education | |
|---|---|---|---|---|---|
| | | | | Completion | Non-Completion |
| Undergraduate | 14 | 28 | 0.50 | 14 | 0 |
| Graduate | 52 | 130 | 0.40 | 29 | 23 |
| Total | 66 | 158 | 0.42 | 43 | 23 |

## Procedure

The dataset for this study included preservice teachers' responses to a survey administered both at the beginning and end of their teacher education program. The survey included both five-point Likert scale questions and open-ended response questions. In addition to the survey data, preservice teachers' edTPA scores were collected at the end of their program.

**Survey Development**

The survey for this study was developed from five existing surveys or assessment tools as follows: (1) the Secondary Science Teaching with English Language and Literacy Acquisition (SSTELLA) survey (Fall, 2015) and Noyce Mathematics Teacher survey (Fall, 2014) from the SSTELLA research project (Tolbert, Stoddart, Lyon, & Solis, 2014); (2) undergraduate STEM education program end of semester (Fall, 2011) survey used at a public university in California; (3) the flexible application and student-centered instruction (FASCI) survey from a public university in Colorado (Talbot, 2011); (4) the pedagogical content knowledge (PCK) of argumentation assessment (McNeil et al., 2016); and (5) the edTPA. The survey consists of four sections and 36 items. Items in sections 2 and 3 are composed of several sub-questions.

**Section 1: Teacher Education Program Information (Items 1-12).** Items in section 1 ask about background information (e.g., name, teaching experiences, education courses, and undergraduate STEM education program participation). These items were either adapted from the SSTELLA-based surveys or developed from scratch.

**Section 2: The Teaching and Learning of Mathematics or Science (Items 13-17).** Items in section 2 were adapted from the SSTELLA-based surveys. Each item has several statements that respondents rate on a 5-point Likert scale. A few statements were added and adapted from one of the participating universities' survey used to collect Noyce data. These items address the NGSS/CCSS practices, reform-based instruction, academic language and literacy development in mathematics or science, ELs, teacher beliefs, and prior school experiences. More specifically, item 13 includes eight statements about secondary students and student learning of mathematics or science. Items 14 and 15 include 10 and 13 statements, respectively, about effective secondary mathematics or science teaching. Item 16 includes 11 statements about respondents' past secondary school experiences in mathematics or science. Item 17 includes seven statements about respondents' preparedness as a beginning teacher in the near future relevant to effective mathematics or science instruction.

For preservice science teachers, the secondary science teacher survey (SST-S) was used, which was adapted from the SSTELLA research project. It drew on the ESTELL Teacher Beliefs Survey, shown to reliably gauge growth in elementary preservice teacher knowledge and beliefs about teaching science to ELs (Bravo, Mosqueda, Solis & Stoddart, 2014; Stoddart, Bravo, Mosqueda & Solís, 2010). The ESTELL survey was piloted with 48 secondary preservice science teachers (teaching in California, Arizona, and Texas) and 78 in-service science teachers (teaching in California). According to the science and mathematics teacher initiative (SMTRI) project narrative (2016), a *Cronbach's alpha* indicated acceptable to high internal consistency for the hypothesized scales of the four SSTELLA instructional practices (scientific sense-making through scientific/engineering practices [SS], scientific discourse through scientific/engineering practices [SD], English language and literacy development [LL], and contextualized science activity [CX]): SS ($\alpha$ = .87); SD ($\alpha$ = .91); LL ($\alpha$ = .92); and CX ($\alpha$ = .86).

For preservice mathematics teachers, the secondary mathematics teacher survey (SMT-S) was used, an adaptation of the SSTS, which measured teacher beliefs and knowledge about teaching mathematics to ELs. The SMT-S contains demographic and background information (e.g., age, gender, ethnicity, second language proficiency, and professional education), 4-point (*strongly disagree* to *strongly agree*) Likert scale items that parallel SST-S and two open-ended prompts. Since the preservice teachers in the treatment group (those who had completed undergraduate STEM educations) and comparison group (those who had not) would be similar in terms of their background and academic preparation, and can be matched based on these characteristics, there should be no systematic differences between participants, other than the impact of an undergraduate STEM education intervention. These characteristics of preservice teachers provided an ideal condition for research on the effect of an intervention without much worry about selection bias.

**Section 3: Teaching Scenarios (Items 18-21).** Item 18 was a pedagogical content knowledge (PCK) scenario and differed for preservice mathematics teachers and science teachers. For the science PCK teaching scenario, an item from McNeill et al.'s (2016) PCK of Argumentation Assessment (the "Mr. Cedillo" item) was used. This item includes 4 multiple-choice questions about the scenario. Two open-ended questions regarding the science and engineering practices from the NGSS were added. For the mathematics PCK teaching scenario, a researcher from one of the participating research universities developed an item that paralleled the science item from McNeill et al. Items 19-21 were adapted from the FASCI survey (Talbot, 2011). These items were the same for preservice mathematics and science teachers. The FASCI focused on instruction that was flexibly adaptive as well as student-centered. FASCI items were changed to reflect sections of the edTPA (planning, instruction, and assessment) and to address the following: (1) eliciting students' ideas or funds of knowledge; (2) engaging students in group work; (3) engaging students in science and mathematical practices, specifically the practice of developing and using models; and (4) students' partial understandings.

**Section 4: Demographic Information (Items 22-36).** Items in section 4 ask for demographic information (e.g., undergraduate major(s) or socioeconomic status growing up) and were adapted from the SSTELLA-based surveys.

**Teacher Performance Assessment (edTPA)**

The Teacher Performance Assessment (edTPA) is a performance-based, subject-specific assessment and support system for preservice teacher candidates, which was developed and field-tested beginning in 2009 and has been used operationally since September 2013 (Sato, 2014). It is used by more than 750 teacher education programs in some 40 states to emphasize, measure, and support the skills and knowledge that all beginning teachers need in the classroom. Developed by educators for educators, edTPA is the first such standards-based assessment to become nationally available in the United States. It builds on decades of work on assessments of teacher performance and research regarding teaching skills that improve student learning. It is intended to transform the preparation and certification of new teachers by complementing subject-area assessments with a rigorous process that requires teacher candidates to demonstrate that they have the classroom skills necessary to ensure students are learning.

The initiative is a joint effort by experts at Stanford University and the Stanford Center for Assessment, Learning and Equity (SCALE) with leadership by the American Association of Colleges for Teacher Education (AACTE). Evaluation Systems, a group of Pearson, was selected as the operational partner to provide the technology and systems for submitting and scoring candidate materials and to provide management support for the multistate use of edTPA (Sato, 2014).

Forty states already have formally adopted and more are considering edTPA for statewide use to license new teachers or approve teacher education programs. Currently as stated above, more than 750 teacher education programs in some 40 states and the District of Columbia are using edTPA at different levels. The education profession has recognized the need for a common, standards- and performance-based assessment of teaching effectiveness that would measure the classroom readiness of preservice teachers and provide information for program improvement. edTPA is comparable to entry-level licensing examinations in other professions, such as the medical licensing examinations, the architecture examinations, or the bar examinations in law. The teaching profession cannot afford to wait a year or more for new teachers to become effective, nor can it afford to lose new teachers who get frustrated early without enough support and leave the field. Thus, edTPA is designed to ensure that those who become teachers not only understand education theory and subject matter content, but can demonstrate their ability to lead a classroom and ensure that students with diverse strengths and needs are learning.

edTPA was designed with a focus on subject-specific student learning and principles from research and theory. edTPA is aligned with the Interstate Teacher Assessment and Support Consortium [InTASC] (Assessment, I. T., & Support Consortium, 2011) as well as subject-matter content and pedagogical standards. In developing edTPA, the Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS) as well as state content standards and national subject matter organizations standards and the teaching practices necessary to support students to master them were also examined. The three tasks embedded in edTPA, planning, instruction, and assessment, are closely aligned with the concepts of the 2013 Charlotte Danielson Framework for Teacher Evaluation Instrument (Danielson, 2013) as well as the 2013 Marzano Teacher Evaluation Model (Marzano & Toth, 2013). edTPA is consistent with the CCSS goals and principles in mathematics and English language arts, NGSS goals and principles for science, and state and subject matter organization "college and career ready" expectations.

Preservice teachers must prepare a portfolio of materials during their student teaching clinical experience. edTPA requires preservice teachers to demonstrate readiness to teach through 3-5 lesson plans designed to support their students' strengths and needs, engage real students in ambitious learning, analyze whether their students are learning, and adjust their instruction to become more effective. Preservice teachers submit two unedited video recordings of no more than 10 minutes each of themselves in science or one or two unedited video recordings of no more than 15 minutes total of themselves in mathematics in a real classroom as part of a portfolio that is scored by highly trained educators (see Tables 7-12). edTPA builds on decades of teacher performance assessment development and research regarding teaching skills and practices that improve students' learning, including the foundational work of the National Board for Professional Teaching Standards.

Table 7

*edTPA Secondary Science Planning Task 1: Planning for Instruction and Assessment*

| What to do | What to submit | Planning rubrics |
|---|---|---|
| Select one class or a group of at least 4 students as a focus for this assessment. | Part A: Context for Learning Information | Rubric 1: Planning for Scientific Understandings |

| | | |
|---|---|---|
| Provide relevant context information (no more than 4 pages, including prompts). | Part B: Lesson Plans for Learning Segment | Rubric 2: Planning to Support Varied Student Learning Needs |
| Identify a learning segment to plan, teach, and analyze student learning. Your learning segment should include 3-5 consecutive lessons (or, if teaching science within a large time block, about 3-5 hours of connected instruction). | Part C: Instructional Materials | Rubric 3: Using Knowledge of Students to Inform Teaching and Learning |
| Determine a central focus for your learning segment. The central focus should support students' use of scientific concepts and application of scientific practices through inquiry to develop evidence-based explanations of or predictions for a real-world phenomenon based on patterns in evidence and/or data. | Part D: Assessments | Rubric 4: Identifying and Supporting Language Demands |
| Write and submit a lesson plan for each lesson in the learning segment (each lesson plan must be no more than 4 pages in length). | Part E: Planning Commentary | Rubric 5: Planning Assessments to Monitor and Support Student Learning |
| Select and submit key instructional materials needed to understand what you and the students will be doing (no more than 5 additional pages per lesson plan). | | |
| Choose one language function and other language demands important to understanding secondary science in your learning segment. | | |
| Identify a learning task where students are supported to use this language. | | |
| Respond to commentary prompts prior to teaching the learning segment (no more than 9 single-spaced pages, including the prompts). | | |
| Submit copies of all written assessments and/or clear directions for any oral or performance assessments from the learning segment. | | |

Table 8

*edTPA Secondary Science Instruction Task 2: Instructing and Engaging Students in Learning*

| What to do | What to submit | Instruction rubrics |
|---|---|---|
| Obtain required permissions for videorecording from parents/guardians of your students and other adults appearing in the video. | Part A: Video Clips | Rubric 6: Learning Environment |
| Identify lessons from the learning segment you planned in Planning Task 1 to be videorecorded. You should choose lessons that show you interacting with students in a positive learning environment to support them to (1) analyze and interpret evidence and/or data they have collected or selected from a scientific inquiry and (2) use their analysis to construct and evaluate explanations of or predictions about a real-world phenomenon. | Part B: Instruction Commentary | Rubric 7: Engaging Students in Learning |
| Videorecord your teaching and select 2 video clips (no more than 10 minutes each). | | Rubric 8: Deepening Student Learning |
| Analyze your teaching and your students' learning in the video clips by responding to commentary prompts. | | Rubric 9: Subject-Specific Pedagogy: Analyzing Evidence and/or Data |
| | | Rubric 10: Analyzing Teaching Effectiveness |

*Note*. Copyright 2015 edTPA Secondary Science Assessment Handbook.

Table 9

*edTPA Secondary Science Assessment Task 3: Assessing Student Learning*

| What to do | What to submit | Assessment rubrics |
|---|---|---|
| Select one assessment from the learning segment that you will use to evaluate your students' developing knowledge and skills. Attach the assessment used to evaluate student performance to the end of the Assessment Commentary. | Part A: Student Work Samples | Rubric 11: Analysis of Student Learning |
| Define and submit the evaluation criteria you will use to analyze student learning. | Part B: Evidence of Feedback | Rubric 12: Providing Feedback to Guide Learning |
| Collect and analyze student work from the selected assessment to identify quantitative and qualitative patterns of learning within and across learners in the class. | Part C: Assessment Commentary | Rubric 13: Student Use of Feedback |
| Select 3 student work samples to illustrate your analysis of patterns of learning within and across learners in the class. At least 1 of the samples must be from a student with specific learning needs. These 3 students will be your focus students. | Part D: Evaluation Criteria | Rubric 14: Analyzing Students' Language Use and Science Learning |
| Summarize the learning of the whole class, referring to work samples from the 3 focus students to illustrate patterns in student understanding across the class. | | Rubric 15: Using Assessment to Inform Instruction |
| Submit feedback for the work samples for the 3 focus students in written, audio, or video form. | | |
| Analyze evidence of students' language use from (1) the video clips from Instruction Task 2, (2) an additional video clips of one or more students using language within the learning segment, and/or (3) the student work samples from Assessment Task 3. | | |
| Analyze your evidence of student learning and plan for next steps by responding to commentary prompts. | | |

*Note.* Copyright 2015 edTPA Secondary Science Assessment Handbook.

Table 10

*edTPA Secondary Mathematics Planning Task 1: Planning for Instruction and Assessment*

| What to do | What to submit | Planning rubrics |
|---|---|---|
| Select one class or a group of at least 4 students as a focus for this assessment. | Part A: Context for Learning Information | Rubric 1: Planning for Mathematical Understandings |
| Provide relevant context information (no more than 4 pages, including prompts). | Part B: Lesson Plans for Learning Segment | Rubric 2: Planning to Support Varied Student Learning Needs |
| Identify a learning segment to plan, teach, and analyze student learning. Your learning segment should include 3-5 consecutive lessons (or, if teaching science within a large time block, about 3-5 hours of connected instruction). | Part C: Instructional Materials | Rubric 3: Using Knowledge of Students to Inform Teaching and Learning |
| Determine a central focus for your learning segment. The central focus should support students to develop conceptual understanding, procedural fluency, and mathematical reasoning and/or problem-solving skills. | Part D: Assessments | Rubric 4: Identifying and Supporting Language Demands |
| Write and submit a lesson plan for each lesson in the learning segment (each lesson plan must be no more than 4 pages in length). | Part E: Planning Commentary | Rubric 5: Planning Assessments to Monitor and Support Student Learning |
| Select and submit key instructional materials needed to understand what you and the students will be doing (no more than 5 additional pages per lesson plan). | | |
| Choose one language function and other language demands important to understanding secondary mathematics in your learning segment. Identify a learning task where students are supported to use this language. | | |
| Respond to commentary prompts prior to teaching the learning segment (no more than 9 single-spaced pages, including the prompts). | | |
| Submit copies of all written assessments and/or clear directions for any oral or | | |

| | | |
|---|---|---|
| performance assessments from the learning segment. | | |

*Note.* Copyright 2015 edTPA Secondary Mathematics Assessment Handbook.

Table 11

*edTPA Secondary Mathematics Instruction Task 2: Instructing and Engaging Students in Learning*

| What to do | What to submit | Instruction rubrics |
|---|---|---|
| Obtain required permissions for videorecording from parents/guardians of your students and other adults appearing in the video. | Part A: Video Clips | Rubric 6: Learning Environment |
| Identify lessons from the learning segment you planned in Planning Task 1 to be videorecorded. You should choose lessons that show you interacting with students to develop their conceptual understanding, procedural fluency, and mathematical reasoning and/or problem-solving skills | Part B: Instruction Commentary | Rubric 7: Engaging Students in Learning |
| Videorecord your teaching and select 1or 2 video clips (no more than 15 minutes total). | | Rubric 8: Deepening Student Learning |
| Analyze your teaching and your students' learning in the video clip(s) by responding to commentary prompts. | | Rubric 9: Subject-Specific Pedagogy: Using Representations |
| | | Rubric 10: Analyzing Teaching Effectiveness |

*Note.* Copyright 2015 edTPA Secondary Mathematics Assessment Handbook.

