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# Examining Preservice Secondary Science Teachers' Implementation of Reform-Based Instruction for English Learners: A Focus on the edTPA

A dissertation submitted in partial satisfaction of the requirements for the degree

Doctor of Philosophy in Education

by

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# ABSTRACT

Examining Preservice Secondary Science Teachers' Implementation of Reform-Based Instruction for English Learners: A Focus on the edTPA

by

Walter Aminger

Students designated as English learners (ELs) are the fastest growing group of students in K-12 public schools across the United States. As such, it is important for teacher education programs across the country to support their preservice teachers in attending to the academic and linguistic needs of ELs in order to foster learning opportunities in the classroom. Moreover, given the push for rigorous and equitable science instruction, preservice science teachers of ELs must also learn how to make cognitively demanding work accessible and understandable so that all students can benefit.

In this qualitative study, I investigated the lesson series of 20 preservice science teachers from four research universities by qualitatively analyzing their edTPA portfolios. These 20 preservice science teachers represented 37% of all preservice science teachers enrolled in these four programs across the two years of this study. Moreover, I separated my preservice teacher participants into two distinct groups: participants who did not have any EL students when completing their second semester takeover and participants who had at least

one EL student in their classrooms at that time. For participants in the EL group, their EL students spoke a variety of home languages and ranged in English proficiency from emerging, to expanding, to bridging (beginning, intermediate, advanced). Further, I then narrowed down my two group samples to only include the participants with the top five and bottom five edTPA scores within each of the two groups. As a result, my final research sample included 20 preservice science teachers, including 10 participants from the EL group and 10 from the non-EL group

Using a lens of Task Analysis Guide in Science (TAGS), I tracked the *NGSS* science and engineering practices and science content included in tasks so as to evaluate both the kind and level of student reasoning and sensemaking required. To do so, I examined if and how preservice secondary science teachers (PSTs) contributed to ways to support ELs in both the content and language of science as well as provided opportunities to integrate complex science content and practices in their instruction. More specifically, I analyzed preservice secondary science teachers' integration of science practices with content and implementation of cognitively demanding tasks as well as whether or not their teaching varied by those preservice teachers who had ELs in their classroom and those who did not. I also examined preservice secondary science teachers' support of academic language demands, and whether or not those types of support differed between those PSTs who taught ELs and those who did not.

One of the major findings was that the PSTs' instructional task content-practice integration and use of cognitively demanding work were clearly related to how successful they were during their performance assessment, as specified by their total edTPA scores. In fact, those 10 participants who scored high on the edTPA (both PSTs with ELs and PSTs without ELs) were

placed in the TAGS Quadrant I: Their instruction showed a high level of integration between science content and practices, and a high level of cognitive demand. In contrast, those 10 participants who had the bottom edTPA scores in each group (both PSTs with ELs and PSTs without ELs) were placed in the TAGS Quadrant III: They were neither able to successfully integrate the subject content and *NGSS* practices nor high cognitively demand during instructional tasks.

A second major finding was in terms of the number and types of academic language supports for ELs identified across PSTs. Overall, I found that participants described types of language support at the discursive level the most often and supports at the syntactic level the least often, with discussion of supports at the lexical level falling in between. In addition, those participants who did not teach ELs were still able to implement many of the same types of support across all three levels when compared to those PSTs with ELs. However, when compared to participants in Quadrant I, Quadrant III participants exhibited a greater variation in terms of supports across both groups (PSTs with ELs and those without ELs) and implemented fewer number of supports in general.

In sum, my findings indicate that some preservice secondary science teachers learned to recognize and appreciate their role in promoting reform-based science classrooms that support all students, especially ELs, better than others. Some PSTs were also able to develop a deeper understanding about academic language at the lexical, syntactic, and discursive levels than others. As such, this study suggests that the four teacher education programs were partially effective in supporting PSTs in developing effective instruction for ELs and implementing ambitious teaching practices aligned with the *NGSS* framework and cognitively demanding tasks. I conclude by providing recommendations for teacher

education programs to better prepare reform-minded secondary science teachers capable of teaching all students, especially English learners.

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# Chapter I: Introduction

## Overview

Students designated as English learners (ELs) are the fastest growing group of students in K-12 public schools across the United States; currently, they account for more than nine percent of students enrolled in U.S. classrooms (National Center for Education Statistics, 2016). During the past 10 years, the number of ELs, more recently called multilingual learners, in the United States has noticeably increased. In fact, almost every single state in the country has experienced a recent growth in the number of ELs attending K-12 schools (NRC, 2012). During the 2012-2013 academic year, for example, ELs numbered approximately 5.4 million and totaled close to 13% of all K-12 students (NGSS Lead States, 2013). It is expected that by the year 2025, ELs will constitute approximately 25% of the student community (NRC, 2012), with large numbers of these students located in California, Florida, New York, and Texas. In general, ELs are a heterogeneous group, including students who vary widely in their language and literacy backgrounds, such as home language and number of and proficiency in languages spoken; country of origin, ethnicity, and culture; levels and quality of academic background; personal history; gender identity; sexual orientation; and socioeconomic status (NGSS Lead States, 2013).

Throughout this study, it is important to indicate that scholars are using the term multilingual learners instead of English learners, but they are actually referring to the same group of students. They are students who enter school speaking a language other than English as their primary language at home. As an example, an EL student in a biology class learns both ecology and English, the language the subject is being taught in, by an English-

speaking teacher. In this study, given the usual and most common references in the current literature, I will use the term “English learners (ELs)” to address these students in general. As mentioned previously, as the EL population continues to expand, it is essential for teacher education programs across the country to help their preservice teachers attend to the needs of ELs in their particular courses – to learn to recognize their students’ linguistic and academic needs in order to foster learning opportunities in the classroom. Moreover, given the adoption of the *Next Generation Science Standards*, or *NGSS* (NGSS Lead States, 2013) and the push for rigorous and equitable science instruction (Windschitl, Thompson, & Braaten, 2018), preservice science teachers of ELs must also learn how to make cognitively demanding work accessible and understandable to ELs so that all students can benefit. As a result, reform documents call for science teacher educators to work with their preservice science teachers to expand their knowledge about efficient practices to fulfill the academic needs of second language learners in content-area classes (NGSS Lead States, 2013). Science teacher educators could benefit from research-based recommendations to deliver a unique set of skills and efficient strategies to meet the instructional needs of ELs in science that will be valuable for their preservice teachers (NGSS Lead States, 2013).

More specifically, ELs’ increasing classroom presence has encouraged teacher education programs to focus more closely on preparing their preservice secondary science teachers to effectively integrate science content and practices with English language and literacy development, usually through disciplinary-specific principles and strategies (Lyon et al., 2016; Smetana & Heineke, 2017). One of these key disciplinary principles asks preservice teachers to recognize and use the diverse languages, cultures, and experiences of ELs as resources for the teaching and learning of their science discipline. Another key EL

principle is a deep understanding of academic language and instructional supports. Indeed, academic language plays a critical role in students' understanding of content, development of reasoning and sense-making, and successful performance in schools (Valdés, Kibler, & Walqui, 2014). Moreover, language and literacy skills are essential to reshape knowledge in the classrooms since students are consistently required to read complex texts and to improve their discourse moves. In science specifically, given the importance of academic language in the recent *NGSS* (NGSS Lead States, 2013), preservice science teachers need to learn how to effectively integrate students' languages, address academic language demands through scaffolds and supports, and implement language-intensive science and engineering practices in secondary science classrooms (Bunch, 2013; Lee, Quinn, & Valdés, 2013). As a result, based on the current reform-based education, science is considered a language-based discipline which includes several types of specific academic language, technical terms, and oral and written guidelines for carrying out science inquiry (Zwiers et al., 2014). Eventually, improving literacy and language competencies in science is key to the increasing population of ELs who most likely experience the challenging linguistic demands and whose academic language skills might negatively impact their academic achievement (Lyon et al., 2016). Therefore, science teacher educators and preservice science teachers must collaborate in order to conceptualize an academic language that is not only comprehensive but can significantly influence the learning of ELs.

As briefly explained earlier, teacher education programs are expected to prepare science teachers for today's culturally and linguistically diverse classrooms, which consists of helping them to support students' content learning and language development. A third key principle of effective EL instruction, then, is the implementation of cognitively demanding

tasks. Both the *Framework for K-12 Science Education* (National Research Council, 2012) and the *NGSS* were created with the idea of "all standards, all students" (NGSS Lead States, 2013). Therefore, "doing" science and engineering according to this reform-based framework (e.g., constructing explanations and arguing from evidence) fundamentally includes language use (Lee, Quinn, & Valdés, 2013). In fact, using language while engaging in science varies significantly from traditional views that concentrate on acquiring vocabulary and grammar beforehand. As acknowledged by current thinking in second language acquisition (SLA), language learning takes place not as a precursor to but as a product of using language through social collaboration (Valdés, 2015; vanLier, 2004). However, while ELs are a main focus in this research, the language-intensive nature of the *NGSS* science and engineering practices (SEPs) should offer opportunities and challenges for most students (Lee et al., 2013), and my conceptual framework and instructional tasks are intended to encourage the science and language learning of all students.

**The *NGSS* as the Basis of Content and Language Learning**

The *NGSS* serve as the foundation for understanding how to better prepare preservice science teachers to teach rigorous and equitable science to ELs. In 2012, the National Research Council (NRC) released *A Framework for K–12 Science Education*, which provided a blueprint for the development of a new set of national standards in science, the *NGSS* (NGSS Lead States, 2013). To date, 40 states have adopted the *NGSS* as their state science education standards, including California, the site of the study conducted here.

To elaborate, *A Framework for K-12 Science Education* (NRC, 2012) and *NGSS* (NGSS Lead States, 2013) provide a new vision for what it means to teach and learn science by moving away from previous strategies that focused on detailed facts or loosely defined

inquiry to a three-dimensional approach comprised of science and engineering practices, crosscutting concepts, and disciplinary core ideas (Lee, Quinn, & Valdés, 2013). The *NGSS* describe eight Science and Engineering Practices that should be implemented with Disciplinary Core Ideas and Crosscutting Concepts in order to teach students reform-based science (NGSS Lead States, 2013). These eight practices define both how scientists investigate and construct models about the natural world and how engineers consistently design, build, and test models and systems. Students are encouraged to engage in these practices to help clarify and make sense of phenomena as well as to enhance their language proficiency in science. While the interconnected nature of scientific sense-making and discourse has long been recognized (Lemke, 1990; Windschitl et al., 2018), the current *NGSS* and the increasing numbers of linguistically diverse students highlight the importance of preparing science teachers who can support both content and language learning (Bunch, 2013; Lee, Quinn, & Valdés, 2013).

As one of the key components in ambitious science teaching, phenomena are key to science learning, as "the goal of science is to develop a set of coherent and mutually consistent theoretical descriptions of the world that can provide explanations over a wide range of phenomena" (National Research Council, 2012). Ideally, in order for students to fully participate in content learning and language development during those learning events, particularly at the discourse level, all students must have equitable access to inquiry-based, language-rich scientific tasks. As such, preservice science teachers are expected to precisely attend to language and build on the rich cultural and linguistic resources that students bring to the classroom to facilitate their engagement in ambitious science learning (Heineke & McTighe, 2018). In fact, while engaging in the *NGSS* three-dimensional learning, students

use language in order to carry out SEPs, particularly arguing from evidence and constructing explanations. Even though the *NGSS* promotes a rich language-learning environment for all students, it is particularly valuable to ELs, who bring a wide range of cultural resources that help them use and support language learning while improving the overall conceptual subject knowledge in the classroom (González, Moll, & Amanti, 2005).

**Introduction to Study**

In California, aside from a small number of experimental teaching credential programs, teacher education (TEPs) is offered at the post-baccalaureate level. The four universities that participated in this study offered post-baccalaureate teacher education programs that consisted of two summers and one academic year. Preservice science teacher participants moved through their coursework and field experiences as a cohort. All four programs offered preservice teachers the opportunity to earn both a California teacher credential and a master's degree.

Learning to teach was considered developmental in nature and was reflected in diverse professional relationships among the candidates and faculty. Program faculty members exhibited a variety of expertise through their roles as professors of education, clinical faculty, practicing teachers, and school administrators. Preservice teachers were offered opportunities to get involved in all aspects of school life through partnerships with local schools. University supervisors assigned to a school campus collaborated with cooperating teachers to mentor preservice teachers.

These four TEPs provided preparation for teaching ELs content and language in a regular classroom setting; each program aimed to prepare its preservice science teachers for

California's culturally and linguistically diverse children and youth. Courses included methods of teaching a second language and developing academic literacy in all discipline areas. Through a combination of coursework, classroom placements, and M.Ed. research projects, preservice teachers learned to integrate theoretical perspectives with teaching practice to be informed, articulate, analytical leaders of educational reform within schools and the communities.

The conceptual frame used for this study consists of a two-dimensional TAGS framework proposed by Tekkumru-Kisa and colleagues (Tekkumru-Kisa, Stein, & Schunn, 2015; Tekkumru-Kisa et al., 2017). The TAGS (Task Analysis Guide in Science) two-dimensional framework enables researchers to track the *NGSS* science and engineering practices and science content included in tasks in order to evaluate both the kind (i.e., integrated or isolated) and level (i.e., cognitive demand) of student reasoning and sensemaking required. The first dimension investigates whether the task is integrated or isolated across the practices and content of the discipline; the second evaluates the degree to which a task promotes authentic disciplinary thinking or is cognitively demanding. As such, in this study, I used the TAGS framework to explore the scientific content and sensemaking defined in the science and engineering practices preservice teachers provided. In fact, the TAGS framework was used to examine both the science and practices included, and the cognitive demand delineated in participants' implementation of lessons

This study's data were collected from two cohorts of preservice secondary science teachers (2016-2017 and 2017-2018) who received a Noyce scholarship and, thus, committed to teach for two years in a high-needs school district upon graduation. As stated above, participants were enrolled in a post-baccalaureate teacher education program located in one

of four public research universities in California. For this study, I examined a total of 20 preservice science teachers (*n*=20). who were separated into specific subgroups. First, I divided my initial sample (*n*=54 participants) into two distinct groups: EL group for those PSTs who had EL students in their classrooms (*n*=30) and non-EL group for those who had no EL students in their classrooms (*n*=24). Further, I then narrowed down my two subgroup samples to only include the participants with the top five and bottom five edTPA scores within each of the two groups for a total of four subgroups.

I examined these 20 preservice teachers' performance assessment (edTPA) portfolios, a national performance-based, subject-specific assessment portfolio and support system used for initial teacher certification in a number of US states, including California. The edTPA has been adopted by more than 750 teacher education programs in some 40 states to highlight, measure, and support the skills and knowledge that all beginning teachers need in the classroom. The edTPA is designed to help ensure that those who become teachers not only understand education theory and subject matter content but can also demonstrate their ability to guide a classroom and guarantee that students with diverse strengths and needs are learning. This portfolio assessment requires preservice teachers to submit instructional materials and reflections related to a three-to-four-day lesson cycle.

For this study, the edTPA was examined to assess preservice teachers' ability to identify and support language demands during cognitively demanding tasks and to analyze their students' language use and learning in sample lessons. I focused specifically on their edTPA lesson plans and instructional commentaries to examine how they supported the discourse demands of tasks implemented as part of their edTPA lesson cycle. I qualitatively investigated these 20 preservice secondary science teachers' understanding of academic

language, the process by which they integrated disciplinary content and practices, the level of cognitive demanding work implemented during instructional tasks, and the types of instructional supports they used to scaffold ELs' academic language use during those tasks.