Table 12

*edTPA Secondary Mathematics Assessment Task 3: Assessing Student Learning*

| What to do | What to submit | Assessment rubrics |
| --- | --- | --- |
| Select one assessment from the learning segment that you will use to evaluate your students' developing knowledge and skills. Attach the assessment used to evaluate student performance to the end of the Assessment Commentary. | Part A: Student Work Samples | Rubric 11: Analysis of Student Learning |
| Define and submit the evaluation criteria you will use to analyze student learning. | Part B: Evidence of Feedback | Rubric 12: Providing Feedback to Guide Learning |
| Collect and analyze student work from the selected assessment to identify quantitative and qualitative patterns of learning within and across learners in the class. | Part C: Assessment Commentary | Rubric 13: Student Use of Feedback |
| Select 3 student work samples to illustrate your analysis of patterns of learning within and across learners in the class. At least 1 of the samples must be from a student with specific learning needs. These 3 students will be your focus students. | Part D: Evaluation Criteria | Rubric 14: Analyzing Students' Language Use and Mathematics Learning |
| Summarize the learning of the whole class, referring to work samples from the 3 focus students to illustrate patterns in student understanding across the class. | | Rubric 15: Using Assessment to Inform Instruction |
| Submit feedback for the work samples for the 3 focus students in written, audio, or video form. | | |
| Analyze evidence of students' language use from (1) the video clips from Instruction Task 2, (2) an additional video clips of one or more students using language within the learning segment, and/or (3) the student work samples from Assessment Task 3. | | |
| Analyze your evidence of student learning and plan for next steps by responding to commentary prompts. | | |

*Note*. Copyright 2015 edTPA Secondary Mathematics Assessment Handbook.

Based on evidence in the portfolio of materials, candidates are scored from 1 to 5 on 15 distinct teaching skills, for a possible score of 75 (see Tables 13-14). A standard-setting process led by three panels of educators and policy makers resulted in a recommended cut-score band ranging from a total score of 37-42 (edTPA Secondary Mathematics Handbook, 2015; edTPA Secondary Science Handbook, 2015). Based on the national field test data for teacher candidates taking edTPA for the first time, the percentage of candidates who would have passed edTPA along this recommended cut-score band ranged from 78 percent (score of 37) to 58 percent (score of 42).

Table 13

*Rubric for edTPA Science Scores*

| Task | Rubric | Score |
|---|---|---|
| 1. Planning for Instruction and Assessment (Planning) | 1. Planning for Scientific Understandings | 1-5 |
| | 2. Planning to Support Varied Student Learning Needs | 1-5 |
| | 3. Using Knowledge of Students to Inform Teaching and Learning | 1-5 |
| | 4. Identifying and Supporting Language Demands | 1-5 |
| | 5. Planning Assessments to Monitor and Support Student Learning | 1-5 |
| | Task 1 Total | 5-25 |
| 2. Instructing and Engaging Students in Learning (Instruction) | 6. Learning Environment | 1-5 |
| | 7. Engaging Students in Learning | 1-5 |
| | 8. Deepening Student Learning | 1-5 |
| | 9. Subject-Specific Pedagogy: Analyzing Evidence and/or Data | 1-5 |
| | 10. Analyzing teaching Effectiveness | 1-5 |
| | Task 2 Total | 5-25 |
| 3. Assessing Student Learning (Assessment) | 11. Analysis of Student Learning | 1-5 |
| | 12. Providing Feedback to Guide Learning | 1-5 |
| | 13. Student Understanding and Use of Feedback | 1-5 |
| | 14. Analyzing Students' Language Use and Science Learning | 1-5 |
| | 15. Using Assessment to Inform Instruction | 1-5 |
| | Task 3 Total | 5-25 |
| Total | | 15-75 |

*Note*. Copyright 2015 edTPA Secondary Science Assessment Handbook. Nationally recommended professional performance standards: 42. State cut-score range: 35-41 (Alabama: 37, California: 41, Delaware: 38, Georgia: 38, Illinois: 37, Iowa: 41, Minnesota: 38 (Planning: 13, Instruction: 13, and Assessment: 12), New Jersey: 37, New York: 41, Oregon: 35, Tennessee: 37, Washington: 40, and Wisconsin: 38).

Table 14

*Rubric for edTPA Mathematics Scores*

| Task | Rubric | Score |
|---|---|---|
| 1. Planning for Instruction and Assessment (Planning) | 1. Planning for Mathematics Understandings | 1-5 |
| | 2. Planning to Support Varied Student Learning Needs | 1-5 |
| | 3. Using Knowledge of Students to Inform Teaching and Learning | 1-5 |
| | 4. Identifying and Supporting Language Demands | 1-5 |
| | 5. Planning Assessments to Monitor and Support Student Learning | 1-5 |
| | Task 1 Total | 5-25 |
| 2. Instructing and Engaging Students in Learning (Instruction) | 6. Learning Environment | 1-5 |
| | 7. Engaging Students in Learning | 1-5 |
| | 8. Deepening Student Learning | 1-5 |
| | 9. Subject-Specific Pedagogy: Using Representations | 1-5 |
| | 10. Analyzing teaching Effectiveness | 1-5 |
| | Task 2 Total | 5-25 |
| 3. Assessing Student Learning (Assessment) | 11. Analysis of Student Learning | 1-5 |
| | 12. Providing Feedback to Guide Learning | 1-5 |
| | 13. Student Understanding and Use of Feedback | 1-5 |
| | 14. Analyzing Students' Language Use and Mathematics Learning | 1-5 |
| | 15. Using Assessment to Inform Instruction | 1-5 |
| | Task 3 Total | 5-25 |
| Total | | 15-75 |

*Note.* Copyright 2015 edTPA Secondary Mathematics Assessment Handbook. Nationally recommended professional performance standards: 42. State cut-score range: 35-41 (Alabama: 37, California: 41, Delaware: 38, Georgia: 38, Illinois: 37, Iowa: 41, Minnesota: 38 (Planning: 13, Instruction: 13, and Assessment: 12), New Jersey: 37, New York: 41, Oregon: 35, Tennessee: 37, Washington: 40, and Wisconsin: 38).

**Data Collection**

The dataset for this study included preservice teachers' responses to an online survey administered both at the beginning (Fall, 2016) and end (Spring, 2017) of their teacher education program. The survey included both five-point Likert scale questions and open-ended response questions. In addition to the survey data, preservice teachers' edTPA scores were collected at the end (Spring, 2017) of their program.

## Analysis

### Teacher Readiness

In this study, teacher readiness was defined as how well preservice teachers were aware of and prepared for (1) the implementation of the *NGSS* science and engineering practices or the CCSS mathematical practices (i.e., standards-based instruction); (2) the facilitation of language and literacy development for all students, including English learners (i.e., language, literacy, and EL instruction); and (3) the belief that teachers have about their abilities and skills as educators (i.e., teacher efficacy). To measure teacher readiness, both open-ended response questions and multiple choice (five-point Likert scale) questions were used.

**Open-Ended Response Questions.** Open-ended response questions used for this study were adapted from the flexible application and student-centered instruction (FASCI) survey (Talbot, 2011). These items were the same for preservice mathematics and science teachers (see Appendix 1). The FASCI focused on instruction that was flexibly adaptive as well as student-centered. FASCI items were changed to reflect sections of the edTPA (planning, instruction, and assessment) and to address the following: (1) eliciting students' ideas or funds of knowledge; (2) engaging students in group work; (3) engaging students in science and mathematical practices, specifically the practice of developing and using models; and (4) students' partial understandings.

To code participants' open-ended responses, a rubric, adopted from the secondary science teacher education with English language and literacy acquisition (SSTELLA) research project (Stoddart et al., 2017), was used. Preservice teachers' responses to the open-ended questions were reviewed and scored by three trained researchers. At first, survey participants' answers to each survey question were reviewed and scored individually using several discrete rubrics on a 3-point (0 – 2) scale, which looked at each answer independently of one another (see Tables 15 – 23).

The first set of open-ended response questions is about planning. These questions ask preservice teachers about how to plan an instruction, assuming they are supposed to teach a high school mathematics or science course to a class of approximately 30 students. The preservice teachers are to assume they are planning the next unit that they will teach to their class. On the first day of instruction for this unit, they initiate a whole class discussion and ask their students what they already know about the topic. Open-ended question 1-a asks about how this activity (a whole class discussion) might facilitate student learning. The first discrete rubric used to score preservice teachers' responses to question 1-a is displayed in Table 15.

Table 15

*Rubric for Open-ended Question 1-a (How might this activity facilitate student learning?)*

| Score | Respondent Characteristics | Example Responses |
|---|---|---|
| 2 | Teacher candidate's statement includes a rationale for **both** promoting discourse practices (e.g., make students' thinking public, students hear others' ideas) **and** engaging students in contextualized learning experiences (constructivist teaching) (e.g., to build from prior knowledge, relate to everyday experiences). | By having a classroom discussion, students can bring up new ideas that other student may not have known. At the same time, it can activate prior knowledge. This will make it easier for the students to connect to what they already know. |

| | | |
|---|---|---|
| 1 | Teacher candidate's statement includes a rationale for **either** promoting discourse practices (e.g., make students' thinking public, students hear others' ideas) **or** engaging students in contextualized learning experiences (constructivist teaching) (e.g., to build from prior knowledge, relate to everyday experiences). | This would let students recall prior knowledge.<br>**Or** I think class discussions are a great way for teaching. |
| 0 | Teacher candidate's statement **does not** include a rationale for promoting discourse practices or engaging students in contextualized learning experiences. Or **inappropriate/inaccurate** rationale is given. | As a teacher, you will not repeat information or you will include necessary extra information. |

Continuing with this scenario, preservice teachers find that students talk about this topic by sharing related terms from their first languages and by giving examples from their home life. Open-ended question 1-b asks preservice teachers to describe both what they would do and what they would expect to happen as a result. The first discrete rubric for question 1-b is displayed in Table 16.

Table 16

*Rubric for Open-ended Question 1-b (Describe both what you would do and what you would expect to happen as a result)*

| Score | Respondent Characteristics | Example Responses |
|---|---|---|
| 2 | Teacher candidate's statement includes how to relate discipline specific terms expressed in their first languages (especially not in English) to the topic **and/or** how to draw on examples/experiences they brought up from their home life to the topic **and/or** have the expectation that this will help students better understand the subject matter (must include at least 2 out of 3 components). | I'm assuming these students are speaking a language that is not English. I would ask them to share with the class, if comfortable, what they were discussing in the best English they can so that others can learn. In addition, I would praise them for connecting what they were talking about from their daily lives to the topic we are learning. This way, I expect this to help students greater understand the purpose of the math concept in the real world. |

| | | |
|---|---|---|
| 1 | Teacher candidate's statement includes **either** how to relate discipline specific terms expressed in their first languages (especially not in English) to the topic, how to draw on examples/experiences they brought up from their home life, **or** have the expectation that this will help students better understand the subject matter (must include at least 1 out of 3). | I will allow them to speak in their home languages first and then encourage them to explain it in English. Or I would consider asking the students to write down an example, so that I can incorporate their examples throughout the unit. Or I expect the students to continue talking about their examples throughout the instructional period. |
| 0 | Does not address how to relate terms from their home language to the topic, how to draw on examples from their home life, or express any expectation that this will help students better understand the subject matter. | I don't know, but I expect confusion might ensue. |

Question 1-c asks preservice teachers if the approach they described above in question 1-b did not produce the result(s) they anticipated by the end of that class session, what they would do in the next class session. The first discrete rubric for question 1-c is displayed in Table 17.

Table 17

*Rubric for Open-Ended Question 1-c (If the approach you described above in (1-b) did not produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?)*

| Score | Respondent Characteristics | Example Responses |
|---|---|---|
| 2 | Teacher candidate's statement includes **both** how to address students' language issues **and** their examples/experiences from their home life. | Allow students to complete their brainstorm at home with their family and community. This helps to potentially ground what students are learning with their community, and gives time for students to practice translating their first language into English. |
| 1 | Teacher candidate's statement includes **either** how to address students' language issues **or** their examples/experiences from their home life. | I would decide on a list of words I would use to discuss the topic when I address the class as a whole, but I would let students use whatever words they wanted when they spoke to their peers. Or I would share from my own experiences as well to make students feel more comfortable to share out if they would like to. |

| | | |
|---|---|---|
| 0 | Neither how to address students' language issues nor their examples/experiences from their home life was addressed or was addressed inappropriately. | Try new methods, though I'm not sure what. |

The second set of open-ended response questions is about instruction. This scenario, related to the first one, is the following (see Table 18). As part of this activity, students work in groups of four to develop a model to describe the relationship between two quantities (in mathematics) or two variables (in science). Question 2-a asks preservice teachers about how this activity might facilitate student learning. The first discrete rubric for question 2-a is displayed in Table 18.

Table 18

*Rubric for Open-Ended Question 2-a (How might this activity facilitate student learning?)*

| Score | Respondent Characteristics | Example Responses |
|---|---|---|
| 2 | Teacher candidate's statement includes a rationale for both engaging students in developing and using models (e.g., to represent a system under study) **and** peer collaboration (group work) (e.g., models can be refined through peer collaboration). | Students would need to collaborate and share varying ideas with one another. This may expand what they originally were thinking about how to represent two quantities using models. |
| 1 | Teacher candidate's statement includes a rationale for either engaging students in developing and using models (e.g., to represent a system under study) **or** peer collaboration (group work) (e.g., models can be refined through peer collaboration). | By working in groups students have a wider range of information since they will all be sharing different perspective and approaches on the subject. OR Students would be able to create a model, which would hopefully allow them to be creative and discover instead of memorizing such models/formulas. |
| 0 | Teacher candidate's statement does not include a rationale for engaging students in developing and using models or a rationale for peer collaboration. Or an inappropriate/inaccurate rationale is given. | Students are beginning to see how the scientific method is just like an argument, and can start to utilize it daily life. Once they understand the basic format of the scientific method, they will be more capable of utilizing it. |

Continuing with this scenario, as the activity proceeds, one group gets frustrated and approaches the preservice teacher – students have come up with two models but cannot agree on which one they should present to the rest of the class. The preservice teacher sees that one model is more accurate than the other. Question 2-b asks how to describe both what they would do and what they would expect to happen as a result. The first discrete rubric used for question 2-b is displayed in Table 19.

Table 19

*Rubric for Open-Ended Question 2-b (Describe both what you would do and what you would expect to happen as a result)*

| Score | Respondent Characteristics | Example Responses |
| --- | --- | --- |
| 2 | Teacher candidate's statement shows his/her knowledge about how to teach which model is more accurate **and** his/her expectation about the result of instruction. | Ask the group to explain the reasoning behind each model, and afterwards have the group recall which model seemed to have demonstrated more data or patterns. Guide students by asking them questions to the model with better representation. This way, students are choosing the model using their reasoning, not because you told them to do so. |
| 1 | Teacher candidate's statement shows his/her knowledge about how to teach which model is more accurate **or** his/her expectation about the result of instruction. | I would ask the two sides to explain why they think their model is better to me and whichever side better conveys the positives of their model will win. OR I would expect the students to come to an understanding and choose the more accurate model. |
| 0 | Neither instruction about models nor an expectation about the result of instruction was described. Or inappropriate instruction about models or expectations was described. | |

Question 2-c asks preservice teachers about if the approach they described above in question 2-b did not produce the result(s) they anticipated by the end of that class session, what they would do in the next class session. The first discrete rubric used for question 2-c is displayed in Table 20.

Table 20

*Rubric for Open-Ended Question 2-c (If the approach you described above in question 2-b didn't produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?)*

| Score | Respondent Characteristics | Example Responses |
|---|---|---|
| 2 | Teacher candidate's statement includes both his/her understanding about the problem (did not produce the anticipated result) **and** trying to come up with a better instructional strategy. | In the next class session, I would do an overview of why I thought the model was correct as well as give my supporting evidence. I would have told the students to continue researching the day before, and use the next class period as a time for them to present what other arguments they found to support their model. |
| 1 | Teacher candidate's statement includes either his/her understanding about the problem (did not produce the anticipated result) **or** trying to come up with a better instructional strategy. | If students are still unsure of which one is better, I would then ask prompting questions as to facilitate why one model can potentially be better than another. |
| 0 | Neither his/her understanding about the problem nor a better instructional strategy was addressed. | I would try to think of a way to quickly revisit the subject matter without cutting to much into the next lesson plan. |

The third set of questions is about assessment. This third, related scenario is that preservice teachers have given their students a quiz to assess their understanding of the first week of the unit. Question 3-a asks preservice teachers about how this activity might facilitate student learning. The first discrete rubric for question 3-a is displayed in Table 21.