More concretely, I investigated preservice teachers' understanding and enactment of *NGSS* instructional supports for ELs during the implementation of cognitively demanding tasks. (a) First, in order to determine if preservice teachers' effectively implemented integrated lessons and high cognitively demanding tasks, I used the two-dimensional TAGS framework to track the *NGSS* science and engineering practices and content included in tasks in order to assess both the kind (i.e., integrated or isolated) and level (i.e., cognitive demand) of student reasoning and sensemaking required. (b) Next, given the previous knowledge of both the level of lesson integration and cognitive demand of tasks implemented by each PSTs, I was able to appropriately place each participant within one of the TAGS quadrants for further analysis of PSTs' supports of academic language to all learners. (c) Lastly, based on the previous examination of each TAGS quadrant, I identified which types of students' academic language (particularly English learners) supports were commonly discussed by preservice teachers while implementing different levels of cognitively demanding tasks; to be considered common, a type of support had to be discussed by a majority of preservice teacher participants in aggregate across their edTPA commentaries (instruction) and lesson plans. In fact. I examined the range of supports preservice teacher participants described using at each of the three language levels – lexical, syntactic, and discursive – focusing primarily at the discourse level.

I posed the following two sets of research questions to guide my research: (1) How did preservice secondary science teachers integrate lessons (science and engineering

practices with content) and implement different levels of cognitive demand in their edTPA tasks? Did the integration (or lack thereof) and level of cognitive demand differ between those preservice teachers who taught ELs and those who did not teach ELs? (2) How did preservice secondary science teachers support the academic language demands of their students, particularly ELs, in terms of accessing and using academic language in the science classroom? Did the kinds of supports implemented differ by those preservice teachers who taught ELs and those who did not teach ELs?

**Overview of Dissertation**

I explored these two questions through qualitative analysis of edTPA portfolios (lesson plans and instructional commentaries) across 20 participants enrolled at four research institutions in California. This dissertation is organized into six chapters and I trace this study from the motivations that guided it, to implications and future research.

Chapters 2 and 3 review relevant research on secondary preservice science teaching specifically attending to Els needs and outlines this study's theoretical framework. In the last century, preservice science teaching became an area with an established research base, one widely used across many fields of study in education. I undertook a review of prior research on PSTs supporting ELs in an effort to identify its various aspects; through this exploration, I compiled a list of the many important aspects of preservice science teaching. Chapter 3 also explores the various ways that preservice science teaching is being conducted at local TEPs, with special attention provided to the needs of ELs in a reform-based instruction context. In addition, I use the TAGS framework to contextualize the participants who are included in this study.

Chapter 4 examines the methods used in this study, including the guiding methodology and methods, contexts, data collection, and qualitative analysis. I also describe the study's context, participants, and data collection procedures. Finally, I outline the different levels of analysis implemented by using participants' edTPA portfolios (lesson plans and instruction commentaries). More precisely, I analyzed preservice secondary science teachers' placement in one of the four TAGS quadrants based on the integration of science practices with content, implementation of cognitively demanding tasks, and whether or not those situations differed between those preservice teachers who had EL instruction and those who did not. Lastly, I also attempted to study preservice secondary science teachers' support of academic language demands of their students, and whether or not those types of supports varied by those PSTs who taught ELs and those who did not.

Chapters 5 and 6 discuss the findings drawn from this study. In chapter 4, Level 1and 2 findings answer both my two research questions. Level 1findings describe preservice secondary science teachers' integration of science practices with content), implementation of cognitively demanding tasks, and whether or not those situations differed between those preservice teachers who had EL instruction and those who did not. In chapter 5, level 2 findings relate to attempts to study preservice secondary science teachers' support of academic language demands of their students, and whether or not those types of supports varied by those PSTs who taught ELs and those who did not.

Finally, I close with a discussion of the overall findings of the study, potential limitations and implications, and future work and research directions. In chapter 6, main findings are reviewed and the limitations of the study—such as sample size and demographic makeup of participants—are discussed. Potential implications of this research as being

broadly applied across the United States are also considered, since the Next Generation Science Standards (NGSS Lead States, 2013) are nation-wide standards being implemented in many states across the country.

# Chapter II: Theoretical Framework

## Overview

Research in science teaching and learning has raised central issues with how science is typically taught and has recommended revisions in K-12 science education. This is an important period in the US as we undertake a new cycle of science education reform within the context of Next Generation Science Standards (*NGSS*; NGSS Lead States, 2013). The *NGSS*, along with *A Framework for K-12 Science Education* (NRC, 2012), has created a unique vision for science teaching and learning that focuses on supporting students' comprehensive understanding of core explanatory ideas and engagement in scientific and engineering practices (Reiser, 2013). Instead of learning science by "reading about science" in books or by memorizing the steps of the scientific method, students are now encouraged to collaborate with one another and their teacher to learn science by "doing science" (Furtak, 2017). Therefore, establishing science classrooms that look and act like communities in professional science promotes students' experiencing science-as-practice, specifically doing science for creating deep and complex content knowledge (NRC, 2012).

The *NGSS* requires teachers to modify the methods in which their students are supposed to learn science and engineering content by asking students to engage in practices in such ways that relate to crosscutting concepts and disciplinary core ideas (Pruitt, 2014). In fact, the *NGSS* includes a total of eight science and engineering practices to be integrated into

teaching: *asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information*. According to the *NGSS,* students should learn disciplinary core ideas within the context of science and engineering practices because "learning science and engineering involves the integration of the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering" (NRC, 2012, p. 11). Science and engineering practices are essential to science education for two important reasons: the practices encompass a large part of what the discipline of science involves, and participation in practices is a way to foster students' conceptual understanding (Furtak, 2017). Moreover, these practices should be integrated and linked together in the classroom in order to foster a discourse that concentrates on students taking an active role in their own learning.

In reality, teaching science as outlined by the *NGSS* and Ambitious Science Teaching is challenging. Even when some integration of practices and concepts is carried out through inquiry activities, these frequently do not mirror the authentic scientific practices that scientists truly engage in when they do science (Sandoval et al., 2016). In addition, Lee and her colleagues (Lee, Quinn, & Valdes, 2013) have argued that engagement with the *NGSS* practices, concepts, and ideas is likely to be language-intensive, particularly for English learners. The existence of language-intensive practices certainly creates challenges and opportunities for ELs as well as for teachers aiming to align their instruction with the *NGSS*. More clearly, these challenges and opportunities originate from the language-intensive

practices that demand using science-specific discourse: asking questions; engaging in argument from evidence; obtaining, evaluating, and communicating information; constructing explanations; and developing and using models. As a result, when students participate in these practices, especially EL students, they require specific support from science teachers (Lee, Quinn, & Valdés, 2013). Therefore, most teachers face numerous challenges when using ambitious teaching to engage students, including EL students, in the *NGSS* science and engineering practices, including figuring out how to assist students in making sense of the practices and concepts within the new standards.

## Situated Learning Theory for Preservice Teachers

Given the push to enact reform-based science instruction, the conceptual framework for my study is composed of three parts: a situated theory of teacher learning, fundamentals of cognitively demanding tasks, including supports to help address academic language demands, and guiding principles for effective instruction of ELs in science. Within the context of a sociocultural paradigm, I begin by noting that I grounded my study in a situated theory of teacher learning, which understands learning as socially constructed through interaction with peers and experts as well as culturally situated in varied contexts with unique histories, ideologies, and norms for interaction (Rogoff, 2003; Vygotsky, 1978). A situated theory considers all learning to occur in a context and for that context, associated activity, and tools to contribute to what is learned (Brown, Collins, & Duguid, 1989; Greeno, 2006; Putnam & Borko, 2000). Lave and Wenger (1991) argued that learning occurs when individuals are members of the communities in which they are acculturated and at the same time participate actively in the diffusion, reproduction, and transformation of in-practice knowledge about agents, activities, and artifacts. They also argued that to know is to be

capable of participating with the requisite competence in the complex web of relationships among people and activities.

In regard to teacher education, I theorize teacher learning as mediated by social interaction with students, educators, and professors, and as situated in the unique cultural contexts of classrooms, schools, and communities (Grossman et al., 2009). However, learning does not occur simply when future teachers are placed in collaborative and contextualized settings; instead, learning occurs when future teachers change and deepen their participation in authentic practices over time (Rogoff, 2003). Specifically, to develop professional expertise, preservice teachers must be allowed to deepen understandings, knowledge, and skills through authentic interaction within unique contexts of teaching and learning across preparatory programs (Grossman et al., 2009).

Situated learning theory suggests that learning is experienced and mediated through relationships with community members or within a "community of practice". Within a community of practice, group members jointly share and develop practices, learn from their interactions with group members, and gain opportunities to develop personally, professionally, or intellectually (Lave & Wenger, 1991). It also understands learning to be developed through social interactions: Learning is conceptualized as increased participation in a community's practices as well as an individual's development as a result of this participation (Lave & Wenger, 1991). Because teacher learning is situated in communities, colleagues can either help each other to develop a more profound understanding of content and instructional practices or constrain efforts to enact equity-minded and reform-based instruction (Putnam & Borko, 2000).

## The Cognitive Demand of Science Tasks

The second part of my conceptual frame utilizes the two-dimensional TAGS framework proposed by Tekkumru-Kisa and colleagues (Tekkumru-Kisa, Stein, & Schunn, 2015; Tekkumru-Kisa et al., 2017). The TAGS (Task Analysis Guide in Science) two-dimensional framework proposed by Tekkumru-Kisa and colleagues (2015) enables researchers to track the *NGSS* science and engineering practices and science content included in tasks so as to evaluate both the kind (i.e., integrated or isolated) and level (i.e., cognitive demand) of student reasoning and sensemaking required. The first dimension of the TAGS framework examines whether the task is integrated or isolated across the practices and content of the discipline; the second determines the extent to which a task promotes authentic disciplinary thinking or is cognitively demanding. Together, these two dimensions create a matrix of four quadrants that range from integrated and high in cognitive demand, to isolated and low in cognitive demand. As a result, in this study, I used the TAGS framework to explore the scientific content and sensemaking described in the science and engineering practices included in preservice teacher participants' lessons. In other words, the TAGS framework was used to investigate both the science and engineering practices included, and the cognitive demand delineated in participants' implementation of their lessons.

To elaborate, regarding the first dimension of the TAGS framework, the integration/isolation dimension identifies whether or not science content and practices are integrated within a task (Tekkumru-Kisa et al., 2015). As discussed above, the eight science and engineering practices (SEPs) included in the *NGSS* describe the types of science expertise that students should develop as they learn scientific content. Initially, within the context of the NRC's (2012) *A Framework for K-12 Science Education,* the integration of content and practices was regarded as embedded in high-level tasks. Nevertheless, students

can be provided with extremely detailed scripts to follow that position them to later participate in disciplinary practices within the context of a scientific idea (e.g., analyzing results of an experiment), but in a superficial way, since all of the thinking demands have been taken away (Tekkumru-Kisa et al. 2015). Likewise, while a science lab can encourage students to collect and analyze data, given the extremely scripted structure of many labs, students may fail to notice what is central to science, which is knowledge building (Duncan & Cavera, 2015). Additionally, most tasks which in theory seem to require student thinking can decline in cognitive demand when actually implemented in a classroom setting. Hence, isolated tasks focus on students' thinking entirely on scientific concepts, such as forces and motion, or on scientific practices, such as modeling. On the other hand, integrated tasks are defined by the integration of science content and scientific practices, so they encourage students to develop an understanding of science ideas and concepts within the context of scientific practices, as highlighted in the *NGSS*.

The second dimension of the TAGS framework addresses the cognitive demand of a task, characterized by the degree of thinking and reasoning essential for students to carry it out (Tekkumru-Kisa et al., 2017). As Tekkumru-Kisa et al. argued, "Existing activities may appear to be aligned with conceptual shifts in the *NGSS* because they are 'hands on' but often miss the mark because they do not address building and testing explanatory ideas" (p. 5). Intellectually challenging tasks in science "prompt students to engage in disciplinary practices that deepen their understanding of the world through reasoning and advance students' thinking by inviting them to link observable phenomena and theoretical ideas" (p. 4). More specifically, high-level cognitively demanding tasks offer substantial opportunities for student reasoning as they are encouraged to engage in the *NGSS* interconnected practices

so as to make sense of scientific ideas and processes. Such tasks give students opportunities to use mathematics for the purpose of developing deeper levels of understanding of scientific phenomena, to engage with the conceptual scientific ideas that underlie procedures in order to complete tasks, and to reexplore and understand the nature of scientific concepts, processes and relationships, including careful planning for and changes to the learning process as to advance on the task (Stein et al., 2009). On the other hand, low-level tasks offer very limited opportunities for student reasoning by encouraging them to recall or replicate prior scientific knowledge; to follow procedures with no connection to the underlying concepts or meaning; and/or to focus on producing correct answers instead of producing scientific understanding. Prior works on tasks (e.g., Doyle 1983; Stein et al. 1996) show that an over-implementation of low-level tasks is responsible for students' lack of understanding, and usually indicates the necessary adoption of more high-level tasks.

In this study, I determined the placement of each preservice teacher participants' lesson series in one of four quadrants in a TAGS matrix based on the opportunities for students to engage in scientific reasoning. I examined the tasks in terms of both the first dimension, integration/isolation, and the second dimension, the cognitive demand of the task. (See Table 2.1 for details.)

Table 2.1

*TAGS Framework Matrix*

| **Quadrant** | **Type of Sensemaking** | **Description** |
|---|---|---|
| I | Integrated - High Cognitive Demand | Students were asked to engage in significant science content and sensemaking within scientific reasoning. One or more science/engineering practices were integrated with science content in such a way that led to greater scientific understanding of the phenomenon under investigation. |

| | | |
|---|---|---|
| II | Isolated - High Cognitive Demand | Students were asked to engage in scientific reasoning and either important science content or science/engineering practices. Although students were positioned to engage in high-level cognitive processes, one or the other of these constructs was not implemented in such a way as to increase students' scientific understanding and sensemaking. |
| III | Isolated – Low Cognitive Demand | Students were asked to focus on the scientific content or science/engineering practices. However, the scientific thinking requirement was low; scientific sensemaking and greater scientific understanding did not occur. |
| IV | Integrated – Low Cognitive Demand | Students were asked to engage with scientific content within the context of one or more science/engineering practices, but the engagement was at a level that did not include any significant scientific sensemaking or reasoning. |

## Five Key Principles of Effective EL Teaching and Learning

The third and final part of my conceptual framework includes five guiding principles integral to the effective instruction of ELs in science: (1) creating a safe classroom community, (2) building on and using students' funds of knowledge and resources, (3) offering students opportunities for rich language and literacy exposure and practice, (4) providing students with cognitively demanding work, and (5) identifying academic language demands and supports for ELs. In describing this set of five principles, I recognize that ELs are diverse in terms of home language, biliteracy, language proficiency, ethnicity, culture, and prior experience and that other conceptual frameworks resonate with what I propose here. I view these principles as providing secondary science teacher educators and their preservice teachers with a comprehensive and synchronized approach to teaching diverse ELs science. I also understand these principles to intersect with and support one another;

even though provided sequentially, they are better seen as interconnected pieces instead of as successive steps.

### Creating a Safe Classroom Community

Additionally, the third principle, creating a safe classroom community, highlights the importance of creating an intellectual safe space for students to engage in productive science talk. In fact, creating a classroom that is organized and that is characterized by mutual respect makes it a lot easier to teach effectively, and one of the most important things teachers can do to promote learning is to create classroom environments where students feel safe asking questions and contributing to discussions (Rosebery, Ogonowski, DiSchino, & Warren, 2010). More specifically, this principle encourages teachers to establish intellectual risk-taking from all students, including ELs, while adopting classroom norms and routines that facilitate engagement in reasoning and sense-making (Luria, Sriraman, & Kaufman, 2017). As such, in a safe classroom environment, teachers facilitate students' opportunities for debate, discussion, and verbal explorations with peers and teachers, thus offering opportunities for improved communication skills in students.