Table 21

*Rubric for Open-Ended Question 3-a (How might this activity facilitate student learning?)*

| Score | Respondent Characteristics | Example Responses |
| --- | --- | --- |
| 2 | Teacher candidate's statement shows that this activity both helps students learn (formative assessment) **and** teachers improve their teaching (reflect on students' learning progression). | Students will be able to find out which topics they have mastered as it becomes easier to go over those questions and which ones they are having more difficulty. This is also very beneficial to me as I will be able to see which topics the students are having more difficulty with and which topics I should give them more support in. |
| 1 | Teacher candidate's statement shows that this activity either helps students learn (formative assessment) **or** teachers improve their teaching (reflect on students' learning progression). | It can help students understand exactly how well they know the concepts. |
| 0 | Neither teacher's perspective nor student's perspective about a quiz was addressed. | It doesn't, it just is a measure of what they have learned. |

Continuing with this scenario, in grading these quizzes, preservice teachers find that their students have repeated the partial understandings they articulated before the small group activity on models. Question 3-b asks preservice teachers about how to describe both what they would do and what they would expect to happen as a result. The first discrete rubric used for question 3-b is displayed in Table 22.

Table 22

*Rubric for Open-Ended Question 3-b (Describe both what would you do and what you would expect to happen as a result)*

| Score | Respondent Characteristics | Example Responses |
| --- | --- | --- |
| 2 | Teacher candidate's statement includes both how to come up with a better instructional strategy to address students' repeated partial understanding **and** his/her expectation about the result of refined instruction. | I would do a Q&A format. I would have them go into groups, write down the questions and/or clarifications they have, and we will address these questions as a class. The class will do most of the work to answer the questions. I will guide them to the answers (provide them info they learned about during class) and expect that this will help them fully understand the topic. |

| | | |
|---|---|---|
| 1 | Teacher candidate's statement includes either how to come up with a better instructional strategy to address students' repeated partial understanding **or** their expectation about the result of refined instruction. | I would hope to clarify that these partial understandings are incomplete and touch on the material again. I would then give students some extra material to look at and work on in order to see if they have a full understanding they needed after the group activity. |
| 0 | Neither a better instructional strategy nor expectation about the result of refined instruction was addressed. | I would review this later, and try to bring them to a full understanding. |

Question 3-c asks preservice teachers about if the approach they described above in question 3-b did not produce the result(s) they anticipated by the end of that class session, what they would do in the next class session. The first discrete rubric used for question 3-c is displayed in Table 23.

Table 23

*Rubric for Open-Ended Question 3-c (If the approach you described above in question 3-b didn't produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?)*

| Score | Respondent Characteristics | Example Responses |
|---|---|---|
| 2 | Teacher candidate's statement includes **both** his/her understanding about the problem (did not produce the anticipated result) **and** trying to come up with a better instructional strategy. | If this didn't work, I would ask a more experienced teacher what they thought would be a better approach. My last result instinct would be just to tell them the answer, but I also understand that it would mean very little to the students since they don't understand where the answer came from. |
| 1 | Teacher candidate's statement includes **either** his/her understanding about the problem (did not produce the anticipated result) **or** trying to come up with a better instructional strategy. | I would form small groups and ask students to focus on different parts of the topic, master them, and then present them to the whole class to help them go over the entire topic in much more detail. |
| 0 | Neither understanding about the problem nor a better instructional strategy was addressed. | |

After discussing the strengths and weaknesses of this way of scoring, research team members agreed to review and score responses holistically, using a unified rubric comprised of four criteria (see Tables 24 - 31): the two rubrics of sense-making and discourse were related to reform-based instruction; and the two of language and literacy, and contextualization, to EL instruction. The rubrics for preservice science teachers were adapted from the Science Classroom Observation Rubric [SCOR], developed from three observation instructions, two of which were tested and implemented with elementary school teachers in culturally and linguistically diverse classrooms: The Standards Performance Continuum [SPC] (Doherty et al., 2002), the Dialogic Activity in Science Instruction Rubric [DAISI] (Bravo, Solis, Stoddart, Tolbert, & McKinney de Royston, 2009), and the SSTELLA Classroom Observation Rubric (Tolbert, Stoddart, Greaney, & Solis, 2014), which was aligned with the NGSS. These three instruments were theoretically grounded in teaching expertise literature to discern teachers who are (1) novices with a *limited* understanding and application of desired practices (not present), (2) advanced beginners, adhering to rules and readily applying theoretical orientations (introducing), (3) competent performers with an organized plan (implementing), or (4) experts, flexibly apply principles in practice to constantly changing situations (elaborating) (Bransford, Brown, & Cocking, 2000; Dreyfus & Dreyfus, 1986; Stoddart et al., 2002). The rubrics for preservice mathematics teachers were developed from the Mathematics Classroom Observation Rubric [MCOR], which was adapted from the SCOR in order to fit mathematics teacher instruction and come into alignment with the Common Core State Standards (CCSS) for Mathematics.

Using a unified and refined rubric, preservice teachers' responses were scored on a 4-point (0 – 3) scale rather than a 3-point (0 - 2) scale to reflect their understanding of the four constructs in detail.

Table 24

*Unified Rubric 1 (Adopted from SSTELLA Rubric 2) of Sense-Making Practices*

| 0 | 1 | 2 | 3 |
|---|---|---|---|
| No Recognition of theme | Recognizes the theme | Recognizes teacher's roles | Identifies *how* the teacher can enact this theme in an *elaborated* way |
| No evidence that science/math instruction should include science & engineering practices/math practice standards. Or a negative instance is given. | Indicates that science/ math instruction should include science & engineering practices/ math practice standards, but proposed enactment lacks depth and/or is incorrect as described by the NGSS/CCSS. | Indicates that the teacher should facilitate students' sense-making through science & engineering practices/math practice standards; proposed enactment is in alignment with NGSS/CCSS descriptions, but lacks depth. | Indicates how the teacher can facilitate/create *specific* activities/structures to support students' sense-making through science & engineering practices/math practice standards; proposed enactment is described in depth and is in alignment with NGSS/CCSS descriptions. |

*Note*. **NGSS Science & Engineering Practices:** Asking questions (for science) and defining problems (for engineering); Developing and using models; Planning and carrying out investigations; Analyzing and interpreting data; Using mathematics and computational thinking; Constructing explanations (for science) and designing solutions (for engineering); Engaging in argument from evidence; Obtaining, evaluating, and communicating information.

**CCSSM Standards for Mathematical Practice:** Make sense of problems and persevere in solving them; Reason abstractly and quantitatively; Construct viable arguments and critique the reasoning of others; Model with mathematics; Use appropriate tools strategically; Attend to precision; Look for and make use of structure; Look for and express regularity in repeated reasoning.

Table 25

*Example Responses of Rubric 1 (Sense-Making Practices)*

| | |
|---|---|
| **Level 3 Example Responses** | **2a**. 1. Students will use and develop a model to guide their inquiry --- students will develop a model and then use this model to obtain, communicate, and evaluate information; this way, students will collect and analyze data in a way a scientist would; this activity will familiarize students with the science and engineering practices and will give them an opportunity to practice science in an inquiry-based manner; students will also be reintroduced to scientific terminology.<br>2. Students will collaborate in order to ask questions, develop a model, and analyze and interpret their data --- science is all about collaboration and communication and will give students an opportunity to support each other in their learning; this will also allow for strategic grouping of students, which, in turn, will provide scaffolds for individualized instruction (e.g. ELs and students with IEPs); Ultimately, students will have an opportunity to move into a zone of proximal development and receive peer support.<br><br>**2b**. "I would ask them: "Which model do you feel more comfortable with and why?". I would ask the group to explain each model in detail and then guide the discussion by carefully leading them towards the more appropriate model; Depending on the project, I would ask questions such as: "How can you tell that ___ will be successful in solving _____ problem?", "What makes this model well suited for _____?", "How could you modify your model to be more ______?", "Compare and contrast your two models. Which one is more efficient"....<br><br>**2c**. I have found that students are usually highly capable of identifying a more "correct" model themselves... They sometimes just require a little bit of guidance. " I would maybe do a jigsaw scenario asking students from each group to move to a different table and to present their findings to another group; that way, each group will be able to take a look at another groups' model; hearing the reasoning behind other groups' designs might guide students in their further steps and ultimately allow them to design a more appropriate model. |
| **Level 2 Example Responses** | **2a.** Developing and using models is one of the science practices. Not only would this activity provide students to become familiar with this practice, it would allow them to discuss their ideas with their peers and hear the ideas of others. It would also provide them with a visual/ physical representation of the science concept.<br><br>**2b**. I would ask the students to describe why they are having trouble choosing. Then I would ask them what points are most important to convey with this model and I would ask them to show me how the model demonstrates these things. I feel that this is best because it allows students to reflect on the purpose of the models and would lead them to discover which model is the best by themselves and I can simply agree.<br><br>**2c**. I would check in on that group to see if there had been any further development in their thoughts. Next, I might summarize what I had heard them say the class before and offer my opinion/ suggestion. |
| **Level 1 Example Responses** | **2a**. Students will be creating something that will illustrate the relationship between two dependent or independent variables.<br><br>**2b**. I would ask guiding questions to get the student who created the incorrect model to see their own mistake.<br><br>**2c.** I would tell students one is correct and ask them to talk for a couple minutes and decide which one is correct and which one isn't, and ask them to be prepared to justify their reasoning. |

| | |
|---|---|
| **Level 0 Example Responses** | **2a.** Collaboration. two minds better than one. Each one has strengths in areas the other may not.<br><br>**2b.** Be careful not to ridicule or discourage the one that is less accurate, but instead focus on points of the less accurate one that are correct or has potential. Discuss where both models have flaws and good parts. However, steer them towards the more accurate one in the end.<br><br>**2c.** Collaborate. |

Table 26

*Unified Rubric 2 (Adopted from SSTELLA Rubric 3) of Discourse: Productive Student Talk*

| 0 | 1 | 2 | 3 |
|---|---|---|---|
| No Recognition of theme | Recognizes the theme | Recognizes teacher's roles | Identifies *how* the teacher can enact this theme in an *elaborated* way |
| No evidence that science/math instruction should include student opportunities for talking about science/math ideas. Or a negative instance is given. | Indicates that science/math instruction should include student opportunities for talking about science/math ideas. | Indicates that the teacher should facilitate student talk about science/math ideas. | Indicates how the teacher can facilitate/create activities/structures to support dialogic student talk about science/math ideas. |

Table 27

*Example Responses of Rubric 2 (Discourse: Productive Student Talk)*

| | |
|---|---|
| **Level 3 Example Responses** | **1a.** 1. Engagement: By connecting the content to students' prior learning, student engagement, participation, and interest will increase.<br>2. Value student input: By leading a whole class discussion, students' input is valued and students are given a voice (= democracy in the classroom).<br>3. Guide future instruction: By finding out where students are at in their learning and/or understanding, the teacher can use this information to guide and potentially modify their future instruction; this will facilitate student learning by providing them with a tailored curriculum.<br>4. Formative assessment: Similarly to (3), this discussion can function as a form of formative assessment; the teacher can identify preconceptions in their students' understanding and address such preconceptions later on" "What I would do: I would definitely encourage the student to share their experiences with the rest of the class; I would potentially use this as an opportunity to teach my students some new word roots (e.g. the relationship between carne [Spanish] and carnivore); I would also ask the class: "Does |

| | |
|---|---|
| | someone else have a similar example?" or "Has anyone else had a totally different experience? Tell us about it."<br><br>**1b**. "What I would expect to happen: other students may have similar experiences and may be able to relate to the student --- this could potentially increase their engagement and interest; students who may have different experiences may learn something new... thereby broadening their personal horizons."<br><br>**1c.** "If the conversation...<br>a) ... resulted in a tangent, I would try to refocus my students by extracting examples or statements that actually ARE related to the content at hand; I might re-refer to these examples when continuing instruction in the next class session.<br>b) ... resulted in a dispute, I would use this opportunity to tell my students that varied perspectives are valued in my classroom and that I do want to give each and every student an opportunity to have their voice be heard; I would ultimately redirect the conversation and move on with the content.<br>c) ... resulted in a longer discussion, I would modify my next class session and make sure that my students are aware of the fact that I truly value their input and collaboration; I would make sure to include examples from the discussion in the upcoming lesson."<br>(Recognizes theme, teacher's role, and specific/detailed strategies of enactment.) |
| **Level 2 Example Responses** | **1a.** You activate prior knowledge.<br><br>**1b**. I would make a poster of their prior knowledge and interests so I acknowledge that is in important. I would then incorporate it into the classroom by creating math problems with those terms. I would expect to learn a lot about my students.<br><br>**1c.** Students might be unwilling to share out verbally. I would create other options for them to talk about it through art, music or writing.<br><br>(Recognizes theme and teacher's role; enactment strategies are general.) |
| **Level 1 Example Responses** | **1a.** It allows the teacher to assess where the students are starting from, i.e. what prior knowledge or misconceptions they have on the subject.<br><br>**1b**. We could brainstorm, as a class, activities related to the aspects of their life they shared that would cover the core concepts of the lesson. This would show the students their life experience is valuable and that they are active members in their own learning.<br><br>**1c**. Collaborate with other teachers and find new activities or materials that would continue our exploration with a new lense.<br><br>(Recognizes theme; no specific strategies for teacher enactment.) |
| **Level 0 Example Responses** | **1a.** Students will have an opportunity to connect the new unit to a previous understanding or to sources of learning that they have had outside the classroom.<br><br>**1b**. The class of thirty may begin to generate an abundance of examples and each expect an opportunity to share. I would consider asking the students to write down an example, so that I can incorporate their examples throughout the unit (negative case).<br><br>**1c.** I would be ready to utilize a different approach in my next class session (no specific enactment strategies). |

Table 28

*Unified Rubric 3 (Adopted from SSTELA Rubric 5) of Language and Literacy: Student Interaction*

| 0 | 1 | 2 | 3 |
|---|---|---|---|
| No Recognition of theme | Recognizes the theme | Recognizes teacher's roles | Identifies *how* the teacher can enact this theme in an *elaborated* way |
| No evidence that science/math instruction should include opportunities for student interaction. Or a negative instance is given. | Indicates that science/ math instruction should include opportunities for student interaction. | Indicates that the teacher should facilitate widespread student interaction and support ELs' participation. | Indicates how the teacher can facilitate/create activities/structures to facilitate widespread student interaction that supports ELs' participation. |

Table 29

*Example Responses of Rubric 3 (Language and Literacy: Student Interaction)*

| | |
|---|---|
| **Level 3 Example Responses** | **1a**. This activity leads students to probe their minds for prior knowledge and "dust off" old ideas they may not have used in a while. This keeps the ideas fresh and primes students to build on them. It also gives the teacher evidence of what students know, which can help the teacher avoid making a boring, redundant lesson in which nobody learns anything new.<br><br>**1b**. I would have students write related terms in their home language and then again in English, perhaps with a diagram or example sentence to provide context. I would expect students to make the connections to the new scientific English terms and slowly become more comfortable using them. I would expect that students would need to look back to these vocab/translation notes later in the unit to describe concepts and relationships in class discussions.<br><br>**1c**. I would give scaffolded vocal lists with terms along with given definitions/notes, with space for students to write the word in their home language, draw diagrams, etc. and construct meaning for themselves but with more support than the strategy above.<br><br>(Recognizes theme, teacher's role, and strategies of enactment.) |
| **Level 2 Example Responses** | **1a.** This enables the teacher to pick up on any misconceptions that students already have before going into the unit. In addition, it is important to know how much students already know about the topic so that instruction can be made accordingly, ranging from the content itself to the math operations that are required to perform this unit. |

| | |
|---|---|
| | **1b**. I would encourage this type of interaction. If students are able to incorporate their culture or worldview into the concept in some way, I believe that students would have more intrinsic motivation toward learning the topic. I would make sure with every lesson, I find a way that I can relate the material to experien they had inside and outside the class.<br><br>**1c**. Revise instruction, using what worked well and scrapping what did not go as planned. For example, if a discussion did not produce an ample amount of volunteers, I would consider having them write down connections to the content and share them with their partners and then the class.<br><br>(Recognizes theme and teacher's role; limited/general strategies of enactment.) |
| **Level 1 Example Responses** | **1a.** It may allow students to talk about their experiences with the phenomenon and also any other prior knowledge they may have of it. They can also discuss what they want to know.<br><br>**1b.** I would really like for my students to elaborate on their own personal experiences. I want to be able to connect their scientific learning to their own backgrounds as much as possible in order to make the learning more relevant to my my students. I would expect that they would be excited to talk about their experiences with the phenomenon, and want to share what they know.<br><br>**1c.** I would think of what other ways I may be able to engage my students with the topic at hand.<br><br>(Recognizes theme; no mention of teacher's role; no specific enactment strategies mentioned.) |
| **Level 0 Example Response** | **1a.** Students will have an opportunity to connect the new unit to a previous understanding or to sources of learning that they have had outside the classroom.<br><br>**1b**. The class of thirty may begin to generate an abundance of examples and each expect an opportunity to share. I would consider asking the students to write down an example, so that I can incorporate their examples throughout the unit (negative case).<br><br>**1c.** I would be ready to utilize a different approach in my next class session (no specific enactment strategies). |