### Building on and Using Students' Funds of Knowledge and Resources

The first principle, building on and using students' funds of knowledge and resources, concentrates on the recognition, observation, and use of the knowledge and expertise students, their families, and their communities carry into the classroom that should be used by teachers as powerful resources to inform instruction (Moll et al., 1992). In fact, all classrooms have a heterogeneous mix of students with different backgrounds and experiences which teachers can and should use as an asset for effective science teaching and learning

(Rosebery, Ogonowski, DiSchino, & Warren, 2010). As such, some examples of relevant practices preservice teachers can implement to address their students' funds of knowledge include utilizing ELs' prior knowledge and experiences; recognizing and using ELs' home languages as resources for learning; encouraging ELs to speak in multiple languages, use different dialects, and/or work across different levels of literacies in their production and display of ideas; and incorporating cultural and community resources into instruction to make content relevant and significant. In brief, contextualizing classroom science activity by building on students' everyday experiences, interests, and home and community knowledges makes the science more meaningful and can enhance learning and participation for all students, particularly the underserved ones (Lyon et al., 2016).

**Offering Students Opportunities for Rich Language and Literacy Exposure and Practice**

The second principle, providing students opportunities for rich language and literacy exposure and practice, reflects on the importance of offering ELs repeated opportunities to understand, engage with, and produce the language of the discipline and discourse of science (Bleicher, Tobin, & McRobbie, 2003; Lee et al., 2013). The new US standards recognize the centrality of discourse in the teaching and learning of science (NGSS Lead States, 2013) since learning science is described as learning how to use the language of science to express ideas and build understanding (Lemke, 1990). Given this integral relationship between language and learning, science teachers are encouraged to facilitate student science discourse. In fact, to learn the language of science, and to develop language and literacy more generally, students need to produce and use language in authentic contexts (Lyon et al., 2018). Moreover, teachers are also advised to provide meaningful opportunities for students

to use writing as an "epistemological tool" and to practice communicating their scientific understandings for a range of audiences and purposes (Prain, 2006). Indeed, sets of explicit guidelines have been developed to help teachers learn how to facilitate productive classroom discussions (Michaels & O'Connor, 2012; Windschitl, Thompson, & Braaten, 2018). As a result, preservice teachers should create opportunities for students both to receive comprehensible input and to produce comprehensible output in ways to engage in negotiations of meaning needed to improve both their English language and science learning. Therefore, engaging in science and engineering practices provides authentic opportunities for students to produce and use language, while promoting language and literacy learning for all students, especially English learners (Tolbert, Stoddart, Lyon, & Solis, 2014).

**Providing Students with Cognitively Demanding Work**

This fifth and final principle, providing students with cognitively demanding work (Windschitl, Thompson, & Braaten, 2018), includes instructional activities that require students to engage in high-level thinking, reasoning, and sensemaking; and asks teachers to offer opportunities for ELs to engage in the same challenging activities and assignments they often reserve only for non-EL students (Lee et al., 2019; Understanding Language, 2013). As explained in the second part of my conceptual framework above, these intellectually challenging tasks encourage students to move away from "detailed facts or loosely defined inquiry" (Lee, Quinn, & Valdés, 2013) to concentrate on the science and engineering practices, crosscutting concepts, and core ideas outlined in the *NGSS* (NGSS Lead States, 2013). Indeed, the NGSS focuses on rigorous learning goals and instruction that engages students in science and engineering practices to develop and use scientific content knowledge (NGSS Lead States, 2013; NRC, 2012). In fact, those practices are expected to promote

students' reasoning and sense-making about natural phenomena and socioscientific issues (Windschitl, Thompson, & Braaten, 2018).

### Identifying Academic Language Demands and Supports

The fourth principle, identifying academic language demands and supports for ELs (Bunch, 2013; Warren et al., 2001), encourages teachers to identify those aspects of language that might be challenging to ELs and to provide appropriate scaffolding for students to understand and produce language (O'Hara et al., 2017; Rosebery & Warren, 2008). Particularly in science, the language and literacy demands of the NGSS and science and engineering practices can be challenging for all students and for English learners, in particular (Bunch, 2013). Therefore, beyond providing opportunities for students to produce language, teachers should concentrate on those aspects of language that might prove challenging and to provide adequate scaffolding for students to interpret and produce language in tasks across the three language dimensions of vocabulary, syntax, and discourse (Zwiers et al., 2014) and the four communicative modes of reading, listening, speaking, and writing. It is important for preservice teachers to understand that academic language does not necessarily mean a list of vocabulary words with specific meanings, but instead the communicative competence required and appropriate for active engagement in science discourse (Bunch, 2013; Moschkovich, 2012). Moreover, this principle also focuses on the significance of engaging students in accessing disciplinary texts, sharing their ideas and thinking, discussing in whole class and small groups, and constructing explanations for or arguments about scientific phenomena (Lyon et al., 2016). More precisely, as teachers engage students in science and engineering practices, they also need to attend to the related language moves and functions (e.g., supporting a claim using evidence) required of students

to engage in these practices (Lyon et al., 2016). However, it is important to note that this principle differs from the third one, rich language opportunities, because preservice teachers need to focus on those aspects of language that might be challenging and to offer appropriate scaffolding for students to understand and engage in scientific discourse (Roberts et al., 2017). In brief, this final principle highlights the distinction between "just good teaching" and effective instruction for ELs (Cohen & Lotan, 2014).

## Focus on Academic Language Demands and Supports

In this study, the academic language of science is defined as embracing several related registers that can be defined in terms of characteristic language functions as well as specialized linguistic forms that can be examined at the lexical, syntactic, and discourse levels. Each of these registers differs depending on the purpose of communication, the theme, the relationship between speakers/writers and their audience, and the method of communication (i.e., oral or written) (Zwiers et al., 2014).

As introduced above, I decided to organize the unique features of academic language in science classrooms by levels of language: lexical, syntactic, and discursive (Zwiers et al., 2014). At the lexical, or vocabulary, level, talking science demands substantial knowledge of discipline-specific and general academic terms as well as with common words that have technical meanings (Fang, 2006; Snow, 2010). At the syntactic, or sentence, level, it involves making sense of the elaborated, information-heavy noun phrases usually seen in formal scientific writing (Fang, 2005, 2006; Snow, 2010); being able to manage the lexical and grammatical resources required to perform academic language functions, such as justifying, hypothesizing, explaining, and arguing (Dutro & Moran, 2003); and making and interpreting graphs, tables, and diagrams (Quinn, Lee, & Valdés, 2012). At the discursive level, it

includes different ways of organizing information; indicating reasonable relationships and producing textual cohesion; and setting up an objective relationship among writers, their subject matter, and their audience (Schleppegrell, 2004). As a result, I sought to find evidence that the preservice teacher participants in my study understood academic language to contain the particular lexical, syntactic, and discursive characteristics essential for doing and talking science.

In terms of how preservice science teachers should scaffold academic language demands, I drew from literature on effective practices for supporting academic language use. I used the following five categories of instructional support to analyze my preservice teachers' implementation of scaffolds for ELs: (1) providing context for language, (2) attending to language comprehension, (3) attending to language production, (4) incorporating students' existing language and linguistic practices, and (5) other. To further explain these instructional supports, the first category assumes making meaningful contexts for using the disciplinary language of science. In this way, preservice teachers should include contextualizing phenomena in written formative assessment tasks (Kang, Thompson, & Windschitl, 2014), and implement activities or labs that contextualize important vocabulary and academic language functions (Lee & Buxton, 2013). The next category of supports helps ensure spoken and written texts are clear to EL students. Preservice teachers must make sure that modifications neither reduce the cognitive demand of the task implemented nor the legitimacy of the disciplinary language used. They are encouraged to provide students with many ways to access the same content by collaborating through various channels (e.g., speech, gestures, visuals, and demonstrations), speaking slowly and clearly, and amplifying instead of simplifying texts. In addition, preservice teachers are advised to use word learning

strategies, including providing definitions, unpacking terms into basic roots and affixes, and recognizing cognates (Nutta, Strebel, Mokhtari, Mihai, & Crevecoeur-Bryant, 2015). A third type of language support is focused on encouraging students to produce spoken and written discourse. Preservice teachers should include clear modeling and effective examples of the target language (Walqui, 2006); implement peer collaboration, such as think-pair-share and small groupwork (Windschitl et al., 2018); use sentence frames to support oral and written output at the discursive level (Zwiers et al., 2014); explain task expectations using examples of student work (Walqui, 2006); and give students rubrics and checklists (Kang et al., 2014). Lastly, while teachers purposefully implement different kinds of support to assist students in understanding and accessing academic language, it is critical that they do so while identifying, authenticating, and leveraging students' current language and linguistic practices (Hudicourt-Barnes, 2003; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001).

# Chapter III: Literature Review

## Overview

Students designated as English learners (ELs) are the fastest growing group of students in K-12 public schools across the United States (National Clearinghouse for English Language Acquisition, 2011). As discussed previously, ELs represent a significant number of the students currently attending K-12 schools in the U.S. (National Center for Education Statistics, 2016). During the past 10 years, the number of ELs, or multilingual learners, in the United States has increased exponentially. As the EL population continues to expand, it is essential for teacher education programs across the country to concentrate more carefully on

supporting their preservice science teachers to effectively teach ELs. Assuming that the number of ELs continues to rise, there is a demand for all preservice teachers to recognize their students' linguistic and academic needs in order to foster learning opportunities in the classroom. In fact, these teachers should draw on their EL students' diverse cultures, home languages, ideas, and experiences as resources for instructional learning.

Another issue related to the performance of ELs in the classroom is the reported achievement gap that exists between ELs and native English speakers across all disciplines, especially in science (Lee, Quinn, & Valdés, 2013). In fact, the academic achievement gap between ELs and their non-ELs peers in science indicates that ELs are not offered the same kinds of opportunities to engage with the content as non-ELs, as observed in the *NGSS* framework (NGSS Lead States, 2013). As a result, reform-based education calls for science teacher educators who work with preservice science teachers to expand their knowledge about efficient practices to fulfill the academic needs of second language learners in content-area classes (NGSS Lead States, 2013). Moreover, as most science teacher educators understand the urgency of supporting preservice teachers to teach ELs, they struggle to come up with a unique set of skills and efficient strategies to meet the instructional needs of ELs in science that will be valuable for beginning and veteran teachers. In order to reduce the achievement gap in science, a more culturally responsive teaching approach should be adopted by science preservice teachers (Bunch, 2013; Lee, Quinn, & Valdés, 2013). In fact, this teaching method highlights the cultural and linguistic diversity that ELs bring to the classroom and encourages students to use their linguistic and cultural resources at school. As a result, by appreciating the diversity ELs bring to the classroom, teachers can help students capitalize on their learning capacity (Bunch, 2013; Lee, Quinn, & Valdés, 2013). In reality,

given the increasing diversity in the current student population, science teacher educators are expected to intentionally re-evaluate what is required to prepare science teachers to teach EL students.

While the interconnected nature of scientific discourse and scientific sense-making has long been recognized (Lemke, 1990; Windschitl et. al., 2018), in the United States, ambitious new *Next Generation Science Standards* (*NGSS*; NGSS Lead States, 2013) and increasing numbers of linguistically diverse students underscore the importance of preparing science teachers who can support both language and content learning. Further, despite this long-standing interest, science educators have much to learn about how teachers can best support language-intensive science and engineering practices, particularly in secondary science classrooms (Lee et. al., 2013). Thus, students are expected to engage in these practices to help reason about and make sense of phenomena as well as to develop greater proficiency in the language of science. In brief, preparing preservice secondary science teachers to adequately support their students in learning science as envisioned in these reform documents should be a priority for all teacher education programs.

## Preservice Secondary Science Teachers and a Focus on Reform-Based EL Teaching

Previous research has found that the classroom teacher is the number one in-school factor influencing student achievement, particularly for students labeled ELs (Gándara & Maxwell-Jolly, 2006). As schools diversify and the EL achievement gap widens, practitioners and scholars recognize the need for all teachers to support students' learning and language development across the school day (Heineke et al., 2019). According to Lee and Buxton (2013), a primary challenge of teaching science to diverse populations consists of viewing students of color and those in poverty as a problem to deal with. They clarified, "For

example, when teachers view English language learners, students of color, or students living in poverty as problems needing to be fixed, then schooling becomes oppressive for the students and their families" (p. 282). According to Warren et al. (2001), students' culture could be used to promote science teaching and act as a bridge toward building more inclusive pedagogical practices. Moreover, the authors argued that teachers should consider language practices as a way to create greater diversity and eliminate the role of scientific language as a potential gatekeeper in students' classroom actions. Therefore, irrespective of discipline, all teachers must learn the knowledge, skills, and dispositions needed to support students' language development simultaneously with content-based classroom instruction (Lee, Quinn, & Valdes, 2013).

Given the current *NGSS* framework, the contemporary science classroom is one in which ELs inquire into core scientific practices using rich linguistic resources and repertoires (Lee et al., 2013). Across different settings, including urban, suburban, and rural classrooms, science teachers must look to meet students' unique and diverse needs for learning and language development (Lee et al., 2016). The changing student population, paired with the shift to the Next Generation Science Standards, has resulted in challenges and opportunities for teachers and teacher educators. It has been known that students develop language simultaneously with disciplinary learning, and ELs require rigorous content instruction as they acquire English (Lee et al., 2013). Instead of sheltering ELs from complex texts, ideas, and experiences, science teachers must support all learners' language development as they engage in rigorous, authentic, inquiry-based science experiences (Capitelli et al., 2016; Stoddart et al., 2011). To achieve this goal, all teachers must be ready to engage the large and growing group of ELs (Gándara & Hopkins, 2010; Valdés et al., 2014).

## Previous Research on Cognitively Demanding Work

According to the current science education literature, one of the most widely implemented instructional models for improving the preparation of preservice science teachers to better support English Learners (ELs) has been developed by Mark Windschitl and colleagues (Windschitl, Thompson, & Braaten, 2018). Ambitious Science Teaching (AST) purposely aims to support students of all backgrounds to actively understand science ideas, engage in the activities of the discipline, and solve original problems. In other words, with the adoption of the *NGSS* framework, science teachers are expected to implement instructional practices that promote the learning of all students by encouraging them to participate in cognitively demanding tasks that are authentic to science (Windschitl et al, 2012). These central instructional practices and skills have been defined as High Level or Ambitious Teaching Practices since they elicit and foster all students' thinking as the basis for continuous sensemaking in the classroom. These core teaching practices encourage students to acquire the necessary intellectual ownership for their learning (NRC, 2012). In practice, ambitious teaching offers opportunities for all students to think about important science ideas, engage in scientific discourse, explore authentic issues, and develop intellectual competency to work independently (Rosebery et al., 2010; Windschitl et al., 2012).

Windschitl and colleagues (2012) originally suggested AST as a framework for K-12 instruction to support preservice science teachers. AST is composed of four sets of discourse-intensive teaching practices: selecting big ideas (recognizing inquiry-worthy ideas); eliciting students' hypotheses (attending to students' experiences and developing ideas); making sense of activity (understanding scientific phenomena); and pressing for evidence-based

explanation (reasoning with descriptive models through phenomena). Sequentially, the first set of core practices includes planning, in which the teacher selects "big" science ideas with explanatory power from instructional materials and then choses an event or process in nature that is both fascinating to students and challenging to clarify. This selection technique is described as an "anchoring event" for the lesson unit, where students engage in a unique phenomenon, so they can revisit it occasionally to elaborate on their complex explanations. During this designing approach, the teacher introduces both a driving question and an explanation of the discrepant event, along with the useful integration of learning tasks and readings. During the second set of practices, the teachers elicit students' preliminary ideas and experiences about the anchoring event. Moreover, students are prompted to construct their conceptual models so that they can be used as a reference for small-group and whole-class discourse. In fact, the teacher is responsible for taking these students' ideas and experiences and using as resources to plan learning activities for the rest of the unit. For the third set of practices, which is frequently re-visited during the unit, the objective is to support students' engagement in scientific practices to construct new knowledge appropriate to the anchoring phenomenon. Finally, during the fourth set of practices, teachers encourage students to gather all ideas and evidence collected during their study to revise their models and improve their explanations for the discrepant event.