Table 30

*Unified Rubric 4 (Adopted from SSTELLA Rubrics 8 & 9) of Contextualization: Relevance & Knowing Students*

| 0 | 1 | 2 | 3 |
|---|---|---|---|
| No Recognition of theme | Recognizes the theme | Recognizes teacher's roles | Identifies *how* the teacher can enact this theme in an *elaborated* way |

| | | | |
|---|---|---|---|
| No evidence that science/math instruction should include connections to relevant contexts outside the classroom and/or elicit students' life experiences. Or a negative instance is given. | Indicates that science/math instruction should include connections to relevant contexts outside the classroom and/or elicit students' life experiences. | Indicates that the teacher should frame lessons or connect student contributions about relevant contexts outside the science classroom and/or leverage students' life experiences. | Indicates how the teacher can frame lessons or connect student contributions about relevant contexts outside the science classroom and/or leverage students' life experiences. |

Table 31

*Example Responses of Rubric 4 (Contextualization: Relevance & Knowing Students)*

| | |
|---|---|
| **Level 3 Example Responses** | **1a.** 1. Engagement: By connecting the content to students' prior learning, student engagement, participation, and interest will increase.<br>2. Value student input: By leading a whole class discussion, students' input is valued and students are given a voice (= democracy in the classroom).<br>3. Guide future instruction: By finding out where students are at in their learning and/or understanding, the teacher can use this information to guide and potentially modify their future instruction; this will facilitate student learning by providing them with a tailored curriculum.<br>4. Formative assessment: Similarly to (3), this discussion can function as a form of formative assessment; the teacher can identify preconceptions in their students' understanding and address such preconceptions later on or "What I would do: I would definitely encourage the student to share their experiences with the rest of the class; I would potentially use this as an opportunity to teach my students some new word roots (e.g. the relationship between carne [Spanish] and carnivore); I would also ask the class: ""Does someone else have a similar example?" or "Has anyone else had a totally different experience? Tell us about it."<br><br>**1b**. What I would expect to happen: other students may have similar experiences and may be able to relate to the student --- this could potentially increase their engagement and interest; students who may have different experiences may learn something new... thereby broadening their personal horizons."<br><br>**19c.** "If the conversation...<br>a) ... resulted in a tangent, I would try to refocus my students by extracting examples or statements that actually ARE related to the content at hand; I might re-refer to these examples when continuing instruction in the next class session.<br>b) ... resulted in a dispute, I would use this opportunity to tell my students that varied perspectives are valued in my classroom and that I do want to give each and every student an opportunity to have their voice be heard; I would ultimately redirect the conversation and move on with the content.<br>c) ... resulted in a longer discussion, I would modify my next class session and make sure that my students are aware of the fact that I truly value their input and collaboration; I would make sure to include examples from the discussion in the upcoming lesson."<br><br>(Recognizes theme, teacher's role, and specific/detailed strategies of enactment.) |

| | |
|---|---|
| **Level 2 Example Responses** | **1a**. This shows student's prior knowledge on the material, which helps inform which way instruction should head. For example, if the lesson was on forces and motion and the student thinks increasing acceleration and speeding up is the same thing, then the teacher can make note of these misconceptions and prior knowledge and inform his or her lesson planning.<br><br>**1b.** I would respond with enthusiasm and encourage the student to elaborate on his response, in order to share his culture with us to get his unique perspective. In my graduate studies, the majority of my research on this topic had lead me to the same conclusion; a culturally responsive education is effective in getting students (including ELLs who speak in their native language) to engage. I would expect the student would be more in tune with the lesson, since I validated his unique viewpoint.<br><br>**1c**. The next class session, I would try to validate his experience further by incorporating a piece of his response into my lesson, reflecting the student's interests or cultural value that he or she shared. I would also include some more time to ask students on their respective experiences (recognizes theme and teacher's role). |
| **Level 1 Example Responses** | **1a.** It will activate prior knowledge and get students thinking about the topic in terms of what they know. This can also help them connect this unit to other disciplines.<br><br>**1b**. I would encourage these types of connections because I expect this would help students find relevance in the topic and feel like their backgrounds are respected and useful in the classroom.<br><br>**1c.** I would remind students that it is great to connect topics in class to their lives and backgrounds (recognizes theme). |
| **Level 0 Example Responses** | **1a.** This activity will help the teacher gauge student learning, which will be useful information as the unit progresses. It will also help students create connections between what they already know and what they are learning which will help their retention and understanding.<br><br>**1b.** I would make explicit connections between their examples and new topics, and I would expect to see more engagement, learning, and involvement.<br><br>**1c.** *I would probably temporarily drop the idea of using that kind of input until I had figured out what went wrong the last time I tried it. I would not repeat the process in the next class* (negative case). |

Since preservice teachers' responses to the open-ended questions were reviewed and scored by three researchers, the researchers who were randomly assigned to score their responses might have a great impact on their scores. Typically, researchers (judges) receive extensive training on scoring their responses in the same manner and each response may be rated a second time by a second researcher. It is essential to try to correct the differences in judges' severity in scoring. However, it seems to be unreasonable to expect all the judges to reach a perfect agreement between them in scoring.

Regarding this problem, there is a good real-world example. It is helpful to consider the use of judges in the Winter Olympics (Boone, Staver, & Yale, 2014). The final event in Winter Olympic figure skating is the long program. Until 2006, when this scoring system was altered, skaters were evaluated by several judges with regard to two traits (i.e., technical merit and presentation) on a 6.0-point scale. The judges for each skater's long program produced a technical merit rating and a presentation rating. These ratings ranged from a low of 0.0 to a high of 6.0. When a total score was computed for a contestant, Olympic officials attempted to correct for easy judges and tough judges by dropping the highest and lowest score from the panel of judges because extreme judges could impact the overall composite scores a skater would receive. Each judge's technical rating and artistic rating are considered as two rough total measures of a skater's technical skill and artistic skill in performing elements (e.g., jumps, spins, step sequences, etc.). In essence, each judge views the contestant's long program and rates the performer on numerous skills, where each skill rating can be viewed as a single survey item for a single trait. Each judge then marks his or her ratings for all parts of the technical skill construct and then produces a total score. Rating each skater's performance by each judge can be seen as a Multifaceted Rasch measurement (MFRM) situation, where a judge, a skater, and the skater's technical skill are considered each of three facets (Boone, Staver, & Yale, 2014).

The same method was employed in this study. Three trained researchers (judges) scored preservice teachers' (skaters') responses (the skaters' technical skill) to the open-ended questions, which were supposed to measure teacher readiness. A total of 66 preservice teachers responded to both pre- and post- open-ended questions. Figure skating and my study were compared in Table 32.

Table 32

*Comparison Between Figure Skating and My Study*

| | Figure Skating | My Study |
|---|---|---|
| Facet 1 | Judges | Researchers (3) |
| Facet 2 | Skaters | Preservice Teachers (66) |
| Facet 3 | Technical Skills | Teacher Readiness (3) |

*Note.* Two cases in which Multifaceted Rasch Measurement (MFRM) should be used to take into account differences in judge severity (Copyright 2014 Boone, Staver, and Yale).

For rating to be fair to all participating preservice teachers, training the researchers (judges) to act in the same manner was one way of guaranteeing fairness. Instead of acting in an identical manner, however, three researchers were trained to be consistent in her or his scoring. Multifaceted Rasch measurement (MFRM) technique was then adopted for a number of reasons. First, any rating is ordinal and therefore nonlinear. Ordinal data can be expressed on a linear, equal-interval scale through the Rasch measurement method. Second, usually a small number of judges evaluate a large number of candidates. Because judges have limited time, using MFRM provides an advantage in that all judges need not evaluate all candidates when a multimatrix design successfully links all candidates on the same scale. A multimatrix design can be seen in the data where there is at least one *link* between each judge (Boone, Staver, & Yale, 2014). In this study, there were six links between each judge. In addition, this technique was useful to correct for the mixture of judges each candidate received. In this study, researcher A was randomly assigned to evaluate 24 candidates; researcher B, 25 candidates; and researcher C, 28 candidates, all including six link candidates. An MFRM technique was then used to deal with the differences in judge severity and calibrate the scores each candidate received using six link candidates' responses. Rasch *Facets* software (Linacre, 2017) was utilized to run an MFRM analysis. This analysis provided measures for the three researchers, measures for the 66 preservice teachers, and measures for each open-ended question item. All measures were expressed on the same linear logit scale, which means the measures were not biased by using raw data. As a result, parametric statistical tests (e.g., multivariate analysis of variance, repeated measures analysis, and canonical correlation analysis) were able to be carried out with confidence using logit measures for the 66 preservice teachers.

**Five-Point Likert Scale (Multiple Choice) Questions.** In addition to the open-ended response questions, multiple choice questions were posed to preservice teachers on a five-point Likert scale to measure their teacher readiness. Survey items were adapted from the SSTELLA-based surveys. Several additional statements were added and adapted from one of the participating research universities' survey. Collectively, these survey items addressed the NGSS/CCSS practices, reform-based instruction, academic language and literacy development in mathematics or science, EL instruction, teacher belief, and prior school experiences. For preservice science teachers, the secondary science teacher survey (SST-S) was used, which was adapted from the SSTELLA project, whereas for preservice mathematics teachers, the secondary mathematics teacher survey (SMT-S) was used, an adaptation of the SST-S.

A total of 20 survey items were included in these multiple-choice questions (see Table 33). Out of 20 items, six items were related to teacher efficacy (TE); eight items, to standard-based instruction (SBI); and the remaining six items, to language, literacy, and EL instruction (LLE).

Table 33

*Survey Items and Three Constructs of Teacher Readiness*

| Construct | Item | Total numbers |
|---|---|---|
| Teacher efficacy (TE) | 1. I feel well-prepared to teach an advanced mathematics/science course (e.g., honors, advanced placement).<br>2. I feel well-prepared to integrate language and literacy in my mathematics/science teaching.<br>3. I feel well-prepared to make mathematics/science relevant to my students.<br>4. I feel well-prepared to involve students in constructing and critiquing mathematical/scientific arguments.<br>5. I feel well-prepared to teach mathematics/science to English language learners.<br>6. I feel well-prepared to find out about my students' lives outside of school. | 6 |
| Standards-based instruction (SBI) | 1. Listening and responding to student ideas about mathematics/ science should be a key focus in most mathematics/science lesson.<br>2. Student discussions should be used sparingly as they often lead to confusion and misunderstanding of mathematics/science concepts (reverse coded).<br>3. Common Core mathematics/Next Generation science and engineering practices should be taught separately from mathematics/scientific content (reverse coded).<br>4. Involve students in developing and using mathematics/ scientific models.<br>5. Discourage students from critiquing their peers' mathematical/scientific reasoning (reverse coded).<br>6. Engage students in sustained discussions about mathematics/ science topics.<br>7. Frame instruction around a big idea or puzzling phenomenon.<br>8. Ask students to explain their reasoning (e.g., Why do you think that? Can you elaborate?). | 8 |
| Language, Literacy, and EL Instruction (LLE) | 1. Students master and retain mathematics/science concepts most effectively when reading, writing, and talking are used in support of mathematics/science learning.<br>2. English language learners need to be able to read and write proficiently in English before being taught mathematics/science (reverse coded). | 6 |

| | |
|---|---|
| 3. Connecting mathematics/science instruction to students' culture and communities will distract them from actually learning mathematics/science content (reverse coded).<br>4. Mathematics/science teachers are to address students' language development as well as their content understanding in mathematics/science lessons.<br>5. Mathematics/science teachers are responsible for teaching students both how to read and produce mathematics/science texts.<br>6. Provide students with language supports (e.g., graphic organizers, sentence frames). | |
| Total | 20 |

In most research involving the collection and analysis of a survey, there are some common problems researchers are confronted with. One of them is that survey data are ordinal, which means they are not at equal intervals or linear (Boone, Staver, & Yale, 2014). Suppose that four high school students are using a 5-point agreement scale to respond to the following statement, “I like chemistry.” John circles *Strongly Agree*, Susan circles *Agree*, Mike circles *Neutral*, Miley circles *Disagree*, and Emily circles *Strongly Disagree*. Is the change in the level of agreement constant from Emily to Miley to Mike to Susan to John? For ordinal data, the answer is no. All we know is that John agrees more than Susan, who agrees more than Mike, who agrees more than Miley, and who agrees more than Emily. With ordinal data, we do not know whether the four intervals (Emily-Miley, Miley-Mike, Mike-Susan, and Susan-John) are equal in size or not. Another way to describe the problem is that we do not know if Susan’s level of agreement (Susan circled *Agree*, which was coded as 4) is twice Miley’s level of agreement (Miley circled *Disagree*, which was coded as 2). Once survey data are numbered or coded in a statistical software (e.g., spreadsheet or SPSS), however, they are treated as if they were linear, which may hide the ordinal nature of survey data. If parametric tests such as a t-test or ANOVA are conducted based on raw data, requirements of parametric tests may be violated. Ignoring the parametric requirement of linear measures may result in incorrect statistical conclusions.

For this study, a Rasch modeling method was used to deal with the non-linearity existing in the survey data. One way in which a Rasch modeling confronts the ordinal nature of data is that it computes and generates equal interval (linear) *measures* (in logit unit) from participants' responses. Using a Rasch software, *Winsteps* (Linacre, 2017), equal interval or linear logit scale, *measures*, were generated from preservice teachers' responses to multiple choice survey questions.

This linear logit scale generated from the 5-point Likert scale multiple choice questions were then merged with that from the open-ended response questions to create a variable representing each construct of teacher readiness (teacher efficacy, standards-based instruction, and language, literacy, and EL instruction). Parametric tests, such as multivariate analysis of variance (MANOVA), repeated measure analysis, and canonical correlation analysis, were then conducted to answer the research questions posed in this study.

To examine if there were significant differences in the levels of teacher readiness between preservice teachers who had completed undergraduate STEM education programs and those who had not at the beginning of their teacher education program, a multivariate analysis of variance (MANOVA) method was used because MANOVA is probably the most used multivariate technique in social sciences research.

In this study, the differences in three dependent variables (three levels of teacher readiness) were compared between two levels of the first independent variable (those who had completed undergraduate STEM education programs and those who had not). In addition, the mean differences between those whose first language is English and those whose first language is not English (English vs. non-English), between mathematics majors and science majors (mathematics vs. science), and between male and female (male vs. female) were also compared.

At the beginning of their teacher education program, a total of 106 preservice teachers participated in this study. However, 40 preservice teachers out of 106 did not continue their participation. Using the same method (i.e, MANOVA), whether there were any significant differences in teacher readiness between those who participated in this study both at the beginning and end of their teacher education program and those who participated only at the beginning of their program was investigated.

Whether there was a significant change (increase) in the levels of teacher readiness between the beginning and end of the program among preservice teachers enrolled in their teacher education program was examined using repeated measure analysis. Whether the change over time differed (1) between preservice teachers attending fifth-year programs (at the graduate level) and an experimental undergraduate program, and (2) between preservice teachers who had completed undergraduate STEM education programs and those who had not was also investigated.

**edTPA Scores**

Preservice teachers' teaching performance was assessed and scored (i.e., edTPA scores) by an external assessment publishing company. Preservice teachers' survey responses were scored by three trained internal researchers. In this regard, it is meaningful to see if there were significant correlations between three levels of teacher readiness and three levels of edTPA scores. As stated above, teacher readiness in this study was defined as (1) teacher efficacy; (2) standards-based instruction; and (3) language, literacy, and EL instruction. The edTPA scores were composed of three components as follows: (1) planning for instruction and assessment (planning); (2) instructing and engaging students in learning (instruction); and (3) assessing student learning (assessment). The outcome variables in this study consist of multiple variables: planning, instruction, and assessment. Given these three outcome variables, three multiple regression analyses might be conducted, one for each outcome variable. Conducting multiple tests on the same data, however, is likely to increase the probability of making type I error. Furthermore, conducting three separate multiple regression analyses predict only a single outcome, and it does not predict the overall outcome (Abu-Bader, 2010; Field, 2009). Therefore, a new multivariate statistical technique was employed to predict several outcome variables based on several factors. This technique was *canonical correlation analysis*. Canonical correlation analysis is an advanced technique of multiple regression analysis, frequently referred to as multivariate multiple regression (MMR). The purpose of canonical correlation is to predict multiple outcomes based on multiple factors (Abu-Bader, 2010). In other words, it examines the relationships between two sets of variables. One set includes multiple independent variables, and the other set includes multiple dependent variables. In this study, one set of multiple independent variables was three levels of teacher readiness (teacher efficacy, standards-based instruction, and language, literacy, and EL instruction) and the other set of multiple dependent variables was three levels of edTPA scores (planning, instruction, and assessment). Like Pearson's correlation coefficient and multiple regression analysis, however, canonical correlation analysis did not test for causality. It examined only the strengths and directions of the relationships between the two sets of variables.