AST attempts to integrate these ideas into a coherent set of core practices that challenge the learning and participation goals for students (Windschitl et al., 2012). According to Windschitl et al. (2012), these are core practices because they support student thinking that is essential to the discipline of science, relate to distinct methods of teaching science and to distinct issues in science, can be re-enacted in more complex and integrated

ways of teaching, voluntarily encourage teachers to learn from their own teaching, and are an integral instructional component that clearly reinforces student learning goals (Windschitl et al., 2018). In fact, ambitious teaching encourages the creation of classroom learning environments that foster the communication and introduction of students' ideas and reasoning, thus making possible teachers' assessment for learning practices. As a result, according to Windschitl et al. (2012), ambitious science teaching practices observe and recognize the diversity of students' knowledge and thinking, and facilitate student learning by offering experiences and discourse opportunities that allow students to broaden their understandings of conceptual ideas, to criticize and assess their claims, and to engage in sharing evidence and knowledge with others.

More specifically, the two main goals of AST align with those of the *NGSS*: They include students taking ownership of engaging in science practices, such as asking questions; designing and carrying out investigations; collecting, analyzing, and interpreting data; and developing models and arguments from such interpretations. Said another way, two key requirements of teachers' AST practice align with the *NGSS*. First, classroom activity needs to foster students' ownership and meaningful significant contributions. According to Osborne (2014), students demand continuous and enhanced opportunities to explore science practices as a way to understand science concepts. Second, teachers need to facilitate rich disciplinary talk among students, in which students are in charge of each other and responsible for the understanding of disciplinary standards.

Nevertheless, according to Winschitl et al. (2012), just urging teachers to participate in a practice does not necessarily make the practice materialize. Therefore, teachers require scaffolding and assistance in understanding how to engage in ambitious science teaching

practices so that they can better press for and attend to students' ideas through effective discursive moves. Science teacher educators need to support their preservice teachers to effectively explore the challenges of ambitious science instruction in a safe environment, and to provide them with opportunities to elicit, question, and promote students' scientific concepts and practices (Windschitl et al., 2012). Within the context of principle-based instructional frameworks and their respective implementation studies, it is essential to investigate and determine how effective these models are in producing well-prepared novice teachers. Eventually, the idea of determining the efficiency of teacher education program models by having PSTs discussing about planning, enacting, and reflecting on their own instruction, enables them to better recognize teaching practices in order to meet ELs' strengths and demands (Windschitl, Thompson, & Braaten, 2018).

## Previous Research on Teaching ELs

This current study also builds on previous research investigating both the education of preservice science teachers to teach ELs and science teachers' understanding and implementation of academic language across the learning-to-teach continuum and grades preK-12 levels.

### Research on Preparing Science Teachers to Teach ELs

As previously discussed, most preservice teachers find it challenging to support students' development of content knowledge while gaining language skills (Bunch, 2013). As such, according to science teacher educators, more research is required to evaluate how science preservice teachers can be successfully trained to achieve content-language integration (Bunch 2013; Lee & Buxton, 2013). Creating a deeper awareness and a more

elaborated understanding of why language is essential to science instruction, and how to effectively meet the science and language learning demands have never been more significant than now. In fact, the discipline of science introduces content knowledge in a different way compared to meanings created in students' conventional language (Fang 2005). According to science educators, ELs must be given authentic opportunities to acquire scientific academic language since the language itself is a significant component of scientific content learning (Bunch, 2013; Lee & Buxton, 2013). As a result, it is imperative for science educators to support teachers in offering ELs genuine experiences to assimilate deep science content knowledge and reasoning while enabling them to develop and improve language skills. When preservice teachers learn using the language and content integration approach, they are expected to attend to the science content they introduce in addition to the language demands. Moreover, these preservice teachers need to learn to be flexible in terms of teaching practices to successfully assess and modify instructional materials, introduce the content in concise and manageable ways, and evaluate what EL students are actually learning throughout the lessons. In summary, preservice teachers should plan and introduce a methods, strategies, and techniques to foster the development of scientific competencies for ELs (Stoddart et al., 2013). Ultimately, by modifying their instruction and offering all students relevant learning experiences, preservice teachers can successfully and positively influence ELs and engage them in authentic content and language acquisition.

As one of one of the most prominent supporters of a culturally responsive approach to teaching ELs, although with a focus on elementary content-area instruction, Lee and her colleagues (2008) emphasized the "crucial importance of understanding cultural displays of knowledge constructed in the everyday routine practices of children and adolescents and the

relationship of such displays to targets of academic knowledge" (p. 736). Moreover, focusing on the work done to understand the connection between the social and school practices of linguistically and culturally diverse students in science, Lee et al. defined the process of "cultural modeling" as "a framework for the design of learning environments that examines what youth know from everyday settings to support specific subject matter learning" (p. 740). In fact, the authors offered classroom situations of teachers implementing what they described as culturally responsive instructional discourse aimed to explore the processes where students' practice of "African American Vernacular English and its rhetorical features can serve as a resource for communicating complex discipline specific reasoning, in this case in the study of literature" (p. 752). As a result, Lee et al. argued that teachers need to acquire a deep and extensive understanding of the nature of the discipline and the importance of culture not only in terms of motivation, topic selection, and classroom organization but also in terms of subject matter learning. Additionally, according to the authors, even though foundational courses in preservice teacher education programs should be beneficial, the "pedagogical toolkit" essential to cultural modeling involves the content knowledge and practices that are only acquired in teachers' own classrooms. Based on Lee's concept of culturally responsive instruction, the study claims that the potential conflict between science and classroom practices and students' everyday language and literacy practices can be reduced when teachers complement the textbook activities by enabling ELs to bring knowledge of scientific concepts from their everyday lives to the classroom. Therefore, Lee's work identifies the significance of this culturally responsive method and of engaging linguistically and culturally diverse students in spoken and written scientific discourse by

creating connections to students' cultures, home languages, and life situations (Lee et al., 2019).

Within the context of a culturally responsive instructional discourse, the cultural modeling framework supports the recent movement in science education, based on the *NGSS* framework, that argues that language skills and content knowledge should be taught to ELs in a completely integrated way, so that all teachers assume the ownership of improving students' academic language associated with their disciplinary content knowledge (Lee et al., 2008). As a result, science teachers should appropriately identify and focus on the important language and literacy practices embedded in their discipline (e.g., explaining and arguing with evidence) to promote the interaction of EL students with science content. Moreover, previous work suggests that most teacher educators realize that instructional accommodations they offered to ELs are somewhat limited and additional modifications applied exclusively to ELs. In fact, according to the authors, science teacher educators should help preservice science teachers realize that the scaffolding strategies beneficial to ELs would also work for the other students who are probably struggling with the academic language demands as well. This way, given that preservice teachers understand that what benefits ELs will apply to their classmates as well, their willingness to implement accommodation strategies for Els should only intensify. As previously mentioned, however, a limited number of beginning and veteran teachers are skilled teaching ELs and most teacher education programs do not address the real importance of integrating academic language and literacy into disciplinary content teaching (Lee et al., 2008).

One possible principle-based instructional framework that could be adopted by teacher education programs to instruct preservice secondary science teachers in supporting

ELs, one that is aligned with the *NGSS* framework, includes five key principles for effective EL teaching (Roberts et al., 2017). According to Roberts and her colleagues, there are not enough sustained, disciplinary-specific opportunities for preservice teachers to learn how to transform their science teaching to support ELs. As such, they created a capstone science methods course to help preservice teachers learn how to effectively teach science to ELs. Their aim was to promote a change in their preservice science teachers from not only attending to pedagogical tools or strategies to support ELs, but to building a willingness to engage in reflective practices to support ELs as well. Moreover, this authentic shift involved recognizing what kinds of resources students bring to the classroom, attending to students' understandings to foster intellectual development, and appropriately evaluating what students have really learned. The five guiding principles of their ELs framework include the following: building on and using students' funds of knowledge and resources, providing students with cognitively demanding work, offering students opportunities for rich language and literacy exposure and practice, identifying academic language demands and supports for ELs, and promoting a safe classroom environment. This instructional framework offers secondary science teacher educators and their preservice teachers a complete and integrated method to teaching diverse ELs science. In addition, it should be noted that these principles naturally overlap with and support one another.

As a second example, Athanases and colleagues (2014) developed and implemented an instructional model for improving the preparation of preservice science teachers to better support English learners that aims to integrate academic language and disciplinary content in science. In this particular instructional framework model, preservice teachers participating in their teacher education programs were involved in a language-based approach to content

instruction (LACI). This teacher preparation model was created across several years of research in content areas with the inclusion of ELs in the classrooms and focused on understanding the content and language needs and demands of ELs. In fact, the authors claimed that LACI provided teachers with opportunities to concentrate on the integration of language and content in the area of science, especially developing solid literacy skills for ELs according to the expectations of the *NGSS* framework (NGSS Lead States, 2013). As a result, this instructional model addressed the current issues of attending to the needs of ELs in this time of standards-based education.

Within the context of a language-based approach to content instruction, given that LACI focuses on language learning in the classroom, it is essential for teachers to use language in order to teach content, instead of using content to teach language (Athanases & de Oliveira, 2014). In fact, instead of selecting appropriate content to enhance language development, this model enables teachers to prioritize the language in order to access the content to build background knowledge by implementing strategies such as collaborative work, graphic organizers and other practices that have been proven to be beneficial to ELs. This way, LACI has the potential to be a comprehensive and effective model of instruction for ELs in a mainstream classroom. As such, a major part of LACI involves offering ELs access to the language of the different content areas by exploring the academic language that builds content knowledge. Essentially, LACI allows teachers to emphasize the content while also providing ELs with opportunities to improve their academic language proficiency, while fostering the language competency of ELs in the classrooms. Ultimately, the LACI instructional model argues that preservice science teachers need to properly address the

academic language demands of ELs to facilitate ELs' content learning while promoting their access to language development as well (Athanases & de Oliveira, 2014).

Previous research on teacher preparation has consistently indicated that contextualizing science instruction is the least implemented instructional practice for teacher's commitment on using culturally responsive science teaching. Contextualizing science activity is an important component of both scientific sense-making (e.g., Rosebery & Warren, 2008) and language acquisition (Krashen, 1982) for ELs, in which students use several language forms and discourse practices to examine everyday problems and issues. Moreover, the idea of making the content accessible by engaging in relevant situations is critical to language acquisition, as well as minimizing the anxiety that language learners go through when faced with new vocabulary and language functions. Further, contextualizing science instruction also encourages students to more effectively recognize relationships between school science learning and their everyday life experiences (National Science Teachers Association, 2010).

As a third example, Stoddart and her colleagues (Stoddart et al., 2010) constructed the SSTELLA framework for effective EL instruction based on sociocultural theory to create a preservice teacher education intervention program intended to integrate an emphasis on inquiry-based science instruction with language and literacy for ELs. In fact, their project involved two important key concepts: enhancing the preparation of teachers to support the growing EL population; and introduction of the Next Generation Science Standards (*NGSS*) and Common Core State Standards for English Language Arts (*CCSS*). Overall, the SSTELLA intervention program was intended to encourage beginner teachers to participate, along with their students, in five main practices that highlight the connecting between science

learning and language/literacy development, as well as the overlapping between the *NGSS* and the *CCSS ELA* practices (Tolbert et al., 2014): integrating science, language, and literacy acquisition; engaging students in scientific discourse; promoting scientific reasoning; collaborative inquiry in science education; and contextualized science teaching. As such, the authors argued that contextualizing science activity is a challenging and complicated practice for science teachers to implement since they are likely to rely on their own instead of their students' sociocultural experiences as a platform for teaching. Eventually, the main idea behind this framework was language to be seen as an essential component of all science learning processes and language and literacy learning support student learning of both language and disciplinary science content especially for ELs (Lyon et al., 2018).

Overall, according to the findings from the implementation of the SSTELLA framework, preservice science teachers who participated in the SSTELLA program were more prepared to use practices that foster science and language learning for ELs than beginning teachers who did not participate. As such, results indicated statistically significant differences between preservice teachers involved in the program when compared to a control group for some categories based on a classroom observation protocol created to address efficient implementation of the SSTELLA principles (Stoddart et al., 2010). Moreover, those preservice teachers implementing the SSTELLA framework adopted instructional tasks that fostered better communication among students and between teacher and students. Therefore, these beginner teachers were encouraged to implement scientific discourse patterns like engaging in argument from evidence, constructing scientific explanations, encouraging inquiry activities, and eliciting students' ideas, which were practices that ELs usually do not have much access to in regular classrooms. In fact, the SSTELLA intervention greatly

improved the candidates' confidence in their willingness to support ELs. Eventually, the main goal of this intervention was to continuously develop a principle-based instructional model to support science teacher educators in preparing preservice teachers to successfully teach science aligned with the *NGSS* framework to ELs across most teacher education programs in the nation (Tolbert et al., 2014).

**Research on the Teaching and Learning of Academic Language**

A number of previous studies examine the teaching and learning of academic language in science classrooms. Most promote the importance of moving beyond the teaching of vocabulary (i.e., the lexical level) to attend to the syntactic and discursive demands of language too (Dong, 2002; Heineke et al., 2019; O'Hara et al., 2017; Richardson Bruna, Vann, & Escudero, 2007). In a prior study, for example, Richardson Bruna et al. (2007) explored a high school teacher teaching an English Learner Science course mainly to Latinx students. The authors concluded that the teacher associated instruction in academic language with the teaching of vocabulary, failing to address both the essential semantic relationships among the phenomena she asked her students to investigate and the linguistic resources they required to create those relationships. In this way, the teacher greatly restricted classroom discourse, restraining ELs not only from talking like scientists but also from thinking like scientists.

In contrast, O'Hara et al. (2017) provided professional development opportunities focused on academic language and literacy development in STEM to teams of practicing middle school teachers. Professional developers emphasized three aspects of complex academic language use: interacting with complex texts, fostering academic interactions, and fortifying academic output. Their findings suggest that the program helped to strengthen

teachers' knowledge of and practices in supporting students' use of complex academic language and their understanding of STEM concepts as well. Along the same lines, Heineke et. al. (2019) investigated secondary science teacher education, especially preparing preservice teachers for ELs through an examination of one secondary teacher candidate completing a 2-year program of study attending to the needs of ELs. In this study, the authors observed how a field-based program that focuses on ELs influences the understandings and pedagogical practices of one secondary science teacher candidate. As it relates to preservice teacher education, the researches indicated that field-based preparatory programs are likely to provide candidates with the significant time and instructional exposure required to develop competence for ELs. Through field-based placements in diverse community and school settings, Heineke et. al. examined the candidate's increasing conceptualization and developing understandings of science teaching practices that promotes skills necessary to support language and ELs in the science classroom. Further, Brown et al. (2019) employed a randomized experimental method to investigate how learning science through complex language discourse decreases working memory potential. The researchers discovered statistically significant differences in the students' responses to complex items. As a result, these findings indicate that starting instruction using simpler scientific language (i.e., everyday language) can decrease the cognitive load on students and facilitate students' understanding of the concepts being introduced.

Several other studies that examine science teachers' understanding and implementation of academic language across the learning-to-teach continuum and grades preK-12 levels underscore the challenges teachers face in their attempts to efficiently scaffold ELs' science content and language learning (Bianchini et al. 2014, 2017; Buck,

Mast, Ehlers, & Franklin, 2005; Cho & McDonnough, 2009). In one study, the 33 in-service secondary science teachers analyzed by Cho and McDonnough (2009) had limited knowledge of the range of instructional supports effective in scaffolding academic language: They did not know how to scaffold their EL students beyond giving them extra time to complete tasks. In another example, the beginning middle school science teacher observed by Buck et al. (2005) changed over time, growing to realize the importance of implementing different types of supports to engage her ELs in cognitively demanding content in the classroom. Still, she found attending to the needs of ELs a more challenging and complex effort than she had previously imagined: Types of instructional supports learned in teacher education needed to be substantially modified or abandoned considering actual classroom constraints. In a final example, Swanson et al. (2014) documented the efforts of an experienced high school science teacher, Ms. H, to engage her ELs in disciplinary talk and practices, including generating and evaluating arguments from evidence, sharing ideas and understandings with others in public forums, and using precise language. They found that she introduced different types of supports, such as home language, groupwork, revoicing of student ideas, templates, and graphic organizers. However, they also found that Ms. H's EL students did not get involved as regularly as their English-speaking peers in whole class discussions and had issues expressing their oral small group interactions in writing on their posters.