# Chapter IV: Results

## Overview

In this study, the first research question was to examine if there were significant differences in the levels of teacher readiness (teacher efficacy, standards-based instruction, and language, literacy, and EL instruction) between preservice teachers who had completed undergraduate STEM education programs and those who had not at the beginning of their teacher education program. In addition, the mean differences in teacher readiness between those whose first language is English and those whose first language is not English (English vs. non-English), between mathematics majors and science majors (mathematics vs. science), and between male and female (male vs. female) were also compared. To answer these questions, multivariate analysis of variance (MANOVA) was utilized because the purpose of MANOVA is to examine the mean differences between levels of one or more independent variables on two or more dependent variables (several dependent variables). MANOVA has several advantages over the ordinary analysis of variance (ANOVA) as follows (Abu-Bader, 2010): (1) MANOVA allows researchers to examine multiple dependent variables at once without the need to conduct multiple ordinary ANOVA tests. (2) MANOVA protects for the inflation of type I error. When several dependent variables are considered for analysis, multivariate analysis mathematically creates one composite variable of a linear combination (centroids) of all dependent variables. It then compares all levels of the independent variable(s) on this composite variable. This method eliminates the need to conduct multiple ordinary ANOVA tests and thus protects against the inflation of type I error. (3) MANOVA allows researchers to examine not only group differences on each dependent variable but also group differences on the combined construct (centroids) of all dependent variables (overall dependent variable). (4) Creating a composite variable of the centroids of all dependent variables maximizes the differences between levels of the independent variable(s) on the dependent variables.

The second research question was to investigate if there was a significant change (increase) in the levels of teacher readiness between the beginning and end of the program among preservice teachers enrolled in their teacher education programs. Whether the change over time differed (1) between preservice teachers attending fifth-year programs (at the graduate level) and an experimental undergraduate program (at the undergraduate level), and (2) between preservice teachers who had completed undergraduate STEM education programs and those who had not was also investigated. To answer this research question, repeated measures analysis of variance was utilized. Repeated measures analysis of variance is an advanced statistical technical that builds upon the dependent *t*-test and analysis of variance. It is used to examine the changes in a dependent variable measured repeatedly among the same subjects. It is also appropriate for longitudinal research in which each subject is measured on the same variable over time.

The third research question was to examine if there were significant correlations between teacher readiness (as determined by the post-survey) and their edTPA scores. Canonical correlation analysis was employed to answer this research question using the concepts of *canonical variate, canonical variates pair, canonical correlation coefficient, variance, redundancy variance, and loadings.* Canonical variate, also known as canonical variable, is a latent, a composite, or an overall variable representing all variables within each set (Abu-Bader, 2010). It is a linear combination of all variables in a particular set. Canonical correlation analysis consists of at least two canonical variates, one for each set: (1) a dependent canonical variate (Y canonical variate) and (2) an independent canonical variate (X canonical variate). In this study, edTPA scores represent the dependent canonical variate. It is a latent or a composite variable of planning, instruction, and assessment. Teacher readiness represents the independent canonical variate. It is a latent or a composite variable of teacher efficacy, standards-based instruction, and language, literacy, and EL instruction. Therefore, the number of possible variates pairs is three, one for each dependent variable. Canonical correlation coefficient represents the correlation coefficient ($R_{XY}$) between both variates within each pair (dependent and independent canonical variates). The number of canonical correlation coefficients equals the number of canonical variate pairs. Usually, the first canonical correlation coefficient is the most significant one. It maximizes the correlation between the first two canonical variates (first canonical variates pair). Variance represents the proportion of variance in each dependent canonical variate that is accounted for by the corresponding independent canonical variate. It is simply the square of the canonical correlation coefficient ($R^2_{XY}$). Redundancy variance represents the proportion of variance in the variables in one canonical variables pair accounted for by the canonical variate of the other set. Typically, there are two redundancy variance values for each canonical correlation, one for the independent canonical variate and the dependent variables ($R^2_{Y_qX}$) and another for the dependent canonical variate and the independent variables ($R^2_{X_pY}$). The first represents the proportion of variance in the dependent variables ($Y_q$) accounted for by the independent (X) canonical variate and the second represents the proportion of variance in the independent variables ($X_p$) accounted for by the dependent (Y) canonical variate. Researchers are, in general, more interested in the first redundancy variance, that is, the variance in the dependent variables accounted for by the independent canonical variate than the second redundancy variance. The greater the redundancy variance is, the more likely the independent canonical variate predicts the dependent variables. Loadings represent the correlation coefficient between each variable and the corresponding canonical variate (e.g., the correlation between X variables and X canonical variate: $R_{X1X}, R_{X2X}, R_{X_pX}, R_{Y1Y}, R_{Y2Y}, R_{Y_qY}$). As a general rule, values with loadings of .30 and above are considered significant contributors to their corresponding variate. A canonical correlation path diagram is displayed in Figure 3.

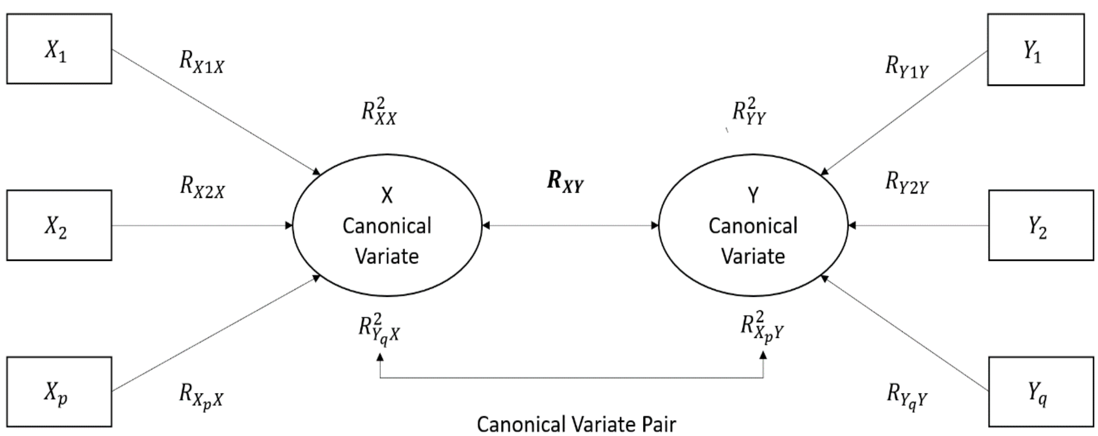



*Figure 3*. Canonical correlation path diagram (Copyright 2010 Abu-Bader).

## Multivariate Analysis of Variance

Prior to the analysis, data were evaluated to ensure that the assumptions for multivariate tests were fulfilled. First, a cross-tabulation of four sets of independent variables (completion of undergraduate STEM education programs, first language, majors, and gender) showed that all cells have a minimum of twenty percent of the total population except for a group of people whose first language is not English, thus indicating a sample size adequate for MANOVA. Second, measures of skewness and kurtosis, histogram, and normal Q-Q plots were examined for overall levels of teacher readiness. Inspection of these measures and plots showed a normal distribution on overall levels of teacher readiness. Next, measures of skewness and kurtosis and plots were evaluated for each dependent variable for each level of the independent variables. No major departure from normality was found. Third, the result of Box's M test of variance-covariance matrices indicated that the overall homogeneity of variance-covariance matrices was met, Box's M = 20.53, $p$ = .98. Levene's test of equality of variances showed that the error variances of standard-based instruction and language, literacy, and EL instruction were equal across groups, $p$ = .64 and $p$ = .09, respectively. However, the error variance of teacher efficacy was not equal across groups, $p < .05$. Finally, the scatterplot of the dependent variables and the results of Bartlett's test and the residuals SSCP matrix showed that the levels of teacher readiness satisfied the assumptions of linearity and multicollinearity.

A factorial MANOVA was utilized to examine the effects of completion of undergraduate STEM education programs, first language, majors, and gender on the overall teacher readiness among a sample of 66 preservice teachers. For this purpose, teacher readiness was conceptualized as a composite of teacher efficacy, standards-based instruction, and language, literacy, and EL instruction.

**Main Effect 1 (Completion of undergraduate STEM education programs)**

The results of the factorial MANOVA showed an overall insignificant difference between preservice teachers who had completed undergraduate STEM education programs [completion] and those who had not [non-completion] on their overall teacher readiness at the beginning of their teacher education program (Wilks' Lambda = .93, $F_{(3, 50)}$ = 1.18, $p$ = .33). Completion of undergraduate STEM education programs accounted for 6.6% of the variance in overall teacher readiness ($\eta^2$ = .066).

The results of the post hoc between-subjects effects, however, indicated that completion and non-completion were significantly different on their understanding of standards-based instruction at the beginning of their teacher education program ($F_{(1, 52)}$ = 3.34, $p$ < .05, $\eta^2$ = .060) but not both on teacher efficacy ($F_{(1, 52)}$ = .23, $p$ = .63, $\eta^2$ = .004) and on language, literacy, and EL instruction ($F_{(1, 52)}$ = .01, $p$ = .91, $\eta^2$ = .00).

In this study, completion of undergraduate STEM education programs had a significantly greater effect on their awareness of standards-based instruction (mean = -1.12 logits, SE = .42) than non-completion (mean = -2.84 logits, SE = .70). On the other hand, both completion and non-completion groups of undergraduate STEM education programs showed no significant difference in teacher efficacy (completion: mean = 1.96 logits, SE = .30; non-completion: mean = 1.52 logits, SE = .50) and no significant difference in language, literacy, and EL instruction (completion: mean = -1.89 logits, SE = .66; non-completion: mean = -3.18 logits, SE = 1.11).

**Main Effect 2 (First language)**

The results of the factorial MANOVA also showed an overall significant difference between those whose first language is English [English] and those whose first language is not English [non-English] on their overall teacher readiness (Wilks' lambda =

.83, $F_{(3, 50)} = 3.35$, $p < .05$). Preservice teachers' first language accounted for 16.8 % of the variance in overall teacher readiness ($\eta^2 = .168$).

The results of the post hoc between-subjects effects showed that the non-English group was significantly different from the English group on their understanding of language, literacy, and EL instruction ($F_{(1, 52)} = 7.03$, $p < .05$, $\eta^2 = .119$) but not both on teacher efficacy ($F_{(1, 52)} = .22$, $p = .64$, $\eta^2 = .004$) and on standards-based instruction ($F_{(1, 52)} = .61$, $p = .44$, $\eta^2 = .012$).

In this study, those whose first language is not English showed significantly higher understanding of language, literacy, and EL instruction (mean = .25 logits, SE = 1.29) than those whose first language is English (mean = -3.77 logits, SE = .64). On the other hand, both non-English and English groups showed no significant difference in teacher efficacy (non-English: mean = 2.18 logits, SE = .58; English: mean = 1.57 logits, SE = .29) and no significant difference in standards-based instruction (non-English: mean = -1.89 logits, SE = .81; English: mean = -1.81 logits, SE = .40).

**Interaction Effect (Completion by First language)**

The results of the factorial MANOVA showed no significant completion by first language interaction effect on preservice teachers' overall teacher readiness (Wilks' lambda = .95, $F_{(3, 50)} = .92$, $p = .44$). In this study, completion by first language interaction accounted for 5.2% of the variance in overall teacher readiness ($\eta^2 = .052$).

The results of the post hoc between-subjects effects confirmed the results of Wilks' lambda of no completion by first language interaction effect on any levels of teacher readiness: teacher efficacy ($F_{(1, 52)} = .15$, $p = .70$, $\eta^2 = .003$); standards-based instruction

($F_{(1, 52)}$ = 1.12, $p$ = .30, $\eta^2$ = .021); and language, literacy, and EL instruction ($F_{(1, 52)}$ = .56, $p$ = .46, $\eta^2$ = .011).

Table 34 showed estimated means of completion of undergraduate STEM education programs, first language, and completion by first language interaction on teacher efficacy, standards-based instruction, and language, literacy, and EL instruction (all means are in logit units). A MANOVA summary table is displayed in Table 35.

Table 34

*Estimated Means of Completion of Undergraduate STEM Education Programs, First Language, and Completion by First Language Interaction on Teacher Efficacy, Standards-Based Instruction, and Language, Literacy, and EL Instruction*

| Variables | | Mean | SE | N |
|---|---|---|---|---|
| Teacher Efficacy | First Language | | | |
| Completion | No | 2.10 | 0.58 | 7 |
| | Yes | 1.86 | 0.28 | 34 |
| | Total | 1.96 | 0.30 | 41 |
| No Completion | No | 2.44 | 1.51 | 1 |
| | Yes | 1.29 | 0.50 | 22 |
| | Total | 1.52 | 0.50 | 23 |
| Total | No | 2.18 | 0.58 | 8 |
| | Yes | 1.57 | 0.29 | 56 |
| | Total | 1.78 | 0.27 | 64 |
| Standards-Based Instruction | First Language | | | |
| Completion | No | -.97 | 0.82 | 7 |
| | Yes | -1.24 | 0.39 | 34 |
| | Total | -1.12 | 0.42 | 41 |
| No Completion | No | -4.66 | 2.12 | 1 |
| | Yes | -2.38 | 0.70 | 22 |
| | Total | -2.84 | 0.70 | 23 |
| Total | No | -1.89 | 0.81 | 8 |
| | Yes | -1.81 | 0.40 | 56 |
| | Total | -1.84 | 0.60 | 64 |

*Note.* All means are in logit unit.

Table 35

*MANOVA Summary Table*

| Source | Dependent Variable | SS | *df* | MS | *F* | *p* |
|---|---|---|---|---|---|---|
| Completion | Teacher Efficacy | 0.53 | 1 | 0.53 | 0.23 | 0.63 |
| | Standards-Based | 15.01 | 1 | 15.01 | 3.34 | < .05 |
| | EL Instruction | 0.15 | 1 | 0.15 | 0.01 | 0.91 |
| First language | Teacher Efficacy | 0.51 | 1 | 0.51 | 0.22 | 0.64 |
| | Standards-Based | 2.73 | 1 | 2.73 | 0.61 | 0.44 |
| | EL Instruction | 79.63 | 1 | 79.63 | 7.03 | < .05 |
| Completion × First Lang | Teacher Efficacy | 0.34 | 1 | 0.34 | 0.15 | 0.70 |
| | Standards-Based | 5.03 | 1 | 5.03 | 1.12 | 0.30 |
| | EL Instruction | 6.37 | 1 | 6.37 | 0.56 | 0.46 |
| Error | Teacher Efficacy | 119.11 | 52 | 2.29 | | |
| | Standards-Based | 233.54 | 52 | 4.49 | | |
| | EL Instruction | 589.14 | 52 | 11.33 | | |
| Corrected Total | Teacher Efficacy | 131.43 | 63 | | | |
| | Standards-Based | 271.30 | 63 | | | |
| | EL Instruction | 742.02 | 63 | | | |

Wilks' lambda = .93, $F_{(3, 50)} = 1.18$, $p = .33$, $\eta^2 = .066$
Wilks' lambda = .83, $F_{(3, 50)} = 3.35$, $p < .05$, $\eta^2 = .168$
Wilks' lambda = .95, $F_{(3, 50)} = .92$, $p = .44$, $\eta^2 = .052$

**Comparison between the pre-survey only group and the pre- and post-survey group**

At the beginning of their teacher education program, a total of 106 preservice teachers participated in this study. However, 40 preservice teachers out of 106 did not participate in the post-survey. Using MANOVA, I investigated whether there were any significant differences in teacher readiness between those who participated in the survey both at the beginning and end of their teacher education program and those who participated in the survey only at the beginning. It was hypothesized that the pre-survey only group (those who participated in the survey only at the beginning) might show lower teacher readiness than the pre- and post-survey group (those who participated in the survey both at the beginning and end of their program).

The results of the factorial MANOVA, on the other hand, showed no significant difference between the pre-survey only group and the pre- and post-survey group on their overall teacher readiness (Wilks' lambda = .98, $F_{(3, 102)}$ = .75, $p$ = .52). Participation difference accounted for only 2.2% of the variance in overall teacher readiness ($\eta^2$ = .022).