## Contributions of This Study

To help fill a gap in the literature, I investigated how preservice secondary science teachers supported the discourse demands of tasks implemented as part of their edTPA lesson cycle (i.e., a national performance-based assessment for preservice teachers). I attempted to

understand the successes and challenges of preservice teachers in teaching ELs rigorous, reform-based science at the secondary level so as to advise both science teacher education for beginning teachers of ELs and science instruction for ELs themselves. More precisely, this study contributes to the current literature on the teaching of cognitively demanding tasks and of academic language to secondary students. It is important to note that secondary students possess more complex linguistic and cognitive backgrounds and are encouraged to negotiate more advanced concepts and texts than younger students (Harper & de Jong, 2004).

To identify the successes and hurdles in preservice secondary science teachers' attempts to understand and support both cognitively demanding work and academic language, I examined 20 preservice secondary science teachers' edTPA portfolios. I used a modified version of the Task Analysis Guide in Science (TAGS; Tekkumru-Kisa, Schunn, Stein, & Reynolds, 2017). The TAGS framework allowed me to assess preservice science teachers' tasks based on the kinds of epistemic and cognitive opportunities they provided for student reasoning – to determine the extent to which these tasks engaged students in learning science practices and content. Preservice teacher participants' tasks were examined along two dimensions: the integration/isolation of science and engineering practices with science content (i.e., the kind of thinking required of students) and the cognitive demand of the science included (i.e., the level of thinking required of students). I also investigated these preservice teachers' understanding of academic language, and the types of instructional supports they implemented to scaffold ELs' academic language use during cognitively demanding tasks in their secondary science classrooms. I attempted to determine how teachers' implementation of cognitively demanding work, their support of academic language, and their scores on their edTPA assessment were related.

There are few existing studies that explore preservice secondary science teachers addressing the needs of ELs in terms of supporting their academic language demands across all three language levels (lexical, syntax, and discourse; e.g., Lyon et al., 2018; Roberts et al., 2017). This study encourages teachers to organize their science content and language instruction around a comprehensive EL framework instead of just implementing a list of disconnected instructional supports (Heineke et al., 2019; Johnson et al., 2016; Lyon et al., 2016, 2018; MacDonald, Miller, & Lord, 2017). A number of these studies highlight the importance of moving beyond the teaching of vocabulary (i.e., the lexical level) to attend to the syntactic and discursive levels of language as well (Dong, 2002; O'Hara et al., 2017; Richardson Bruna, Vann, & Escudero, 2007). This study attempts to understand the successes and struggles of preservice teachers in teaching ELs rigorous, reform-based science at the secondary level as a way to inform both science teacher education for beginning teachers of ELs and science instruction for ELs themselves. Therefore, this paper begins to fill a missing gap in the literature by focusing on the strengths and limitations of preservice secondary science teachers' implementation of academic language supports for effective EL instruction in the context of both content-practice integration and cognitive demand in their edTPA lesson series (Tekkumru-Kisa, Schunn, Stein, & Reynolds, 2017). More specifically, this work attempts to offer new insights into preservice secondary science teacher education as it provides a systemic comparison in terms of supporting academic language for ELs during ambitious science teaching between PSTs with and without EL instruction enrolled in TEPs at research-intensive institutions (Windschitl et al., 2018).

# Chapter IV: Methods

## Context

This study is part of a larger ongoing research project focused on assessing the impact of undergraduate and graduate teacher preparation programs on preservice science teachers. Preservice secondary science teacher participants were enrolled in a post-baccalaureate teacher education program located in one of four public research universities in California: University B, University C, University D, and University R. Participants moved through the program as a cohort, participating in secondary science classrooms during the day and taking courses at the university in the evenings. More specifically, University D had a post-baccalaureate program with the option to earn an M.A. during the following year. Their 11-month program attempted to educate practitioners who advocated for educational equity, adopted a reflective lens, collaborated with other professionals, and engaged in inquiry. University R offered a 12-month, post-baccalaureate program with the option to earn an M.Ed. concurrently with a credential, providing a strong focus on developing educators who are culturally responsive. University B also offered the option to earn an M.Ed. concurrently with a credential during their program. In addition, their primary focus was on recognizing and responding to students' holistic needs (including academic, social, and emotional needs) to further their success; establishing and protecting inclusive classroom communities; advocating with student groups that are historically underserved; and preparing creative teacher leaders. Finally, University C also ran a 12-month post-baccalaureate program with the option of earning an M.A. concurrently with a credential. Moreover, their program emphasized equity and social justice, focusing on the education of culturally and linguistically diverse students while unpacking specific strategies for working with English learners and culturally relevant pedagogy. Overall, across all four programs, preservice teachers completed three sets of courses and experiences designed to support their learning

about ELs and effective ways to teach them. In general, these three sets of courses and experiences included: (1) Professional Issues in Teaching Science course and intensive classroom-based practicum experiences in grades 7-12 science classrooms; (2) courses that specifically addressed teaching linguistically and culturally diverse students and provided foundational information about academic language and practices to support English language development and disciplinary content; and (3) science methods courses that focused on reform-based science instruction to develop PSTs' understanding of instructional strategies, student learning, curriculum design, science education research, and the teaching of science to ELs.

As a second set of courses related to language and literacy, preservice teachers completed courses that quite emphasized PSTs working with linguistically and culturally diverse students. Collectively, these courses explored the diversity of ELs, provided foundational information about academic language, and identified best practices for supporting ELs in their development of the English language (ELD) and understanding of content. The courses presented academic language as more than discipline-specific vocabulary (Bunch, 2013) – as an essential mediator of the teaching and learning process that supports students' ability to access and communicate their understanding of core ideas (Lee et al., 2013) across the lexical, syntactic, and discursive levels of language (Zwiers et al., 2014). Finally, preservice teacher participants enrolled in science methods courses that focused on reform-based science instruction. Usually, these courses examined the recently adopted *NGSS*, theories of student learning, and examples of reform-based science curriculum, instruction, and assessment. Occasionally, in at least one TEP (University B), teachers were given two options for their additional methods course: an integrated science

and mathematics methods course focused on the teaching of these disciplines to ELs; or a bilingual methods course.

In California, future preservice science teachers must complete a bachelor's degree in a particular subject, such as biology, chemistry, or physics. Upon completion of their undergraduate degree, students might choose to receive their teaching credential and finish master's level coursework at the graduate teacher education program (TEP). In fact, these programs prepared preservice science teachers to engage in graduate coursework in science education, thus providing a solid theoretical research-based foundation in science teaching. Moreover, PSTs received coaching and supervision during one or more intensive student teaching experiences, as well as the necessary guidance to fulfill the requirements of the teaching credential. The program coursework of these four TEPs were based on current research and prepared students to plan, implement, and assess learning in several ways, integrating research-based practices that supported academic achievement for all students. In addition, these four programs combined coursework and extensive field experiences to provide with a specific stepwise, developmental progression aligned with research on best practices in teacher education (Cochran-Smith & Lytle, 1999). Generally, PSTs spent more than 600 hours in the classroom during their credential programs. During field placements, supervisors collaborated with cooperating teachers to support PSTs while learning to work in diverse classroom settings, as well as assisting their cooperating teachers in the classroom. Finally, these four TEPs required PSTs to have had prior work or volunteer experience with students; and PSTs must have shown the skills and aptitude to become leaders and continue teaching in the future.

In general, preservice teachers were also enrolled in a year-long professional issues in science teaching course, where they discussed connections between theory and practice and reflected on their student teaching placement experiences with an experienced science teacher educator. More specifically, at University D, preservice science teachers underwent two concurrent placements throughout the credential year, usually one in a middle school and the other in a high school. In their primary placement, PSTs started by observing/helping, followed by taking full teaching responsibilities for one class period per day starting in January. In their secondary placement, PSTs observed, helped as needed, and took on some instructional responsibilities but did not necessarily takeover as in their primary placement. In comparison, preservice teachers at University B were required to complete 3 placements: their first placement started on the first day of the K-12 school year (August) and ended in October, while their second placement lasted from October to December, and their third placement lasted from January to the end of K-12 school year (early June). Additionally, PSTs often completed two placements with the same cooperating teacher. Teacher participants at University C completed two student teaching placements, one placement in a middle school and the other in a high school. Their first placement lasted from August to November where participants began with initial observations of the class and then assumed increasing levels of responsibility, such as teaching small groups, parts of lessons, and full lessons. Their second placement began in November: Participants assumed more responsibility for instruction, which culminates with solo teaching where PSTs assumed responsibility for all aspects of instruction in two courses for at least one public school grading period. In contrast, PSTs completed two different placements at the University R, with the first placement in fall and then the second in winter. Normally, one placement took

place in a middle school and the other one in a high school, but not always. In addition, both placements could be in same school site but would necessarily be for different grade levels or different courses. Lastly, the actual number of field experience hours per week increased each quarter (fall through spring).

**Participants**

Data were collected from two cohorts of preservice science teachers (2016-2017 and 2017-2018) who received a Noyce scholarship and, thus, committed to teach for two years in a high-needs school district upon graduation. As stated above, participants were enrolled in a post-baccalaureate teacher education program located in one of four public research universities in California. For this study, I examined a total of 20 pre-service science teachers ($n$=20). These 20 preservice science teachers represented 37% of all preservice science teachers enrolled in these four programs across the two years of this study. Moreover, I separated my preservice teacher participants into two distinct groups: participants who did not have any EL students when completing their second semester takeover and participants who had at least one EL student in their classrooms at that time. For participants in the EL group, their EL students spoke a variety of home languages and ranged in English proficiency from emerging, to expanding, to bridging (beginning, intermediate, advanced).

As part of the selection criteria for this particular study, I ranked all 54 preservice science teachers within each group according to their total edTPA scores; the edTPA is a teacher performance assessment required by California and several other states for credentialing purposes. Preservice science teachers' scores ranged from 37 to 67 points for those teaching EL students, or those in the EL group, and from 43 to 52 for those who had no EL students in their classrooms, or those in the non-EL group. I first divided my initial

sample (*n*=54 participants) into two distinct groups: PSTs with ELs (*n*=30) and PSTs without ELs (*n*=24). Further, I then narrowed down my two group samples to only include the participants with the top five and bottom five edTPA scores within each of the two groups. As a result, ten of the 54 participants scored at least a full standard deviation above the average of this study population (score of 52 or higher); and seventeen, at least a half standard deviation above (score of 50 or higher). Overall, five participants from the EL group (top 5 tier) scored a full standard deviation above the average of this study population; whereas two participants from the non-EL group (PSTs with ELs) scored a full standard deviation above and three scored at least a half standard deviation above the average of this study population (all from top 5 tier). In fact, the other participants from both groups scored below the population average. As a result, my final research sample included 20 preservice science teachers, including 10 participants from the EL group and 10 from the non-EL group (PSTs without ELs; $\mu$=47.96; $\sigma$=4.49). Table 4.1 shows the distribution of participants across the four campuses, while Tables 4.2 and 4.3 present demographic and placement information of the PSTs.

Table 4.1

*Distribution of Secondary Science PST Participants*

*Across the Four Universities Under Study*

| | **Year 1** | **Year 2** | **Total** |
|---|---|---|---|
| University A | 4 | 1 | 5 |
| University B | 3 | 5 | 8 |
| University C | 5 | 0 | 5 |
| University D | 0 | 2 | 2 |
| | | | 20 |

Table 4.2

*PST Participants' Demographics*

| | |
|---|---|
| **Gender** | |
| Female | 50% |
| Male | 50% |
| **Race/Ethnicity** | |
| White/European American | 70% |
| Asian/Asian American | 10% |
| Latinx/Hispanic | 5% |
| Multiracial | 10% |
| Other | 5% |
| **First Language** | |
| English | 80% |
| Language(s) other than or in addition to English | 20% |

*Note.* All demographic data are self-reported.

Table 4.3

*Preservice Teacher Participants' Demographic and Classroom Placement Information*

| Name | Race/ Ethnicity | Gender | Teaching Credential(s) | Takeover Placement School | Takeover Placement Course | # of ELs | PSTs' Study Group |
|---|---|---|---|---|---|---|---|
| Rachel | European American | F | Biology/Earth | MS/City | Integrated Science 7th | 5 | EL |
| Miles | European American | M | Chemistry | HS/Town | Chemistry | 2 | EL |
| Mickey | European American | M | Earth | HS/Town | Environmental Science | 5 | EL |
| Sophie | European American | F | Chemistry | HS/Suburb | Chemistry | 3 | EL |
| Eliza | European American | F | Physics | HS/Suburb | Physics | 4 | EL |
| Jackson | Asian American | M | Physics | HS/Town | Physics | 4 | EL |
| Nadin | Latino | F | Chemistry | HS/Town | Chemistry | 5 | EL |
| George | Multiracial | M | Biology | HS/Suburb | Biology | 3 | EL |
| Jennifer | European American | F | Earth | MS/Urban | Science 8th | 3 | EL |
| Jackie | Multiracial | F | Chemistry | HS/Town | Chemistry | 3 | EL |
| Kim | Asian American | F | Biology | HS/Suburb | Biology | 0 | Non-EL |
| Leo | European American | M | Physics | HS/Suburb | Engineering Physics | 0 | Non-EL |
| Zander | European American | M | Physics | HS/Suburb | Physics | 0 | Non-EL |
| Priscila | European American | F | Chemistry | HS/City | Chemistry | 0 | Non-EL |
| Jasmine | European American | F | Chemistry | HS/Suburb | Biology | 0 | Non-EL |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Nick | European American | M | Biology | HS/Town | Biology | 0 | Non-EL |
| James | European American | M | Biology | HS/Suburb | Biology | 0 | Non-EL |
| Max | European American | M | Biology | HS/Rural | Biology | 0 | Non-EL |
| Anderson | Middle Eastern | M | Physics | HS/Suburb | Physics | 0 | Non-EL |
| Leah | European American | F | Biology | MS/Suburb | Physical Science | 0 | Non-EL |

## Data Collection

As mentioned before, data were collected across the teacher education programs in 2016-2017 and 2017-2018. In fact, data for this study came from preservice teachers' performance assessment (edTPA) portfolios, a national performance assessment portfolio used for initial teacher certification in a number of US states, including California. The edTPA focuses on a three-to-four-day lesson series and consists of three sections: planning, instruction, and assessment. Preservice teachers submit written lesson plans related to their lesson cycle, instructional materials, two short videos excerpts of their instruction from two lessons, and three samples of student work on an assessment task given at the end of the lesson cycle. Preservice teachers also submit three written commentaries – one each for planning, instruction, and assessment – where they respond to specific prompts; together, commentaries typically constitute 25 pages of single-spaced text. These three commentaries ask preservice teachers to explain how they supported students to analyze and interpret data and to construct evidence-based explanations; as a result, these two *NGSS* practices are featured prominently in preservice teachers' lessons and assessments.

Particularly relevant to this study, the edTPA specifically assesses preservice teachers' ability to identify and support language demands during cognitively demanding tasks and to analyze their students' language use and learning in sample lessons. As

previously explained, this portfolio assessment requires preservice teachers to submit instructional materials and reflections related to a three-to-four-day lesson cycle. For this study, I focused specifically on preservice teachers' edTPA lesson plans and instructional commentaries. Usually, lesson plans ranged in length from 4 to 8 single-spaced, typed pages. Since lesson plans were intended to guide classroom learning, I decided to analyze them in order to better measure what students needed to learn, how it would be taught, and how learning would be conducted. In addition, instructional commentaries were analyzed since they effectively reflected how PSTs engaged and extended student learning in the lesson segments that they video recorded and submitted as part of their edTPA.