The results of the post hoc between-subjects effects also found no significant difference between the pre-survey only group and the pre- and post-survey group on teacher efficacy ($F_{(1, 105)}$ = .17, $p$ = .68, $\eta^2$ = .002), standards-based instruction ($F_{(1, 105)}$ = .16, $p$ = .69, $\eta^2$ = .001), and language, literacy, and EL instruction ($F_{(1, 105)}$ = 1.79, $p$ = .18, $\eta^2$ = .017).

In this study, although the pre- and post-survey participant group showed slightly higher teacher efficacy (mean = 1.40 logits, SE = .17) than the pre-survey only group (mean = 1.29 logits, SE = .22), the difference (Δ = .114) was not statistically significant, $p$ = .68. On the other hand, the pre-survey only group showed slightly higher standards-based instruction (mean = 2.41 logits, SE = .20) than the pre- and post-survey group (mean = 2.31 logits, SE = .16). However, the difference (Δ = .102) was not statistically significant, $p$ = .69. The mean difference (Δ = .315) in language, literacy, and EL instruction between the pre-survey only group (mean = 2.07 logit, SE = .19) and the pre- and post-survey group (mean = 1.76 logit, SE = .15) was not statistically significant, either.

**Repeated Measures Analysis**

Prior to the repeated measures analysis, data were screened to ensure that the test's assumptions of the mixed design were fulfilled. Descriptive statistics, including skewness and kurtosis coefficients, histograms, and normal Q-Q plots were examined for the pre- and post-surveys on teacher efficacy, standards-based instruction, and language, literacy, and EL instruction for both completion and non-completion groups and both graduate TEP and non-graduate TEP groups. These measures and plots showed that the assumption of normality was fulfilled on the pre- and post-surveys of teacher readiness across completion and TEPs.

A mixed design MANOVA (mixed between-within-subjects MANOVA) was utilized to examine if there was a significant change (increase) in the levels of teacher readiness between the beginning and end of the program among preservice teachers and whether these measures were different based on the type of teacher education programs (graduate program versus undergraduate program) and the completion of undergraduate STEM education programs (completion versus non-completion).

**Within-Subject Effect (Time)**

The results of the tests of within-subjects effects showed an overall significant change between the beginning and end of their teacher education program on their overall teacher readiness ($F_{(3, 58)} = 4.79$, $p < .01$). Overall scores for teacher readiness were significantly greater at the end of their teacher education program (mean = -.58, SE = .14) than at the beginning (mean = -91, SE = .21), $p < .01$. However, teacher efficacy showed a significant decrease through the program ($F_{(1, 60)} = 8.56$, $p < .01$). More specifically, scores for teacher efficacy among preservice teachers enrolled in an experimental undergraduate teacher education program were significantly lower at the end (mean = .93, SE = .35) than at the beginning (mean = 2.36, SE = .54), $p < .01$.

**Within-Between-Subject Effect 1 (Time × TEP Type)**

The results of the multivariate Wilks' lambda test showed a significant effect between time (pre- and post-survey) and TEP type on overall teacher readiness (Wilks's Lambda = .82, $F_{(3, 58)} = 4.14$, $p < .05$). Specifically, the effect was significant on teacher efficacy ($F_{(1, 60)} = 8.21$, $p < .01$) and language, literacy, and EL instruction ($F_{(1, 60)} = 6.45$, $p < .05$). Preservice teachers enrolled in teacher education programs at the graduate level showed a significantly greater understanding of language, literacy, and EL instruction at the end (mean = -1.50 logits, SE = .35) than at the beginning (mean = -3.40 logits, SE = .49), whereas preservice teachers enrolled in an experimental undergraduate teacher credential program showed a significantly lower teacher efficacy at the end (mean = .93 logits, SE = .35) than at the beginning (mean = 2.36 logits, SE = .54).

**Within-Between-Subjects Effect 2 (Time × Completion)**

The results of the multivariate Wilks' lambda test showed no significant effect between time (pre- and post-survey) and completion of undergraduate STEM education programs on overall teacher readiness (Wilks's Lambda = .99, $F_{(3, 58)} = .28$, $p = .84$). In addition, completion of undergraduate STEM education programs had no significant effect on the change in each level of teacher readiness, teacher efficacy ($F_{(1, 60)} = .02$, $p = .90$), standards-based instruction ($F_{(1, 60)} = .15$, $p = .70$), and language, literacy, and EL instruction ($F_{(1, 60)} = .86$, $p = .36$) between the beginning and end of their program. Descriptive statistics and a summary table of the results of the repeated measures analysis are displayed in Tables 36 – 37.

Table 36

*Descriptive Statistics of the Results of Repeated Measures Analysis*

| | Time | Pre | Post |
|---|---|---|---|
| Teacher Readiness | Mean | -0.91 | -0.58 |
| | SE | 0.21 | 0.14 |
| | *n* | 63 | 63 |
| Teacher Efficacy | Mean | 1.60 | 1.31 |
| | SE | 0.18 | 0.16 |
| | *n* | 63 | 63 |
| Standard-Based Instruction | Mean | -1.49 | -1.37 |
| | SE | 0.26 | 0.17 |
| | *n* | 63 | 63 |
| Language, Literacy, and EL Instruction | Mean | -2.91 | -1.65 |
| | SE | 0.43 | 0.31 |
| | *n* | 63 | 63 |

*Note.* Means are all in logit unit.

Table 37

*Summary Table of the Results of Repeated Measures Analysis*

| Source | Measure | SS | *df* | MS | *F* | *p* |
|---|---|---|---|---|---|---|
| Time | Teacher Efficacy | 9.26 | 1 | 9.26 | 8.56** | < .01 |
| | Standards-Based Instruction | 0.03 | 1 | 0.03 | 0.01 | 0.92 |
| | Language, Literacy, and EL Instruction | 18.69 | 1 | 18.69 | 3.58 | 0.06 |
| Time×TEP Type | Teacher Efficacy | 8.88 | 1 | 8.88 | 8.21** | < .01 |
| | Standards-Based Instruction | 3.20 | 1 | 3.20 | 1.26 | 0.27 |
| | Language, Literacy, and EL Instruction | 33.69 | 1 | 33.69 | 6.45* | < .05 |
| Time×Completion | Teacher Efficacy | 0.02 | 1 | 0.02 | 0.02 | 0.90 |
| | Standards-Based Instruction | 0.39 | 1 | 0.39 | 0.15 | 0.70 |
| | Language, Literacy, and EL Instruction | 4.47 | 1 | 4.47 | 0.86 | 0.36 |
| Error | Teacher Efficacy | 64.92 | 60 | 1.08 | | |

| | | | |
|---|---|---|---|
| Standards-Based Instruction | 151.99 | 60 | 2.53 |
| Language, Literacy, and EL Instruction | 313.47 | 60 | 5.23 |

*$p < .05$. **$p < .01$. ***$p < .001$

## Canonical Correlation Analysis

Canonical correlation analysis or multivariate multiple regression (MMR) was conducted to examine the impact of teacher readiness (teacher efficacy, standards-based instruction, and language, literacy, and EL instruction) as determined by the post-survey on their edTPA scores (planning, instruction, and assessment). In other words, what teacher readiness best predicts their edTPA scores among preservice teachers enrolled in one of six teacher education programs in California was investigated. The results of the overall Wilks' lambda multivariate tests of significance showed no significant correlation between the teacher readiness variate and the edTPA scores variate (Wilks' lambda = .87, $F_{(9, 112)} = .74$, $p = .66$). The results of the Wilks' lambda dimension reduction analysis test also revealed that no canonical variates pair was significant. Overall, the correlation between teacher readiness and the edTPA scores was .31. The results of the univariate regression analysis showed that any component of the edTPA scores was not a function of any component of teacher readiness.

# Chapter V: Discussion

## Overview

Despite many years and multiple plans by educational policy makers and government agencies to increase the number of a high-quality teacher, the country is still experiencing a severe teacher shortage with no sign of improvement. (Darling-Hammond, 2000; Harris & Sass, 2011; Rice, 2003; Stronge, Ward, Tucker, & Hindman, 2007). A quality teacher has been found to be highly influential in improving student achievement (Christidou, 2011). Specifically, California's teacher shortage is worsening with many districts struggling to find enough qualified teachers to fill vacancies. To help recruit and better prepare beginning science and mathematics teachers in California, a group of public universities launched undergraduate STEM education programs in 2005. Undergraduate STEM majors who have completed undergraduate STEM education programs are expected to continue to pursue science and mathematics teacher credentials in teacher education programs (TEPs). In California, with the exception of experimental programs, teacher education programs (TEPs) are administered at the post-baccalaureate level. For the majority of universities participating in this study, the teacher education program was a one-year, post-baccalaureate program (2 summers and one academic year). One of the programs participating in the study was an experimental teacher education program, where undergraduates who have completed their undergraduate STEM education minor program and have declared a major in a STEM field were eligible to apply for the credential program, which supports them to get a mathematics or science secondary school teacher credential and begin teaching middle or high school after graduation.

This research examined if and how undergraduate STEM education programs and teacher education programs contributed to facilitating science and mathematics teacher readiness and improving teacher performance assessment (edTPA) scores. Teacher readiness was defined as (1) teacher efficacy, (2) standards-based instruction, and (3) language, literacy, and EL instruction. edTPA scores were composed of (1) planning, (2) instruction, and (3) assessment.

First, I investigated whether there were significant differences in the levels of teacher readiness between preservice teachers who had completed undergraduate STEM education programs and those who had not at the beginning of their teacher education programs. Findings from my research revealed that completion of undergraduate STEM education programs had a significant effect on preservice teachers' understanding of standards-based instruction at the beginning of their teacher education program. However, the undergraduate STEM education programs' impact on the overall teacher readiness was not significant. More specifically, their impact on teacher efficacy and language, literacy, and EL instruction was not significant. Judging from the overall structure of the current undergraduate STEM education programs, it was evident that the programs play a crucial role in facilitating the implementation of ambitious or high-leverage teaching practices and the NGSS/CCSS practices through the coursework and fieldwork. However, classes on how to teach English learners (ELs) science or mathematics or how to help students develop academic language and literacy in science or mathematics were rather limited. The lack of classes on language, literacy, and EL instruction seemed to be reflected in the findings from this study.

According to Bandura (1997), teacher efficacy is mostly developed by mastery teaching experiences. Enacted mastery teaching experiences are the most influential source of efficacy information because they provide the most authentic evidence of whether one can muster whatever it takes to succeed (Gavora, 2010). Through these experiences, teachers demonstrate their own success of teaching, and thus they feel that they are competent teachers. Classes and field experiences offered by the current undergraduate STEM education programs seemed to be not enough to enhance teacher efficacy. Teacher efficacy was expected to be developed by a year-long teacher education program from the field placement and student teaching experiences.

In addition, I examined if teacher readiness between preservice teachers whose first language is English [English] and those whose first language is not English [non-English] differed. Findings from this study showed that there was a significant difference between those two groups on their overall teacher readiness. As expected, preservice teachers whose first language is not English showed a significantly greater understanding of language, literacy, and EL instruction than those whose first language is English (Lee & Oxelson, 2006). The results did make sense. However, there was a limitation on this interpretation because the sample size of the non-English group was just 12 percent of the total participants. Since the sample size was less than the 20 percent needed for an acceptable for a response rate for a parametric test, the size of the effect or the statistical power of the findings was small (Raykov & Marcoulides, 2012).

At the beginning of their teacher education program, a total of 106 preservice teachers participated in this study. However, 40 preservice teachers out of the 106 did not participate in the post-survey. This concerned teacher education researchers because preservice teachers with low teacher readiness at the beginning were thought more likely to stop participating in any research or even stop their teacher education program itself. However, preservice teachers who did not participate in the post-survey showed no significant difference in terms of their teacher readiness compared to those who participated in both the pre- and post-survey. There appears to be many reasons why they decided not to participate in the survey at the end. The survey questionnaires might be too long. They did not have enough time to participate in this study. Or the importance of the study might not have been fully conveyed to them. Further research is required to explain this finding.

Overall, teacher readiness was greatly improved among preservice teachers through their teacher education program. Specifically, preservice teachers who enrolled in their teacher education program at the graduate level showed a higher improvement in language, literacy, and EL instruction than those enrolled in an experimental undergraduate teacher credential program. This finding was somewhat expected because unlike undergraduate STEM education programs or an experimental undergraduate teacher credential program, the TEPs at the graduate level offer a number of classes related to the topic of language, literacy, and EL instruction. Therefore, preservice teachers were able to enhance their understanding of language, literacy, and EL instruction through the coursework and field placement experiences.

Contrary to our expectation, teacher efficacy of preservice teachers enrolled in an experimental undergraduate teacher education program was lowered through their program. An experimental education program consists of only two components: (1) apprentice teaching and (2) student teaching. Unlike the rest five TEPs, no seminar style classes are offered in this program. They might have had very limited opportunity to discuss any crucial issues arising from their teaching experiences. This may have resulted in low teacher efficacy. Even so, it is still problematic that teacher efficacy of teacher candidates was lowered through their teacher education program. More in-depth research is again required to explain this finding.

It was expected that teacher readiness developed by their teacher education programs would have a significant effect on teacher performance determined by edTPA scores. Contrary to our expectations, however, findings revealed that teacher readiness did not significantly influence their edTPA scores. There was a discrepancy between the results from their self-reported responses and the evaluation by an external assessment publishing company. As seen in Tables 13 – 14 and 33, all three levels of edTPA scores (planning, instruction, and assessment) seemed to be closely associated with all three levels of teacher readiness (teacher efficacy, standards-based instruction, and language, literacy, and EL instruction). The survey questionnaires on teacher readiness used for this study might not be aligned with all constructs of their teaching performance. Therefore, their self-reported responses to the survey questions might not be consistent with their teaching performance. Preservice teachers might not be consistent in responding to the survey items because they thought the survey questionnaires were too long. Or they did not have enough time to concentrate on the survey. Teacher education programs and teacher educators should consider how to help preservice teachers better achieve high edTPA scores.

## Limitations

In this study, the sample size was sufficient for the analyses performed here. But the absolute size was rather small. So, it might not detect small differences that would have been detected by a larger sample. Considering the proportion of each sample relative to the total target population, however, it was deemed adequate (undergraduate participants: 50%; graduate participants: 40%; and total participants: 42%). With regard to the sample size, there were no restrictions on the statistical analyses performed here. (RayKov & Marcoulides, 2012). Other, more complex analyses, however, could have been performed with a larger sample.

Overall, teacher readiness was significantly improved among preservice teachers through their teacher education program. In other words, teacher education programs played a crucial role in enhancing teacher readiness. Specifically, preservice teachers who enrolled in their teacher education program at the graduate level showed a higher improvement in language, literacy, and EL instruction. While a significant increase between pre- and post-survey was found among preservice teachers, we were not certain about whether the increase was linear, exponential, or quadratic because data were collected at just two time-points. Data collection across just two time-points was not enough to create a growth model. With growth modeling, we can identify whether the growth is linear, quadratic, or exponential. Therefore, data collection across at least three time-points is highly recommended for any future longitudinal studies.

While teacher efficacy of preservice teachers enrolled in one of five teacher education programs at the graduate level did not change much, teacher efficacy of preservice teachers enrolled in an experimental undergraduate teacher education program was lowered through their program. One possible explanation was that they might have had very limited opportunity to discuss any crucial issues arising from their teaching experiences because no seminar style classes were offered by their experimental program. This might have resulted in low teacher efficacy. However, more in-depth research to explain this finding is required in the near future.

It was expected that teacher readiness developed by their teacher education programs would have a significant effect on teacher performance determined by edTPA scores. Contrary to our expectations, teacher readiness did not significantly influence their edTPA scores. There was a discrepancy between the results from their self-reported responses and the evaluation by an external assessment publishing company. Preservice teachers' responses to the survey might not be consistent. Or the survey questionnaires on teacher readiness used for this study might not be aligned with all three constructs of their teaching performance. To see if the survey questionnaires measure the constructs they are supposed to measure, a validity study is required. Survey validity can be examined by looking at differential item functioning (DIF) and measurement invariance analysis. For a validity study on the current survey used for this study, however, the sample size was relatively small. If more are accumulated through continued study, a highly reliable validity study on the current survey would be possible.

## Implications

This study examined if and how undergraduate STEM education programs and teacher education programs contributed to teacher readiness, if there was a significant increase in teacher readiness between the beginning and end of the programs among preservice teachers, if teacher readiness differed between fifth-year and undergraduate programs, and how teacher readiness was associated with teacher performance-based assessment (edTPA) scores.