**Data Analysis**

For this study, I analyzed preservice teachers' edTPA instructional commentaries and lesson plans. Across data sources, I coded each natural meaning unit (Brinkmann & Kvale, 2015), which I defined as a collection of statements related to the same central meaning. I then conducted four cycles of coding to analyze the edTPA instructional commentaries and lesson plans, using a different set of a priori or emergent codes for each cycle (Saldaña, 2016). In order to answer the two set of research questions, I collected the complete edTPA portfolio for each PST, specifically focusing on the commentaries and lesson plans. I began by qualitatively analyzing the written commentaries (instructional) and lesson plans, using four cycles of analysis and a different set of *a priori* or emergent codes for each (Saldaña, 2016).

Overall, for my first cycle of analysis, I used five a priori codes constructed from the principles on effective teaching of ELs (theoretical framework), especially focusing on cognitively demanding tasks and academic language demands for further tier 2 coding.

During my second cycle of analysis, within the tier I coding for cognitively demanding tasks, I coded for each of the eight *NGSS* science and engineering practices (e.g., engaging in argument). In addition, within tier I coding for academic language demands, I determined the level of academic language/linguistic demand (i.e., lexical, syntactic, and discursive) and types of instructional support preservice teachers implemented (e.g., word walls, sentence frames, and peer collaboration). Next, in my third cycle of analysis, I coded for the integration or isolation of science content and practices according to the TAGS framework, as well as the level of cognitive demand of instructional tasks following the TAGS framework once again. Finally, given the previous knowledge of both the level of lesson integration and cognitive demand of tasks implemented by each PSTs, I was able to appropriately place each participant within one of the TAGS quadrant for future analysis.

More specifically, for my first cycle of analysis, or tier 1 coding (see Table 4.4), I used four a priori codes constructed from the principles on effective teaching of ELs (i.e., funds of knowledge, cognitively demanding work, language opportunities, creating a safe classroom environment, and academic language demands and supports). This first round allowed me to initially address both of my research questions by qualitatively analyzing both edTPA's written commentaries (instruction) and lesson plans of all participants, especially focusing on cognitively demanding tasks and academic language supports for further tier 2 coding and analysis.

Table 4.4

*Five Principles of Effective EL Instruction*

| | |
|---|---|
| Academic language demands | PST describes providing ELs supports to scaffolding academic language demands at the vocab, syntax, or discourse level. |

| | |
|---|---|
| Cognitively demanding tasks | PST describes providing ELs opportunities to engage in rigorous, standards-aligned tasks. |
| Funds of knowledge | PST describes providing ELs opportunities to draw on their experiences, interests, languages, cultures, or community connections. |
| Language opportunities | PST describes providing ELs opportunities to engage with oral or written discourse. |
| Safe classroom community | PST describes creating a safe classroom environment and establishing norms and routines that support sense-making. |

During the second, or tier 2, cycle of analysis, in order to address my first research question regarding PSTs' lesson integration (science and engineering practices with science content) and implementation of different levels of cognitive demand tasks, I coded for each of the eight *NGSS* science and engineering practices (e.g., engaging in argument) using both lesson plans and instructional commentaries (see Table 4.5).

Table 4.5

*Eight Science and Engineering Practices (SEPs) from the Next Generation Science Standards*

- 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

Continuing with my tier 2 cycle of analysis and in order to answer my second research question related to PSTs supporting the academic language demands of their students (particularly English learners), I determined the level of academic language/linguistic demand (i.e., lexical, syntactic, and discursive) and type of instructional

support (e.g., word walls, sentence frames, and peer collaboration) using both lesson plans and instructional commentaries. In particular, I focused on the most common (implemented by a majority of preservice teacher participants) types of support preservice teacher participants used to scaffold academic language demands at all three language levels, especially at the discursive level given its importance in the current *NGSS* reform-based instruction (Table 4.6). Moreover, the goal was to determine when and in the context of which other science practices teachers were enacting discursive instructional academic language supports for ELs while implementing those specific language-intensive practices (e.g., constructing an explanation). More specifically, I narrowed my focus to all meaning units coded during the first round as cognitively demanding tasks, specifically focusing on the intersection with academic language demands and supports at all language levels level for further analysis.

Table 4.6

*Tier 2 Codes: Categories, Types, and Definitions of Academic Language Supports Implemented by PSTs*

| Category of Support | Type of Support | Definition |
|---|---|---|
| **Providing context for language** | Hands-on activity | Teacher contextualizes content and language learning by engaging students in a hands-on activity. |
| | Socioscientific issue | Teacher contextualizes content and language learning using a socioscientific issue (e.g., climate change or genetic engineering). |
| | Starting with a phenomenon | Teacher contextualizes content and language learning by starting with a complex or puzzling phenomenon—a concrete event or process—rather than an abstract idea (e.g., students watch a video of a parachute opening or a demonstration of a can imploding). |
| **Attending to language comprehension** | Guided notes | Teacher provides students with a structured format for recording new vocabulary, taking notes, etc. |
| | Providing clear directions/ speaking clearly | Teacher makes speech more comprehensible by speaking more slowly, clearly, and/or concisely; attending to clarity of written directions; and/or |

| | | |
|---|---|---|
| | | providing directions in multiple modalities (e.g., spoken and written). |
| | Structured reading | Teacher uses a strategy such as popcorn reading, reading guides, highlighting and annotating, or Collaborative Strategic Reading. |
| | Visuals and realia | Teacher uses illustrations, drawings, videos, physical objects/realia, manipulatives, or demonstrations to develop and reinforce meaning. |
| | Word learning strategies | Teacher clarifies the meaning of new terms by supplying definitions and/or teaching word learning strategies (e.g., decomposing terms into constituent roots and affixes, identifying cognates, or using context clues). |
| **Attending to language production** | Facilitating discussions | Teacher deliberately uses questions, wait time, and other discourse moves during whole class or small group discussions. |
| | Modeling | Teacher models academic language for students (e.g., deliberately incorporating disciplinary terms into their talk, using think-alouds to model the reading or writing process, or providing exemplars or discussing samples of student work). |
| | Peer collaboration | Teacher intentionally organizes students to work in pairs or small groups. |
| | Sentence frames | Teacher provides students with sentence frames or sentence starters. |
| | Word walls | Teacher displays word walls in the classroom or provides students with word banks on assignments. |
| **Incorporating students' existing language and linguistic practices** | Home language | Teacher includes students' home languages in instruction (e.g., providing translations, grouping students with the same home language, or encouraging translanguaging). |
| **General strategies** | Chunking the task | Teacher breaks down the activity or assignment into smaller, more manageable parts. |
| | Differentiation | Teacher provides different tasks or different options within a given task for students with different needs. |
| | Individual instruction | Teacher provides an individual student with targeted instruction not provided to the entire class (e.g., pulling a student aside to clarify content, or asking a student to come before or after class to get help on a task). |

During the third cycle of analysis, or tier III, and in order to answer my first set of research questions related to PSTs' lesson integration (science and engineering practices with science content) and implementation of different levels of cognitive demand tasks , I used the previous two tiers of codes and began by coding along two dimensions according to the TAGS framework: (1) I determined the level (i.e., high/low cognitive demand) of student

reasoning and sensemaking required during instructional tasks by analyzing PSTs' lesson plans. (2) I determined the level of integration (i.e., integrated or isolated) between science content (focusing on cross-cutting concepts and disciplinary core ideas) and *NGSS* science and engineering practices by examining PSTs' instructional commentaries. In fact, in order to assess the level of cognitive work implemented by PSTs, I coded the instructional tasks according to the two different levels of cognitively demanding tasks defined by the four types of instructional tasks described in the framework: high level characterized by guided and open-inquiry tasks; and low level characterized by scripted and memorization tasks (see Table 4.7).

Table 4.7

*Tier 3 Codes: Cognitive Demand Levels and Associated Types of Instructional Tasks*

| Cognitive Demand | Instructional Task |
|---|---|
| High | Open-Inquiry/Doing Science<br>Guided |
| Low | Scripted<br>Memorization |

Finally, during my fourth cycle of analysis, or tier IV, and to comprehensively answer both of my research questions described earlier, I used the qualitatively analysis of lesson plans and instructional commentaries from previous three tiers of codes to strategically place each PST participants in one of the four quadrants in the TAGS framework (see Table 2.1). This way, I was able to address my first research question defined by how effectively PSTs integrated (science and engineering practices with science content) and successfully implemented different levels of cognitive demand tasks. Moreover, the effort to appropriately place PSTs into those quadrants led me to address my second research question regarding

PSTs supporting the academic language demands of their students (particularly English learners).

## Chapter V: Research Findings Set 1

As mentioned previously, the central component of my conceptual frame is the two-dimensional TAGS (Task Analysis Guide in Science) framework proposed by Tekkumru-Kisa and colleagues (Tekkumru-Kisa, Stein, & Schunn, 2015; Tekkumru-Kisa et al., 2017) that includes science. The original framework enables researchers to track the *NGSS* science and engineering practices and content included in tasks in order to assess both the kind (i.e., integrated or isolated) and level (i.e., cognitive demand) of student reasoning and sensemaking required. Additionally, one dimension of this framework examines whether a task is integrated or isolated across the practices and content of the discipline; the other analyzes the extent to which a task promotes authentic disciplinary thinking or cognitive demand. In this study, the TAGS framework was used to investigate both the *NGSS* science and practices included, and the cognitive demand introduced in participants' implementation of their edTPA lessons.

In our current school science context, there is an urgent need to plan and implement reform-based instructional tasks since the integration of content and language is crucial for the success of ELs. In addition, reform-based instruction demands that ELs frequently engage in the types of reform-minded, academically rigorous tasks that are often regularly reserved for non-EL students (Iddings, 2005). Therefore, it is imperative that PSTs learn to offer all students opportunities to engage in cognitively demanding work and to use scaffolding tools to maintain student engagement in intellectually demanding tasks (Kang et al., 2016).

To address my first research question, I placed each PST's lesson series in one of the four quadrants of the TAGS framework. I found that 10 PSTs' lessons were placed in Quadrant I (Q.I): These lessons both integrated science content (i.e., disciplinary core ideas and/or crosscutting concepts) and practices as well as engaged students in cognitively demanding tasks in order to promote students' scientific sensemaking. On the other hand, I found that 10 PSTs' lessons could be thought of as isolated in science content and practices as well as low in cognitive demand: They were placed in Quadrant III (Q.III) of the TAGS framework (see Table 5.1 for a summary of the findings).

Table 5.1

*PST Participants and Their edTPA Lesson Series*

| PST | edTPA Score | ELs (Number) | Subject | TAGS Quadrant | Integration/ Isolation | Cognitive Demand |
|---|---|---|---|---|---|---|
| Rachel | 67 | Yes (5) | Integrated Science 7th | I | Integrated | High |
| Miles | 59 | Yes (2) | Chemistry | I | Integrated | High |
| Mickey | 58 | Yes (5) | Environmental Science | I | Integrated | High |
| Sophie | 55 | Yes (3) | Chemistry | I | Integrated | High |
| Eliza | 53 | Yes (4) | Physics | I | Integrated | High |
| Kim | 52 | No (0) | Biology | I | Integrated | High |
| Leo | 52 | No (0) | Physics | I | Integrated | High |
| Zander | 51 | No (0) | Physics | I | Integrated | High |
| Priscila | 50 | No (0) | Chemistry | I | Integrated | High |
| Jasmine | 50 | No (0) | Chemistry | I | Integrated | High |
| Jackson | 43 | Yes (4) | Physics | III | Isolated | Low |
| Nadin | 43 | Yes (5) | Chemistry | III | Isolated | Low |
| George | 42 | Yes (3) | Biology | III | Isolated | Low |
| Jennifer | 39 | Yes (3) | Science 8th | III | Isolated | Low |
| Jackie | 37 | Yes (3) | Chemistry | III | Isolated | Low |
| Nick | 45 | No (0) | Biology | III | Isolated | Low |
| James | 45 | No (0) | Biology | III | Isolated | Low |

| | | | | | | |
|---|---|---|---|---|---|---|
| Max | 44 | No (0) | Biology | III | Isolated | Low |
| Anderson | 44 | No (0) | Physics | III | Isolated | Low |
| Leah | 43 | No (0) | Physical Science | III | Isolated | Low |

**Finding Set 1.1: Integration of Content and Practices When Implementing Tasks in Science**

Regarding the TAGS framework's first dimension, the integration/isolation dimension can be used to determine whether or not science content and scientific practices are integrated within a task. The eight science and engineering practices (SEPs) included in the *NGSS* indicate the types of science activities that students should engage in while they learn the subject content. However, in some instructional situations, students could be offered a detailed script to follow and later encouraged to engage in disciplinary practices within the context of a scientific idea (e.g., analyzing results of an experiment) such that all of the thinking demands have been removed (Mehalik et al. 2008; Tekkumru-Kisa et al. 2015). Similarly, although a science lab could lead to students collecting and analyzing data, students might not understand why they are engaged in these practices central to science – which is knowledge building (Duncan & Cavera, 2015). Consequently, some tasks could concentrate almost entirely on specific disciplinary core concepts or ideas, such as forces and motion, chemical reactions, or natural selection. In contrast, other tasks could focus on specific scientific practices that scientists engage in as they investigate and construct explanations about the world. In short, isolated tasks concentrate on students' thinking exclusively about scientific concepts, such as evolution, or on engaging students exclusively in scientific practices, such as argumentation. Alternatively, integrated tasks are

characterized by the integration of science content and scientific practices in a way that promotes students' understanding of science core ideas and concepts within the context of scientific practices as recommended in the *NGSS*.

Scientific practices are central to science education for two important reasons: engagement in practices helps enhance students' conceptual understanding, and practices outline an essential part of what the discipline of science involves (Fortus & Krajcik, 2012). In addition, researchers (Evagorou & Osborne, 2013) claim that students should learn disciplinary content knowledge (i.e., core ideas and crosscutting concepts) within the context of scientific practices since ''learning science and engineering involves the integration of the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering'' (NRC, 2012, p. 11). Unfortunately, even when some integration of practices and content is present during hands-on inquiry activities, these activities frequently do not represent the authentic scientific practices that scientists engage with when they do science (Chinn & Malhotra, 2002).

In order to address the first part of my first research question, then, I investigated the instructional tasks of the participants in terms of how successfully they integrated subject content and practices. (Finding Set 1.2 below examines how cognitively demanding these instructional tasks were.) I organized my discussion of the integration of instructional tasks based on their respective total edTPA scores and on whether or not they had ELs in their classroom (see again in Table 5.1). A major finding was that the science preservice teachers' instructional task integration was highly dependent on how successful they were during their performance assessment, as indicated by their total edTPA scores. The participants who ranked in the top five edTPA scores in each group (PSTs with ELs and PSTs without ELs)

were placed in Q.I of the TAGS framework, which indicates that they were able to efficiently integrate the subject content (i.e., core ideas and/or cross-cutting concepts) and science practices. The participants who ranked in the bottom five edTPA scores in each group (PSTs with ELs and PSTs without ELs) were placed in Q.III of the TAGS framework.

As introduced above, I found that 10 of my PST participants implemented edTPA lesson series that fell within Quadrant I of the TAGS framework: Rachel, Miles, Mickey, Sophie, Eliza, Kim, Leo, Zander, Priscila, and Jasmine (see Tables 5.2a and 5.2b). As such, those 10 participants – those with the highest edTPA scores for both PSTs with ELs and PSTs without ELS – integrated science content, particularly core ideas and/or cross-cutting concepts, and SEPs into their instruction.

Table 5.2a

*Opportunities PSTs With ELs Provided Their Students to Participate in Integrated, High Cognitively Demanding Scientific Sensemaking in Quadrant I*

| **Preservice Science Teacher** | | Rachel (Bio/Earth) | Miles (Chem) | Mickey (Earth) | Sophie (Chem) | Eliza (Physics) |
|---|---|---|---|---|---|---|
| **TAGS - Framework** | | Quadrant I | | | | |
| **Integration of Content and Practices** | ***NGSS Science Content*** | | | | | |
| | Content standard(s) *(The * relates science content to science modeling, which is considered both content and practice)* | MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. | HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge | HS-ESS2-4: Use a model to describe how variations in the flow of energy result in changes in climate. HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the future impacts to Earth's systems. | HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. | HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | of the patterns of chemical properties | | | acceleration. |
| | ***NGSS Science and Engineering Practices*** | | | | | |
| | SEP1. Ask questions and define problems. | | | | | |
| | SEP2. Develop and use models. | | | | | |
| | SEP3. Plan and carry out investigations. | | | | | |
| | SEP4. Analyze and Interpret data. | | | | | |
| | SEP5. Use mathematical and computational thinking. | | | | | |
| | SEP6. Construct explanations and design solutions. | | | | | |
| | SEP7. Engage in argument from evidence. | | | | | |
| | SEP8. Obtain, evaluate, and communicate information. | | | | | |
| **Cognitive Demand** | ***Science Emphasis (instructional task)*** | Open inquiry and/or guided task | Open inquiry and/or guided task | Open inquiry and/or guided task | Open inquiry and/or guided task | Open inquiry and/or guided task |

*Note.* A shaded cell means students engaged in this practice during a participant's lesson series.

Table 5.2b

*Opportunities PSTs Without ELs Provided Their Students to Participate in Integrated, High Cognitively Demanding Scientific Sensemaking in Quadrant I*

| **Preservice Science Teacher** | Kim (Bio) | Leo (Physics) | Zander (Physics) | Priscila (Chem) | Jasmine (Bio) |
|---|---|---|---|---|---|

| **TAGS - Framework** | | Quadrant I | | | | |
|---|---|---|---|---|---|---|
| **Integration of Content and Practices** | ***NGSS Science Content*** | | | | | |
| | Content standard(s) *(The * relates science content to science modeling, which is considered both content and practice)* | HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. | HS-PS3-3 . Design, build, and refine a device to convert one form of energy into another form of energy. HS-ETS1-2. Design a solution to a complex real-world problem that can be solved through engineering. | HS-PS2-3 Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. | HS-LS2-2 Using Mathematics and Computational Thinking for statistical analysis to analyze, represent, and model data. | HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. |
| | ***NGSS Science and Engineering Practices*** | | | | | |
| | SEP1. Ask questions and define problems. | | | | | |
| | SEP2. Develop and use models. | | | | | |
| | SEP3. Plan and carry out investigations. | | | | | |
| | SEP4. Analyze and Interpret data. | | | | | |
| | SEP5. Use mathematical and computational thinking. | | | | | |
| | SEP6. Construct explanations and design solutions. | | | | | |
| | SEP7. Engage in argument from evidence. | | | | | |
| | SEP8. Obtain, evaluate, and communicate information. | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Cognitive Demand** | ***Science Emphasis (instructional task)*** | Open inquiry and/or guided task | Open inquiry and/or guided task | Open inquiry and/or guided task | Open inquiry and/or guided task | Open inquiry and/or guided task |

*Note.* A shaded cell means students engaged in this practice during a participant's lesson series.

In one example, Leo had no multilingual learners in his classroom but performed well on the edTPA (total score of 52 and ranked top 5 in his group, PSTs without ELs). In addition, Leo, who was an 11$^{th}$ grade engineering physics teacher, worked with his students on engineering design projects as they moved through engineering and physics. Leo's lesson series was intended to help students understand the relationship between gear ratio and mechanical advantage as well as power, torque, and rotational speed while working with a model transmission to explore the behavior of those relationships. During his lesson series, he engaged his students in science inquiry and used an *NGSS* performance expectation related to energy (HS-PS3-3): Design, build, and refine a device to convert one form of energy into another form of energy. Moreover, within the engineering context, students were expected to design a solution to a complex, real-world problem that could be solved through engineering (HS-ETS1-2). In general, through calculations and interactive examples of transmissions and compound gears, students were able to identify a transmission and different kinds of gears; calculate the gear ratio, rotational speed, radius, and number of teeth in simple and compound gear trains; measure the rotational speeds of a transmission and analyze their differences; and design a transmission under certain criteria based on the type of power source.

As stated earlier, Leo was placed in Q.I because he was able to successfully integrate science content in terms of motion, forces, and interaction (i.e., disciplinary core ideas) and energy and matter/structure and function (i.e., crosscutting concepts) with science and

engineering practices. More specifically, to successfully integrate the science content with *NGSS* science and engineering practices, he engaged his students in sensemaking through the implementation of several SEPs, such as *developing and using models, using mathematics and computational thinking, engaging in argument from evidence*, and *planning and carrying out investigations* (as seen again in Table 5.2b). Furthermore, Leo included the terms "direct relationship" and "inverse relationship" in a list of vocabulary words that "students must know and be able to apply" [Leo, Lesson Plan, University B, PST without EL]. As such, students used mathematical relationships to describe a phenomenon by reasoning abstractly about the implied quantitative relationship they had observed, thereby integrating the science content of kinetic motion and energy with the *NGSS* science and engineering practices of *constructing explanations and designing solutions, using mathematics and computational thinking,* and *developing and using models*. Therefore, the content of the science, using simple gears to calculate using equations the relationship between its parts, was integrated with the *NGSS* practices of *constructing explanations and designing solutions, using mathematics and computational thinking,* and *developing and use models*, indicating a high level in cognitive demand. The example below provides insight into Leo's integration of chemical energy and mechanical energy (i.e., disciplinary content) while designing and building an electric motor to convert one form of energy into another through the implementation of several SEPs, such as *developing and using models*, *constructing explanations and designing solutions*, and *engaging in argument from evidence*:

> *In Lesson 2, students are shown discussing the second iteration of their bumper design as I ask probing questions. In this clip, students discuss observations and information about the prototype bumpers they have designed. The questions and*

*comments that I offer as I circulate serve to engage students in describing their observations and evidence about their designs. I also engage students in using this information as evidence to make predictions about their bumpers' performance in the upcoming crash test.* [Leo, Instruction Commentary, University B, PST without EL]

As mentioned earlier, one of the major findings was the fact that the science preservice teachers' instructional task integration was highly dependent on how successful the participants were during their performance assessment, as indicated by their total edTPA scores. On the other end of the spectrum, then, the participants who ranked in the bottom five edTPA scores in each group (PSTs with ELs and PST without ELs) were placed in the Q.III of the TAGS framework: They were unable to successfully integrate the subject content (i.e., core ideas and/or crosscutting concepts) and *NGSS* practices. (See Tables 5.2c and 5.2d.)

Table 5.2c

*Opportunities PSTs With ELs Provided Their Students to Participate in Isolated, Low Cognitively Demanding Scientific Sensemaking in Quadrant III*

| **Preservice Science Teacher** | | Jackson (Physics) | Nadin (Chem) | George (Bio) | Jennifer (Earth) | Jackie (Chem) |
|---|---|---|---|---|---|---|
| **TAGS - Framework** | | Quadrant III | | | | |
| **Integration of Content and Practices** | ***NGSS Science Content*** | | | | | |
| | Content standard(s) *(The * relates science content to science modeling, which is considered both content and practice)* | HS-PS2-3 Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. | HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperatur e or concentrati on of the | HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations. HS-LS2-6. Evaluate the | MS-LS4 - 5 Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. | MS-PS1-4: Develop a model that predicts and describes changes in particle motion, temperatu re, and state of matter of a pure substance |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | reacting particles on the rate at which a reaction occurs. | claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms. | | when thermal energy is added or removed. |
| | ***NGSS Science and Engineering Practices*** | | | | | |
| | SEP1. Ask questions and define problems. | | | | | |
| | SEP2. Develop and use models. | | | | | |
| | SEP3. Plan and carry out investigations. | | | | | |
| | SEP4. Analyze and Interpret data. | | | | | |
| | SEP5. Use mathematical and computational thinking. | | | | | |
| | SEP6. Construct explanations and design solutions. | | | | | |
| | SEP7. Engage in argument from evidence. | | | | | |
| | SEP8. Obtain, evaluate, and communicate information. | | | | | |
| **Cognitive Demand** | ***Science Emphasis (instructional task)*** | Scripted and/or memorization | Scripted and/or memorization | Scripted and/or memorization | Scripted and/or memorization | Scripted and/or memorization |

*Note.* A shaded cell means students engaged in this practice during a participant's lesson series.

Table 5.2d

*Opportunities PSTs Without ELs Provided Their Students to Participate in Isolated, Low Cognitively Demanding Scientific Sensemaking in Quadrant III*

| **Preservice Science Teacher** | | Nick (Bio) | James (Bio) | Max (Bio) | Anderson (Physics) | Leah (Phys. Sci.) |
|---|---|---|---|---|---|---|
| **TAGS – Framework** | | Quadrant III | | | | |
| **Integration of Content and Practices** | ***NGSS Science Content*** | | | | | |
| | **Content standard(s)** ***(The * relates science content to science modeling, which is considered both content and practice)*** | HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations. HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in the emergence of new species over time, and the extinction of other species. | LS4 - 5 Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. | HS-LS1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins. | HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. | MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures. MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. |
| | ***NGSS Science and Engineering Practices*** | | | | | |
| | SEP1. Ask questions and define problems. | | | | | |
| | SEP2. Develop and use models. | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | SEP3. Plan and carry out investigations. | | | | | |
| | SEP4. Analyze and Interpret data. | | | | | |
| | SEP5. Use mathematical and computational thinking. | | | | | |
| | SEP6. Construct explanations and design solutions. | | | | | |
| | SEP7. Engage in argument from evidence. | | | | | |
| | SEP8. Obtain, evaluate, and communicate information. | | | | | |
| **Cognitive Demand** | ***Science Emphasis (instructional task)*** | Scripted and/or memorization | Scripted and/or memorization | Scripted and/or memorization | Scripted and/or memorization | Scripted and/or memorization |

*Note.* A shaded cell means students engaged in this practice during a participant's lesson series.

For example, Jackson had some multilingual learners ($n$=4) in his classroom but performed just above passing on the edTPA (i.e., total score of 43 and ranked bottom 5 of PSTs with ELs). Jackson, who was also a high school physics teacher like Leo, taught a lesson series that was part of a unit on forces and interactions in his physics class. Jackson's lesson series was designed to encourage his students to associate the impulse-momentum theorem to safety practices built into cars, as well as to critique engineering safety features using this same theorem. More specifically, the purpose of his physics lesson series was for students to understand the phenomena of collisions and explosions in relation to the law of conservation of momentum. During Jackson's lesson series, as explicitly indicated in the

*NGSS* performance expectation HS-PS2-2, students were expected to use mathematical representations to support their claims. As indicated by the *NGSS* performance expectation HS-PS2-3, students were also encouraged to design, evaluate, and refine a device that minimizes the force on an object during a collision.

As mentioned earlier, Jackson was placed in Q.III since he did not effectively integrate the science content of impulse-momentum theorem (i.e., core ideas) and *systems and system models* (i.e., crosscutting concepts) with science and engineering practices. More precisely, in Jackson's edTPA lesson series, he did not fully engage his students in sensemaking through the implementation of a number of the SEPs, such as *using mathematics and computational thinking*, *constructing explanations and designing solutions*, *engaging in argument from evidence*, and *analyzing and interpreting data* (see again Table 5.2c). The example below summarizes Jackson's lack of integration of momentum and impulse (i.e., disciplinary content) when asking students to attempt to design a device that minimizes the force on an object during a collision through the implementation of only two SEPs, including *developing and using models*, and *planning and carrying out investigations*:

> *After I take this student's comment about the collision activity, I take a mental note and actually ended up showing the video at the end of the day on Day 3 while the students finish annotating their Momentum Article. The reason I had my students write their collision designs on the board was to provide more examples for the whole class of what an engineering device looked like, and to provide my students with an outlet for creativity and personalization of their learning.* [Jackson, Lesson Plan, University D, PST with EL]

Jackson's lessons on the conservation of momentum took an engineering design focus. Students carried out an investigation to discover how bumpers and crumple zones affect collisions so as to evaluate the effectiveness of different bumper designs. Even though Jackson asked students to create force versus time graphs, he did not encourage students to analyze and compare each other's, thus failing to engage students in opportunities to graphically display and analyze empirical results. In addition, he was not able to successfully promote the discourse of science in the classroom by engaging his students in comparative data analysis, active argumentation, or construction of explanations to conceptually address the concept of momentum. Specifically, Jackson did not attempt to engage his students in explaining how or where the adopted scientific model connected to the phenomenon (Crash Test Dummy Video – Sudden Stops in Real Life) being examined during the investigation. In this case, the student groups were not given the opportunity to construct arguments on how to interpret momentum and impulse from their data. Therefore, most of Jackson's instructional tasks concentrated almost completely on specific disciplinary core concepts or ideas, such as forces and momentum. On the contrary, some of his other tasks focused exclusively and entirely on either one of the following two *NGSS* practices or a combination of both: *developing and using models*, and *planning and carrying out investigations*. As such, Jackson's implementation of isolated tasks concentrated on students' thinking exclusively about scientific concepts or on scientific practices.

In closing, using the first dimension of the TAGS framework, I analyzed the instructional tasks of PST participants in terms of how successfully they integrated subject content and practices. In this way, I was able to better understand the degree of integration/isolation of PSTs' lessons in terms of subject content and *NGSS* science and

engineering practices. As a result, I found that 10 participants could be placed in Q.I, since they were able to integrate science content (particularly core ideas and/or crosscutting concepts) and SEPs, and 10 could be placed in Q.III. Equally important, it was clear that the participants' placement is those two TAGS quadrants was related to their total edTPA scores. Indeed, I found that those participants who had a high edTPA score (i.e., the top 5 in each group, ranging from 50 to 67) were placed in Q.I due to their high level of integration in instructional tasks. On the other hand, I found that those participants who had a low edTPA score (i.e., the bottom 5 in each group, ranging from 37 to 43) were placed in Q.III given their high level of isolation in instructional tasks (see again in Table 5.1). Further, in terms of participants' placement in quadrants using the first TAGS dimension, I found few differences between participants who had ELs in their classroom and those who did not. Similarly, for those PSTs who had ELs in their classrooms, there was no pattern in placement for those who had few in comparison to those who had several.

### Finding Set 1.2: The Cognitive Demand of Instructional Tasks in Which Students Were Asked to Engage

As previously stated, the second dimension of the TAGS framework determines the degree to which a task encourages authentic disciplinary thinking or is cognitively demanding. This part of the framework describes the cognitive demand, or the kind and level of thinking required for students to effectively engage with a task (Stein et al., 2009). Within the context of reform-based instruction, PSTs have the important role of encouraging students to think deeply about scientific concepts and ideas (Roth & Givvin, 2008). Based on previous studies, inquiry-based instruction that focuses on active student thinking (i.e., thinking creatively and/or building on prior knowledge) has been recognized as connected to

improved student content learning (Minner, Levy, & Century, 2010). As a result, students in classrooms that are aligned with the new science standards should be expected to participate in intellectually complex and deep thinking and reasoning related to scientific big ideas. Therefore, in addition to the important integration of practices and content, the academic challenges embedded in the new science standards requires a significant transformation on the part of classroom teachers (Spillane & Zeuli, 1999). The *NGSS* urges all science teachers to engage students in authentic experiences addressing the practice of science so as to acquire deeper understanding of the practices and disciplinary core ideas. Moreover, these practices should be integrated and interconnected in the classroom in order to promote a scientific discourse that concentrates on students becoming an active agent in their own learning. As such, PSTs should select and implement cognitively demanding instructional tasks aligned with the *NGSS* in order to offer academically challenging opportunities for students while learning science.