I found that preservice teachers who had completed undergraduate STEM education programs were significantly better prepared for quality teaching compared to those who had not completed such a program at the beginning of the study. Specifically, preservice teachers who had completed undergraduate STEM education programs showed a greater understanding of standards-based instruction. As seen in Tables 2 – 3, the topic of standards-based instruction was well discussed through the introductory course and science and mathematics education minor courses offered by the programs.

In terms of teacher efficacy and language, literacy, and EL instruction, there was no significant difference between those who had completed undergraduate STEM education programs and those who had not. Teacher efficacy is the basic belief that teachers have about their abilities and skills as teachers. Teacher efficacy has been shown to be an important characteristic of the teacher and one strongly related to success in teaching. Considering the importance of teacher efficacy specifically among beginning teachers, the current undergraduate STEM education programs need to consider how to enhance teacher efficacy, including what courses to offer for this purpose, how to deal with this issue through teaching experiences, and so on.

In addition, although there were several classes addressing *language, literacy, or instruction of English learners*, such as 'Language, Culture and Education' or 'Innovative Practices for English Language Learners in K-12 Mathematics and Science Classrooms' offered by several universities, classes on how to teach English learners (ELs) science or mathematics or how to help students develop academic language and literacy in science or mathematics, in general, seemed to be rather limited. Under the new science and mathematics standards which emphasize language use in the science and mathematics classroom through implementing science, engineering, or mathematics practices, the undergraduate STEM education programs need to be directed to addressing academic language and literacy development in science and mathematics. Furthermore, considering the K-12 student population in California where 43 percent of the state's public school enrollment speak a language other than English at home, how to teach ELs science or mathematics will be a very urgent task for teachers compared to other states in the US. In this study, those whose first language was not English showed significantly higher understanding of language, literacy, and EL instruction than those whose first language was English. Even though this was not one of my research questions, this finding indicated that we need to recruit undergraduate STEM majors whose first language is not English and encourage them to pursue science or mathematics teaching careers.

While overall teacher readiness was improved through their teacher education programs, teacher efficacy of preservice teachers enrolled in an experimental undergraduate teacher education program was lowered. Teacher educators involved in this program are required to consider how to address this issue arising from their teaching experiences (apprentice teaching and student teaching).

Using the new science and mathematics standards as a guide, repeated measures analysis of teacher readiness made visible which components of teacher readiness were well addressed and which were not in the participating teacher education programs. Preservice teachers attending fifth-year, post-baccalaureate teacher education programs showed a significant increase in language, literacy, and EL instruction. This result was expected because methods of teaching a second language and developing academic language and literacy in all discipline areas were well addressed through their integrated model of coursework. However, there was no significant change in standards-based instruction through their program. Even though the effect of undergraduate STEM education programs was significant on standards-based education, its effect was not associated with an increase in standards-based instruction through their teacher education programs.

Contrary to our expectations, teacher readiness determined by the post-survey was not much associated with their teaching performance determined by their edTPA scores. In other words, there was a discrepancy between the results from their self-reported responses and evaluation by an external assessment publishing company. Using accumulated data through continued study, a highly reliable validity study on the current survey questionnaires is required to explain this finding.

## Conclusion

In conclusion, undergraduate STEM education programs were effective in developing standards-based instruction. Fifth-year, post-baccalaureate teacher education programs were effective in developing language, literacy, and EL instruction, whereas an experimental undergraduate teacher education program was not. Both undergraduate STEM education programs and teacher education programs were not very effective in developing teacher efficacy. Specifically, teacher efficacy of participants attending an experimental undergraduate program was lowered through their program.

I conclude with recommendations for teacher educators, for ways teacher education programs can be revised to better prepare reform-minded science and mathematics teachers skilled in teaching all students, including English learners. Teacher educators and curriculum developers involved in undergraduate STEM education programs should consider how to address and include the topic of language, literacy, and EL instructions in their programs. Teacher educators involved in teacher education programs (TEPs) should consider how to improve preservice teachers' understanding of standard-based instruction through their programs as well. Both undergraduate STEM education programs and teacher education programs need to find ways of how to develop teacher efficacy of participants in their programs. Specifically, teacher educators involved in an experimental undergraduate teacher education program should provide an opportunity for preservice teachers to address low teacher efficacy issues arising from their apprentice teaching and student teaching experiences.

## References


Abu-Bader, S. H. (2010). *Advanced and multivariate statistical methods for social science research with a complete SPSS guide*. Lyceum Books, Incorporated.

Adeyemi, A. A., Mustafa, D., & Oladipo, S. L. (2013). A second-order factor gender-measurement invariance analysis of financial exclusion in Ilorin, Nigeria. *International Journal of Trade, Economics and Finance, 4*(6), 398.

Assessment, I. T., & Support Consortium. (2011). InTASC model core teaching standards: A resource for state dialogue. *Washington, DC: Council of Chief State School Officers*.

Ballantyne, K. G., Sanderman, A. R., & Levy, J. (2008). Educating English Language Learners: Building Teacher Capacity. Roundtable Report. *National Clearinghouse for English Language Acquisition & Language Instruction Educational Programs*.

Barton, A. C., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *The Journal of the Learning Sciences, 19*(2), 187-229.

Boone, W. J., Staver, J. R., & Yale, M. S. (2014). *Rasch analysis in the human sciences*. Dordrecht: Springer.

Bravo, M. A., Solís, J. L., & Mosqueda, E. (2011). Pre-service teacher efficacy and practices with responsive science pedagogy for English learners. *National Association for Research in Science Teaching Orlando*.

Brinton, S. (1989). Wesche. *Content-Based Language Instruction*.

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms: Understanding A Framework for K-12 Science Education. *Science and Children*, *49*(4), 10.

Chang, L. (1995). Connotatively consistent and reversed connotatively inconsistent items are not fully equivalent: Generalizability study. *Educational and Psychological Measurement*, *55*(6), 991-997.

Chang, L. (1995). Connotatively inconsistent test items. *Applied Measurement in Education*, *8*(3), 199-209.

Chen, F. F., Sousa, K. H., & West, S. G. (2005). Teacher's corner: Testing measurement invariance of second-order factor models. *Structural equation modeling*, *12*(3), 471-492.

Christidou, V. (2011). Interest, Attitudes and Images Related to Science: Combining Students' Voices with the Voices of School Science, Teachers, and Popular Science. *International Journal of Environmental and Science Education*, *6*(2), 141-159.

Custer, M. (2015). Sample Size and Item Parameter Estimation Precision When Utilizing the One-Parameter" Rasch" Model. *Online Submission*.

Danielson, C. (2013). *The framework for teaching: Evaluation instrument*. Princeton, NJ: Danielson Group.

Darling-Hammond, L. (2006). Constructing 21st-century teacher education. *Journal of teacher education*, *57*(3), 300-314.

De Ayala, R. J. (2013). *The theory and practice of item response theory*. Guilford Publications.

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

Doherty, R. W., Hilberg, R. S., Epaloose, G., & Tharp, R. G. (2002). Standards performance continuum: Development and validation of a measure of effective pedagogy. *The Journal of Educational Research*, *96*(2), 78-89.

Dover, A. G., Schultz, B. D., Smith, K., & Duggan, T. J. (2015). Who's preparing our candidates? edTPA, localized knowledge and the outsourcing of teacher evaluation. *Teachers College Record*.

Dray, B. J., Lowenthal, P. R., Miszkiewicz, M. J., Ruiz-Primo, M. A., & Marczynski, K. (2011). Developing an instrument to assess student quality for online learning: A validation study. *Distance Education*, *32*(1), 29-47.

Fang, Z., & Schleppegrell, M. J. (2008). Technicality and reasoning in science: Beyond vocabulary. *Reading in secondary content areas: A language-based pedagogy*, 18-38.

Fang, Z., Schleppegrell, M. J., Lukin, A., Huang, J., & Normandia, B. (2008). *Reading in secondary content areas: A language-based pedagogy*. University of Michigan Press.

Field, A. (2009). *Discovering statistics using SPSS*. Sage publications.

Foley, B. P. (2010). *Improving IRT parameter estimates with small sample sizes: Evaluating the efficacy of a new data augmentation technique*. The University of Nebraska-Lincoln.

Echevarria, J., Vogt, M., & Short, D. (2004). *Making content comprehensible for English learners: The SIOP model*. Boston: Allyn and Bacon.

Gándara, P., Maxwell-Jolly, J., & Driscoll, A. (2005). Listening to Teachers of English Language Learners: A Survey of California Teachers' Challenges, Experiences, and Professional Development Needs. *Policy Analysis for California Education, PACE (NJ1)*.

Gee, J. P., Rosebery, A. S., & Warren, B. (2008). What is academic literacy. *Teaching science to English language learners*, 57-70.

George, D., & Mallery, M. (2003). Using SPSS for Windows step by step: a simple guide and reference.

Green, K. E., & Frantom, C. G. (2002, November). Survey development and validation with the Rasch model. In *International Conference on Questionnaire Development, Evaluation, and Testing, Charleston, SC*.

Guilleux, A., Blanchin, M., Hardouin, J. B., & Sébille, V. (2014). Power and sample size determination in the Rasch model: evaluation of the robustness of a numerical method to non-normality of the latent trait. *PloS one*, *9*(1), e83652.

Hansen-Thomas, H. (2008). Sheltered instruction: Best practices for ELLs in the mainstream. *Kappa Delta Pi Record*, *44*(4), 165-169.

Hart, J. E., & Lee, O. (2003). Teacher professional development to improve the science and literacy achievement of English language learners. *Bilingual Research Journal*, *27*(3), 475-501.

He, Q., & Wheadon, C. (2013). The effect of sample size on item parameter estimation for the partial credit model. *International Journal of Quantitative Research in Education*, *1*(3), 297-315.

Hula, W., Fergadiotis, G., & Martin, N. (2011). The effects of sample size and guessing on parameter recovery in IRT modeling of aphasia test data.

Jones, M. T., & Eick, C. J. (2007). Implementing inquiry kit curriculum: Obstacles, adaptations, and practical knowledge development in two middle school science teachers. *Science Education*, *91*(3), 492-513.

Kagan, D. M. (1992). Implication of research on teacher belief. *Educational psychologist*, *27*(1), 65-90.

Kloser, M. (2014). Identifying a core set of science teaching practices: A Delphi expert panel approach. *Journal of Research in Science Teaching*, *51*(9), 1185-1217. doi:10.1002/tea.21171.

Lamb, R. L., Annetta, L., Meldrum, J., & Vallett, D. (2012). Measuring science interest: Rasch validation of the science interest survey. *International Journal of Science and Mathematics Education*, *10*(3), 643-668.

Lacelle-Peterson, M., & Rivera, C. (1994). Is it real for all kids? A framework for equitable assessment policies for English language learners. *Harvard Educational Review*, *64*(1), 55-76.

Lachuk, A. J., & Koellner, K. (2015). Performance-based assessment for certification: Insights from edTPA implementation. *Language Arts*, *93*(2), 84.

Lee, J. S., & Oxelson, E. (2006). “It's not my job”: K–12 teacher attitudes toward students' heritage language maintenance. *Bilingual Research Journal*, *30*(2), 453-477.

Lee, O., Maerten-Rivera, J., Penfield, R. D., LeRoy, K., & Secada, W. G. (2008). Science achievement of English language learners in urban elementary schools: Results of a first-year professional development intervention. *Journal of Research in Science Teaching*, *45*(1), 31-52.

Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics. *Educational Researcher*, *42*(4), 223-233.

Linacre, J. M. (1994). Sample size and item calibration stability. *Rasch measurement transactions*, *7*(4), 328.

Linacre, J. M., & Wright, B. D. (1989). The “length” of a logit. *Rasch Measurement Transactions*, *3*(2), 54-55.

Magnusson, S. (1992). The relationship between teacher content and pedagogical content knowledge and student content knowledge of heat energy and temperature.

Marsh, H. W., & Hocevar, D. (1985). Application of confirmatory factor analysis to the study of self-concept: First-and higher order factor models and their invariance across groups. *Psychological bulletin*, *97*(3), 562.

Marzano, R. J., & Toth, M. D. (2013). *Teacher evaluation that makes a difference: A new model for teacher growth and student achievement*. ASCD.

McNeill, K. L., González-Howard, M., Katsh-Singer, R., & Loper, S. (2016). Pedagogical content knowledge of argumentation: Using classroom contexts to assess high-quality PCK rather than pseudoargumentation. *Journal of Research in Science Teaching, 53*(2), 261-290. doi:10.1002/tea.21252

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Papanastasiou, C. (2002). School, teaching and family influence on student attitudes toward science: Based on TIMSS data for Cyprus. Studies in Educational Evaluation, 28, 71–86.

PISA, O. (2012). Results in Focus: What 15-year-olds know and what they can do with what they know. *2014-12-03]. http:////www, oecd. org/pisa,/keyfindings,/pisa-2012-results-overview, pdf*.

Podolsky, A., & Sutcher, L. (2016). California Teacher Shortages: A Persistent Problem.

Ponterotito, J. G., Baluch, S., Greig, T., & Rivera, L. (1998). Development and initial score validation of the teacher multicultural altitude survey. *Educational and Psychological Measurement*, *58*(6), 1002-1016.

Raykov, T., & Marcoulides, G. A. (2011). *Introduction to psychometric theory*. Routledge.

Raykov, T., & Marcoulides, G. A. (2012). *An introduction to applied multivariate analysis*. Routledge.

Rivet, A. E., & Krajcik, J. S. (2008). Contextualizing instruction: Leveraging students' prior knowledge and experiences to foster understanding of middle school science. *Journal of Research in Science Teaching, 45*(1), 79-100.

Sahin, A., & Anil, D. (2017). The Effects of Test Length and Sample Size on Item Parameters in Item Response Theory. *Educational Sciences: Theory and Practice*, *17*(1n), 321-335.

Sato, M. (2014). What is the underlying conception of teaching of the edTPA?. *Journal of Teacher Education*, *65*(5), 421-434.

Senk, S. L., Tatto, M. T., Reckase, M., Rowley, G., Peck, R., & Bankov, K. (2012). Knowledge of future primary teachers for teaching mathematics: an international comparative study. *ZDM*, *44*(3), 307-324.

Smith, L. I. (2002). A tutorial on principal components analysis. *Cornell University, USA*, *51*(52), 65.

Stoddart, T., Bravo, M., Solis, J., Mosqueda, E., & Rodriguez, A. (2011). Effective science teaching for English language learners (ESTELL): Measuring pre-service teacher practices. In *annual meeting of the American Educational Research Association, New Orleans*.

Stoddart, T., Bravo, M., Mosqueda, E., & Solis, J. (2013). Restructuring pre-service teacher education to respond to increasing student diversity. *Research in Higher Education Journal*, *19*, 1.

Stoddart, T., Pinal, A., Latzke, M., & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. *Journal of Research in Science Teaching, 39*(8), 664-687.

Talbot, R. M. (2011). *Validity issues in the evaluation of a measure of science and mathematics teacher knowledge*. (Doctoral dissertation). Available from ProQuest Dissertations and Theses Database. (UMI No. 3468489).

Talton, E. L., & Simpson, R. D. (1986). Relationships of attitudes toward self, family, and school with attitude toward science among adolescents. *Science Education*, *70*(4), 365-374.

Tatto, M. T., Peck, R., Schwille, J., Bankov, K., Senk, S. L., Rodriguez, M., ... & Rowley, G. (2012). *Policy, Practice, and Quality to Teach Primary and Secondary Mathematics in 17 Countries: Findings from the IEA Teacher Education and Development Study in Mathematics (TEDS-MM)*. International Association for the Evaluation of Educational Achievement. Herengracht 487, Amsterdam, 1017 BT, The Netherlands.

Tolbert, S., Stoddart, T., Lyon, E. G., & Solis, J. (2014). The next generation science standards, common core state standards, and English learners: Using the SSTELLA framework to prepare secondary science teachers. *Issues in Teacher Education*, *23*(1), 65.

Trent, S. C., Kea, C. D., & Oh, K. (2008). Preparing preservice educators for cultural diversity: How far have we come? *Exceptional Children, 74,* 328-350.

Van Dierendonck, D., & Nuijten, I. (2011). The servant leadership survey: Development and validation of a multidimensional measure. *Journal of business and psychology*, *26*(3), 249-267.

Warren, B., & Rosebery, A. (2008). Using everyday experience to teach science. *Teaching science to English language learners*, 39-50.

Wilson, M. (2004). *Constructing measures: An item response modeling approach*. Routledge.

Windschitl, M. (2009, February). Cultivating 21st century skills in science learners: How systems of teacher preparation and professional development will have to evolve. In *National Academies of Science Workshop on 21st Century Skills*.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education, 96*(5), 878-903. doi:10.1002/sce.21027

Works, T. (2012). High leverage practices.

Wright, A. G., Lukowitsky, M. R., Pincus, A. L., & Conroy, D. E. (2010). The higher order factor structure and gender invariance of the Pathological Narcissism Inventory. *Assessment*.

Wright, B. D., & Stone, M. H. (1979). Best Test Design. Rasch Measurement.

Youngs, P., & Whittaker, A. (2015). The role of EdTPA in assessing content specific instructional practices. *Improving teacher evaluation systems*, 89-101.

Appendix 1: The Science and Mathematics Teacher Research Initiative Survey

**Introduction**

Thank you for agreeing to complete the following survey. Your thoughtful responses are an important part of the SMTRI research project and will help us better understand how to improve teacher education programs for science and mathematics teacher candidates.

The survey is divided into four parts. It should take less than 45 minutes to complete. You may stop the survey at any time and return to it later by clicking on the link in the e-mail you received. (However, you must return to the survey on the same internet browser on the same computer, without cleared cookies, to finish the survey.)

**Section 1: Teacher Education Program Information**

This first section asks you questions about your Teacher Education Program. Questions about your name and email address are included so that we can track responses over the course of the project.

1. What is your name? *(Your name will be used only to match responses across sources of data.)*
2. What is your permanent email address?
3. In which teacher education program are you enrolled?

   ○ UC Berkeley

   ○ UC Davis

   ○ UC Riverside

○ UC San Diego

○ UC Santa Barbara

○ UC Santa Cruz

4. Please list any courses in education you have taken as an undergraduate. *(List the title of the courses, rather than the number. If you do not remember a course title, provide a brief description of what the course was about. Do not list the ones you are currently enrolled in. If none, state none.)*

5. Please list any teaching experiences you have had. (*Include the content, grade/age level, and length of time for each. If none, state none.)*

6. Please list any research experiences you have had. *(Include the content and length of time for each. If none, state none.)*

7. If you are attending or have attended a UC school as an undergraduate, are you or have you been a part of a CalTeach program?

○ Yes

○ No

○ Did not attend a UC as an undergraduate

[If no or did not attend, skip #8)]

8. What CalTeach activities are you or have you been involved with? *(Select all that apply*.)

○ Courses

○ Field placements

○ Research experiences

○ Internships (not connected to a course)

○ Workshops/seminars

○ Career counseling

○ Other (please explain):

[For UCB students]

9a. Are you currently student teaching in a mathematics or science classroom? *(Select one.)*

○ Mathematics

○ Science

[For students at other campuses]

9b. Are you a mathematics or science teacher candidate? *(Select one.)*

○ Mathematics

○ Science

10. In what specific discipline are you earning your primary teaching credential this year (e.g., foundational-level mathematics, single subject mathematics, single subject biology, etc.)?

11. In what other disciplines are you earning a teaching credential this year, if any?

12. In future years, in what other disciplines are you planning on earning a teaching credential, if any?

[Items for mathematics teacher candidates]

**Section 2: The Teaching and Learning of Mathematics**

**This second set of questions asks about your views of and experiences with the teaching and learning of mathematics.**

13. **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.**

| | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| To understand mathematics concepts, secondary students need real, concrete, hands-on experiences. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Students master and retain mathematics concepts most effectively when reading, writing, and talking are used in support of mathematics learning. | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| Mathematics is learned best when it is connected to students' everyday lives. | ☐ | ☐ | ☐ | ☐ | ☐ |
| All students have some background knowledge in mathematics. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reaching the correct solution is more important than making sense of problems and persevering in solving them. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Excelling in mathematics requires special abilities that only some people possess. | ☐ | ☐ | ☐ | ☐ | ☐ |
| English language learners need to be able to read and write proficiently in English before being taught mathematics. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Students can still learn mathematics even if they have had a history of failing the subject. | ☐ | ☐ | ☐ | ☐ | ☐ |

14. **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.**

| | **Strongly Agree** | **Agree** | **Neutral** | **Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| Listening and responding to student ideas about mathematics should be a key focus in most mathematics lessons. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Student discussions should be used sparingly as they often lead to confusion and misunderstanding of mathematics concepts. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Common Core mathematics practices should be taught separately from mathematics content. | ☐ | ☐ | ☐ | ☐ | ☐ |
| It is better to cover more mathematics topics than to teach fewer topics in more depth. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Mathematics teachers should communicate the lesson's learning goal(s) to students. | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| Connecting mathematics instruction to students' culture and communities will distract them from actually learning mathematics content. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Small group work is an integral part of mathematics teaching. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Mathematics teachers are to address students' language development as well as their content understanding in mathematics lessons. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Mathematics teachers are responsible for teaching students both how to read and produce mathematics texts. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Lecture should be a key focus in most mathematics lessons. | ☐ | ☐ | ☐ | ☐ | ☐ |

15. **Please mark the option that best describes how important you think it is for secondary (grades 6-12) mathematics teachers to do the following:**

| | **Very Important** | **Important** | **Neutral** | **Not Important** | **Very not Important** |
|---|---|---|---|---|---|
| Provide students with language supports (e.g., graphic organizers, sentence frames). | ☐ | ☐ | ☐ | ☐ | ☐ |
| Involve students in developing and using mathematical models. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Discourage students from critiquing their peers' mathematical reasoning. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Engage students in sustained discussions about mathematics topics. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Help students understand how mathematics is used in their everyday life. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Elicit students' prior knowledge about mathematics concepts. | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| Involve students in reflecting on what they have learned during the lesson. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Use multiple representations (e.g., diagrams, photos, words) to facilitate student understanding. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Teach mathematics as objective and culture free. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Focus on teaching mathematics vocabulary words, facts, and procedures. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Use multiple modalities (e.g., reading, writing, listening, and speaking) while teaching and assessing students. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Frame instruction around a big idea or puzzling phenomenon. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Ask students to explain their reasoning (e.g., Why do you think that? Can you elaborate?). | ☐ | ☐ | ☐ | ☐ | ☐ |

16. **From what you recall during your secondary (grades 6-12) schooling, how frequently were the following approaches used in mathematics classes?**

| | **Very Frequently** | **Somewhat Frequently** | **Occasionally** | **Rarely** | **Never Done** |
|---|---|---|---|---|---|
| Class discussions on mathematics topics | ☐ | ☐ | ☐ | ☐ | ☐ |
| Solving real-world problems | ☐ | ☐ | ☐ | ☐ | ☐ |
| Focusing on mathematical reasoning | ☐ | ☐ | ☐ | ☐ | ☐ |
| Using multiple representations of concepts or procedures | ☐ | ☐ | ☐ | ☐ | ☐ |
| Lectures | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reading from the textbook | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reading materials other than the textbook | ☐ | ☐ | ☐ | ☐ | ☐ |
| Small group work | ☐ | ☐ | ☐ | ☐ | ☐ |
| Individual seat work | ☐ | ☐ | ☐ | ☐ | ☐ |
| Individual or group projects | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| Projects based in the community | ☐ | ☐ | ☐ | ☐ | ☐ |

17. **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…**

| | **Strongly Agree** | **Agree** | **Neutral** | **Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| implement Common Core State Standards for Mathematics. | ☐ | ☐ | ☐ | ☐ | ☐ |
| teach an advanced mathematics course (e.g., honors, advanced placement). | ☐ | ☐ | ☐ | ☐ | ☐ |
| integrate language and literacy in my mathematics teaching. | ☐ | ☐ | ☐ | ☐ | ☐ |
| make mathematics relevant to my students. | ☐ | ☐ | ☐ | ☐ | ☐ |
| involve students in constructing and critiquing mathematical arguments. | ☐ | ☐ | ☐ | ☐ | ☐ |
| teach mathematics to English language learners. | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| find out about my students' lives outside of school. | ☐ | ☐ | ☐ | ☐ | ☐ |

[Items for science teacher candidates]

**Section 2: The Teaching and Learning of Science**

This second set of questions asks about your views of and experiences with the teaching and learning of science.

13. **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.**

| | **Strongly Agree** | **Agree** | **Neutral** | **Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| To understand science concepts, secondary students need real, concrete, hands-on experiences. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Students master and retain science concepts most effectively when reading, writing, and talking are used in support of science learning. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Science is learned best when it is connected to students' everyday lives. | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| All students have some background knowledge in science. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Following investigation procedures is more important than asking testable questions and constructing explanations of phenomena. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Excelling in science requires special abilities that only some people possess. | ☐ | ☐ | ☐ | ☐ | ☐ |
| English language learners need to be able to read and write proficiently in English before being taught science. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Students can still learn science even if they have had a history of failing the subject. | ☐ | ☐ | ☐ | ☐ | ☐ |

14. **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.**

| | **Strongly Agree** | **Agree** | **Neutral** | **Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| Listening and responding to student ideas about science should be a key focus in most science lessons. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Student discussions should be used sparingly as they often lead to confusion and misunderstanding of science concepts. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Science and engineering practices should be taught separately from content. | ☐ | ☐ | ☐ | ☐ | ☐ |
| It is better to cover more science topics than to teach fewer topics in more depth. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Science teachers should communicate the lesson's learning goal(s) to students. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Connecting science instruction to students' culture and communities | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| will distract them from actually learning science content. | | | | | |
| Small group work is an integral part of science teaching. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Science teachers are to address students' language development as well as their content understanding in science lessons. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Science teachers are responsible for teaching students both how to read and produce science texts. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Lecture should be a key focus in most science lessons. | ☐ | ☐ | ☐ | ☐ | ☐ |

15. **Please mark the option that best describes how important you think it is for secondary (grades 6-12) science teachers to do the following:**

| | **Very Important** | **Important** | **Neutral** | **Not Important** | **Very not Important** |
|---|---|---|---|---|---|
| Provide students with language supports (e.g., graphic organizers, sentence frames). | ☐ | ☐ | ☐ | ☐ | ☐ |
| Involve students in developing and using scientific models. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Discourage students from critiquing their peers' scientific reasoning. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Engage students in sustained discussions about science topics. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Help students understand how science is used in their everyday life. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Elicit students' prior knowledge about science concepts. | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| Involve students in reflecting on what they have learned during the lesson. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Use multiple representations (e.g., diagrams, photos, words) to facilitate student understanding. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Teach science as objective and culture free. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Focus on teaching science vocabulary words, facts, and procedures. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Use multiple modalities (e.g., reading, writing, listening, and speaking) while teaching and assessing students. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Frame instruction around a big idea or puzzling phenomenon. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Ask students to explain their reasoning (e.g., Why do you think that? Can you elaborate?). | ☐ | ☐ | ☐ | ☐ | ☐ |

16. **From what you recall during your secondary (grades 6-12) schooling, how frequently were the following approaches used in science classes?**

| | **Very Frequently** | **Somewhat Frequently** | **Occasionally** | **Rarely** | **Never Done** |
|---|---|---|---|---|---|
| Class discussions on science topics | ☐ | ☐ | ☐ | ☐ | ☐ |
| Open-ended explorations (e.g., students asked their own questions and/or did the planning) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Guided laboratory or field work | ☐ | ☐ | ☐ | ☐ | ☐ |
| Engineering projects | ☐ | ☐ | ☐ | ☐ | ☐ |
| Lecture | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reading from the textbook | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reading materials other than the textbook | ☐ | ☐ | ☐ | ☐ | ☐ |
| Small group work | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| Individual seat work | ☐ | ☐ | ☐ | ☐ | ☐ |
| Individual or group projects | ☐ | ☐ | ☐ | ☐ | ☐ |
| Projects based in the community | ☐ | ☐ | ☐ | ☐ | ☐ |

17. **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…**

| | **Strongly Agree** | **Agree** | **Neutral** | **Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| implement the Next Generation Science Standards. | ☐ | ☐ | ☐ | ☐ | ☐ |
| teach an advanced science course (e.g., honors, advanced placement). | ☐ | ☐ | ☐ | ☐ | ☐ |
| integrate language and literacy in my science teaching. | ☐ | ☐ | ☐ | ☐ | ☐ |
| make science relevant to my students | ☐ | ☐ | ☐ | ☐ | ☐ |
| involve students in constructing and critiquing scientific arguments. | ☐ | ☐ | ☐ | ☐ | ☐ |
| teach science to English language learners. | ☐ | ☐ | ☐ | ☐ | ☐ |

find out about my students' lives outside of school. ☐ ☐ ☐ ☐ ☐

**Section 3: Teaching Scenarios**

This third set of questions asks you about two teaching scenarios.

[Scenarios for both mathematics and science teacher candidates]

**Scenario 2**

**For this second scenario, assume that you are teaching a high school course to a class of approximately 30 students. If you are a mathematics teacher candidate, assume you are teaching a mathematics course. If you are a science teacher candidate, assume you are teaching a science course.**

Planning

19. You plan the next unit that you will teach to your class. On the first day of instruction for this unit, you initiate a whole class discussion and ask your students what they already know about the topic.

    a) How might this activity facilitate student learning?

    You find that students talk about this topic by sharing related terms from their first languages and by giving examples from their home life.

    b) Describe both what you would do and what you would expect to happen as a result.

c) If the approach you described above in (b) didn't produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?

<u>Instruction</u>

20. As part of this unit, students work in groups of four to develop a model to describe the relationship between two quantities (in mathematics) or two variables (in science).

    a) How might this activity facilitate student learning?

As the activity proceeds, one group gets frustrated and approaches you—they've come up with two models but cannot agree on which one they should present to the rest of the class. You see that one model is more accurate than the other.

b) Describe both what you would do and what you would expect to happen as a result.

c) If the approach you described above in (b) didn't produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?

<u>Assessment</u>

21. You have given your students a quiz to assess their understanding of the first week of the unit.

a) How might this activity facilitate student learning?

In grading these quizzes, you find that your students have repeated the partial understandings they articulated before the small group activity on models.

b) Describe both what would you do and what you would expect to happen as a result.

c) If the approach you described above in (b) didn't produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?

**Section 4: Demographic Information**

[Demographic questions are the same for all teacher candidates (math and science)].

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

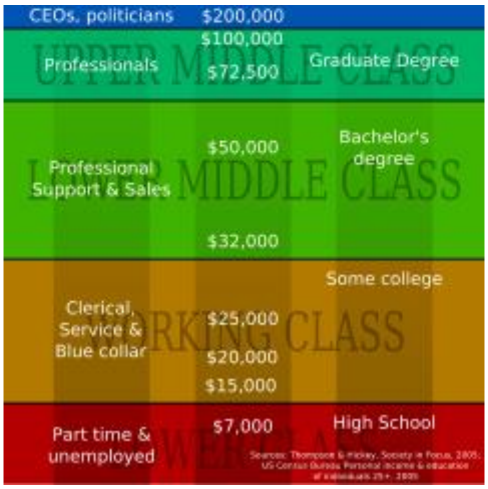
22. **List all high schools attended in chronological order, starting with the most recent.**

23. **List all colleges/universities attended in chronological order, starting with the most recent.**

24. **What is/was your undergraduate major(s)?**

25. **What is/was your undergraduate minor(s), if any?**

26. **Do you hold one or more graduate degrees? If yes, in what field(s)?**




27. **Using the visual above, how would you <u>best</u> describe your socioeconomic status growing up?** *(Select one.)*

- ☐ Lower class
- ☐ Working class
- ☐ Lower middle class
- ☐ Upper middle class
- ☐ Upper class (e.g., CEOs, politicians)

28. **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):

29. **How would you best describe the population of the community in which you completed most of your secondary (grades 6-12) schooling?** *(Check one.)*

☐ Varied cultural and racial backgrounds

☐ Predominantly people of color

☐ Predominantly people who are White/European American

30. **How would you best describe the population of <u>students in the classes you took</u> for most of your secondary (grades 6-12) schooling?** *(Check one.)*

☐ Students of varied cultural and racial backgrounds

☐ Predominantly students of color

☐ Predominantly White/European American students

31. **What is your gender**? ☐ Male ☐ Female ☐ Other (*please specify*) __________

32. **Are you Hispanic, Latina/o, or of Spanish origin?**

☐ Yes ☐ No

33. **What is your racial/ethnic background** *(check all that apply)*?

☐ Asian/Asian American (please specify): ____________________

☐ Black/African American

☐ Native American/American Indian or Alaskan Native

☐ Pacific Islander

☐ White/European American

☐ Multiracial (please specify): ___________________________

☐ Other (please specify):________________________________

34. **What is your age**?_________

35. **What is your first language? ____________________**

36. **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).]