Although the TAGS framework evaluates cognitively demanding tasks, it is important to mention that low-level tasks are not always inappropriate for science classrooms. In fact, PSTs are expected to engage students in some instances of low-level activities, along with high-level ones, when developing curricular materials and implementing classroom activities. Nevertheless, PSTs should focus on promoting and supporting opportunities for students' participation in cognitively demanding tasks. Indeed, based on previous studies, researchers have demonstrated the success of these intellectually challenging tasks in promoting students' learning of science (Boaler & Staples, 2008; Stein & Lane, 1996), in addition to inquiry-based activities that motivate students to acquire a

greater understanding of scientific ideas, resulting in significantly higher science performance in general (Schneider, Krajcik, Marx, & Soloway, 2002).

Given the current context of *NGSS* reform-based instruction, cognitively demanding tasks can be described as ones that "prompt students to engage in disciplinary practices that deepen their understanding of the world through scientific reasoning and advance students' thinking by inviting them to link observable phenomena and theoretical big ideas in science" (Kang et al., 2016, p. 1335). In fact, lessons grounded in big ideas are essential to promoting rigorous learning in science given that these ideas focus on "substantive relationships between concepts in the form of scientific models that help learners understand, explain, and predict a variety of important phenomena in the nature world" (Windschitl, Thompson, & Braaten, 2018, p. 182). In contrast, low cognitively demanding tasks prompt students to recall, remember, check, define, or replicate prior scientific concepts and facts.

More specifically, in relation to this study and based on the TAGS framework, low cognitive demand instructional tasks were categorized into two main groups: Level 1 includes memorization tasks and level 2 includes scripted tasks. The first category of low-level work includes memorization tasks (level 1, or the lowest level). As such, these tasks involve the exact recreation of prescribed knowledge (i.e., definitions, rules, formulas, and principles), with clear and straightforward directions to students. In tasks involving scripts (level 2), there is a lack of uncertainty regarding what students should do; the tasks provide students with clear instructions. In addition, students do not attend to scientific ideas or principles because the scripted activities lead students to the correct answer instead of science sensemaking. As a result, tasks in both of these levels deliver minimal opportunities

for students to participate in thinking and sensemaking in regard to science content and/or practices.

High cognitive demanding instructional tasks were also divided into two main groups: Level 3 includes tasks that encompass guidance for understanding, and level 4 involves ‘‘doing science’’ tasks. Thus, tasks in these upper two levels offer great opportunities for scientific reasoning. The first category of high-level tasks includes guidance for understanding (level 3) since they demand significant cognitive effort; however, these tasks usually offer proposed pathways but require students to understand what they are doing and why as well. In addition, the second group includes doing science tasks (level 4) that are the most open or unstructured, encouraging students to use a significant amount of cognitive effort. This way, students are able to increasingly and effectively enhance their understanding of a natural phenomenon by making use of appropriate content and engaging in scientific practices.

To address the second part of my first research question, then, I determined additional ways that PSTs' edTPA lessons supported or constrained students' engagement in scientific sensemaking. In order to better understand the cognitive demand of PSTs' lessons as described in the second dimension of the TAGS framework, I examined the degree of intellectual demand of instructional tasks PSTs implemented in their classrooms. I identified differences in the cognitive demand of lessons by the ways in which opportunities were or were not available to students to participate in science and engineering practices. In fact, these opportunities were dictated by the type of questions and instructional tasks implemented by the PSTs. Some PSTs offered students numerous challenging opportunities

that promoted students' high intellectual thinking and effective engagement in those practices while others did not.

To elaborate, in order to address the second part of my first research question so to better understand the cognitive demand of PSTs' lessons as described in the second dimension of the TAGS framework, I first investigated the instructional tasks of the participants in terms of how successfully they implemented the *NGSS* science and engineering practices by engaging their students in cognitively demanding work. Once again, I organized my discussion of the successful implementation of cognitively demanding tasks based on their respective total edTPA scores and on whether or not they had ELs in the classroom (see again in Table 5.1). An important finding in this study was the fact that the science preservice teachers' adoption of cognitively demanding work during instructional tasks was associated with how well the participants performed on the edTPA, indicated by their total scores. This pattern held whether or not PSTs had ELs in their classroom. The participants who ranked in the top-five edTPA scores category in each group (PSTs with ELs and PSTs without ELs) were placed in the Q.I of the TAGS framework, which indicates that they were able to engage their students in deep cognitive reasoning and scientific thinking. The participants who ranked in the bottom-five edTPA scores category in each group (PSTs with ELs and PSTs without ELs) were placed in the Q.III of the TAGS framework.

As introduced above, I found that 10 of my PST participants (see again in Tables 5.2a and 5.2b) implemented lesson series that fell within Quadrant I of the TAGS framework. As such, those 10 participants supported students' engagement in intense scientific sensemaking while implementing high intellectual level tasks. These PSTs were able to employ instructional tasks that encouraged open inquiry/doing science and/or guided instruction

levels during most of their lesson series. As a result, these high intellectual activities offered great opportunities for students to participate in cognitive reasoning and deep scientific thinking.

In one example, Miles, performed very well on the edTPA (total score of 59 and ranked top 5 in his group, PSTs with ELs) and had two multilingual learners in his classroom. Miles, who was a chemistry teacher, worked with his students on predicting outcomes of chemical reactions, classifying reactions as having either physical or chemical changes. His lesson series was intended to help students identify the name and state of matter of each compound in a given chemical reaction, explain what will happen in a chemical reaction when given a chemical equation, determine what information is and is not given by a chemical equation, and effectively define physical change and chemical change. During his lesson series, he engaged his students in science inquiry and used an *NGSS* performance expectation related to chemical reactions (HS-PS1-2): Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. Moreover, students were expected to use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction (HS-PS1-7).

As previously mentioned, Miles was placed in Q.1 because he was able to successfully implement high cognitively demanding work through open inquiry and/or guided instructional tasks. More specifically, in Miles's edTPA lesson series, he was able to engage his students in scientific sensemaking through the implementation of several SEPs such as *develop and use models, plan and carry out investigations, analyze and interpret data, use mathematical and computational thinking, construct explanations and design*

*solutions, engage in argument from evidence,* and *obtain, evaluate, and communicate information* (as seen again in Table 5.2a). As an example, students were able to consider how the fact that atoms are conserved, together with the knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. In order to successfully integrate the science content with *NGSS* science and engineering practices, Miles encouraged students to engage in the following SEPs: *develop and use models, construct explanations and design solutions,* and *engage in argument from evidence.* Moreover, in order to complement and enhance the high level of intellectual demand of the task, Miles consistently introduced guided and open-inquiry activities that allowed opportunities for students to experience scientific reasoning and use a substantial amount of cognitive effort.

The instance below best summarizes Miles' implementation of high cognitively demanding work (levels 3 and 4) during an instructional task where students were encouraged to predict the outcome of a chemical reaction when given a chemical equation. In this specific scenario, Miles introduced a guided task while engaging students in reform-based instruction through the implementation of several SEPs, including *developing and using models,* a*nalyzing and interpreting data, constructing explanations and designing solutions,* and *engaging in argument from evidence*:

> *Students then will look at the equation for a reaction they haven't observed and will predict what they would observe, explain why, cite a specific reaction from the lab, and reference at least 1 pattern that we analyzed earlier. Students will work in groups to brainstorm ideas and will be randomly selected for sharing. I will post a different chemical equation on the board for a reaction that we did not examine in the*

*experiment. Individually, students will write explanations about what will happen in the unknown reaction, incorporating the data and patterns we just discussed.* [Miles, Lesson Plan, University D, PST with EL]

On the other end, the 10 PST participants who ranked in the bottom five edTPA scores in each group (PSTs with ELs and PSTs without ELs) were placed in the Q.III of the TAGS framework, because they were unable to successfully implement intellectually demand tasks. These PSTs presented memorization and scripted tasks, making it difficult for students to attend to scientific ideas or principles and minimizing their engagement in science sensemaking.

In one example, Leah did not perform well on the edTPA (total score of 43 and bottom top 5 in her group, PSTs without ELs) and had no multilingual learners in her classroom (see again in Table 5.1). Leah, who was a middle school physical science teacher, worked with her students on developing models to describe the atomic composition of simple molecules and extended structure (e.g., diamond). Leah's lesson series was intended to help students identify the different families of the periodic table, analyze the properties of elements associated with each family of the periodic table, and recognize and examine the relationship between the number of valence electrons of an element and the number of chemical bonds that element can form. During her lesson series, she attempted to involve her students in science inquiry and used an *NGSS* performance expectation related to structural models in chemistry (MS-PS1-1): Develop models to describe the atomic composition of simple molecules and extended structures. Additionally, students were expected to develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. (MS-PS1-5).

As stated earlier, Leah was placed in Q.III since she was not able to effectively implement high cognitively demanding work through open inquiry and/or guided instructional tasks. More precisely, in Leah's edTPA lesson series, she was able to engage her students in limited scientific sensemaking through the implementation of only one SEP: *develop and use models* (as seen in Table 5.2d). For instance, students were not able to conceptually create models to describe the atomic composition of simple molecules and extended structures in an effective manner. Therefore, while attempting to successfully integrate the science content with *NGSS* science and engineering practices, Leah failed to a certain extent to connect the idea of understanding the atomic composition of molecules and structures to the practice of *developing and using models* supported by the vision of the current reform-based instruction. Moreover, regarding the second dimension of the TAGS framework, Leah could not manage to consistently implement intellectually demanding tasks. As a result, Leah mainly introduced scripted and/or memorization tasks that did not allow or greatly minimized the opportunities for students to experience scientific reasoning and use a significant amount of cognitive effort.

The instance below best summarizes Leah's implementation of low cognitively demanding work (levels 1 and 2) during an instructional task where students were expected to develop models to describe the atomic composition of simple molecules that vary in complexity. In this particular situation, Leah introduced a scripted task while attempting to engage students in reform-based instruction through the implementation of a single SEP, such as *developing and using models*:

> *After reviewing the periodic table, students will complete the "Families of the Periodic Table" worksheet. The worksheet is to be given prior to the lecture so that*

*students may explore the properties of each family using the textbook on their own. The teacher will review the directions for how to complete the worksheet with the students. Students will work together in their pre-assigned groups to find the answers to the worksheet. Students will use their textbooks to complete the worksheet. The page number where the answers for each family can be found is provided on the worksheet; this will be explained to them while reviewing the directions.* [Leah, Lesson Plan, University R, PST without EL]

In summary, according to the results described in this chapter, I attempted to determine further ways the science lessons implemented by PSTs supported or constrained students' engagement in scientific sensemaking. This way, I was able to better understand the cognitive demand of PSTs' lessons as described in the second dimension of the TAGS framework by examining PSTs' degree of intellectual/cognitive demand of instructional tasks in the classroom. As a result, I identified differences in the cognitive demand of lessons by the ways in which opportunities were or were not afforded students to participate in the *NGSS* engineering and science practices, as well as by examining the types of questions/instructional tasks implemented by the PSTs. Overall, I found that the participants were able to implement two types of instructional tasks in their lesson series consisting of a wide range of cognitive demand levels: levels 4 and 3 open inquiry/doing science and guided instruction tasks, which offered great opportunities for students to participate in cognitive reasoning and deep scientific thinking; and levels 1 and 2 memorization and scripted tasks, which greatly reduced the opportunities for students to experience authentic scientific reasoning.

Based on these findings regarding the implementation of cognitively demanding tasks in the lesson series, it is evident that the participants' placement is the TAGS quadrants resonates with their total edTPA scores. Those PSTs with a high edTPA score (i.e., top 5 in each group ranging from 50 to 67) were placed in Q.I due to their high-level tasks (i.e., open inquiry or guided) implemented and effective application of several *NGSS* practices in the science classroom. In contrast, I found that those PSTs with a low edTPA score (i.e., bottom 5 in each group ranging from 37 to 43) could be placed in Q.III given their low-level tasks (i.e., scripted or memorization) implemented and appropriate use of very few *NGSS* practices in the science classroom. It was also clear that the inclusion or not of ELs in the classroom did not affect the placement of participants within the TAGS quadrants. To elaborate, I determined that having English learners in the classroom did not affect the PSTs' placement in Q.I or Q.III since PSTs with the bottom 5 edTPA scores (PSTs with and those without ELs) were placed in Q.III whereas PSTs with the top 5 edTPA scores (PSTs with and those without ELs) were placed in QI. In addition, for those PSTs who had ELs in their classrooms, there was no pattern between number of ELs and placement in the TAGS quadrants.

**Summary of Findings**

In general, the TAGS framework considers both the integration and the cognitive demand dimensions to think deeply about the different opportunities PSTs offer to students to engage in science sensemaking in the classrooms. The framework provides a way to determine cognitive demand and incorporate cognitive demand with the current focus on the integration of practices and content. The recent *NGSS* emphasize engaging students in scientific practices and the integration of core science ideas with scientific practices while teaching science (Berland & Reiser, 2011; Evagorou & Osborne, 2013). Within this context,

students should learn disciplinary core ideas within the context of scientific practices because ‘‘learning science and engineering involves the integration of the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering’’ (NRC, 2012, p. 11). Even though the *NGSS*’s emphasis on the integration of content with scientific practices might suggest that all tasks that encourage students to participate in scientific practices within the context of scientific content are of high quality, that is not always accurate. According to the TAGS framework’s Q.IV, tasks could include both science content and scientific practices but at a very low level of cognitive demand. For instance, most science labs and hands-on science activities generally encourage students to follow an established set of actions and steps within the context of specific science content but without encouraging students to understand the disciplinary core ideas and concepts.

To answer my first research question, I placed each PST’s lesson series in one of the four quadrants of my TAGS framework. I found that 10 PSTs’ lessons were placed in Quadrant I: These lessons both integrated science content (i.e., disciplinary core ideas and/or cross-cutting concepts) and practices, and engaged students in cognitively demanding tasks in order to promote students’ scientific sensemaking. As a result, these 10 PSTs successfully attempted to engage their students in practices to make sense of content and recognize how the scientific body of knowledge is developed. While doing so, PSTs typically implemented types of instructional tasks that promote the integration of content and practices, as well as a high cognitive demand. I also found that 10 PSTs’ lessons were placed in Quadrant III: These lessons neither integrated science content (i.e., disciplinary core ideas and/or cross-cutting concepts) and practices, nor engaged students in cognitively demanding tasks in order to

promote students' scientific sensemaking. PSTs placement in Q.I or Q.III resonated with their total edTPA scores; their quadrant placement did not align with whether or not they had ELs in their classroom.

As a transition to the next chapter on my second research question, it is helpful to elaborate on level 4 and 3 instructional tasks. Level 4, or high-level, instructional tasks are defined as "doing science" tasks, which encourage students to behave like a scientist. During these tasks, students are expected to use several scientific practices in order to promote and enhance their understanding of a scientific idea while they investigate a natural phenomenon or work on an authentic problem (i.e., solving a current engineering problem). As part of an authentic scientific discourse, these tasks enable students to work as a group in order to make sense of a scientific idea. In this scenario, PSTs have limited interference in terms of support for learning as students attempt to construct an explanation of a natural phenomenon for a question that they themselves asked. However, previous research highlights the issues that students normally come across while engaging in "doing science" tasks. In reality, students usually perceive them as being ambiguous since it is frequently not obvious what to do in these tasks and how to do it (Doyle, 1983; Stein et al., 1996). When facing those barriers, students regularly convince teachers to create a more explicit task and thus, to minimize the intellectual demand of the task.

The second type of high-level instructional tasks, or level 3 tasks, is defined as guided integration, where PSTs' guidance for working with practices is linked to a specific content. Students are encouraged to engage in high-level thinking through scaffolding provided by the PSTs (or a more expert peer) or by support prompts found within the given task itself. In most science classrooms, since the cognitive demand that is necessary for students to engage

in “doing science” tasks is extremely high, students frequently require more guidance in order to engage in activities. In fact, educators suggest the implementation of guidance and instructional scaffolds in order for PSTs to effectively teach inquiry in science classroom (Moog & Spencer, 2008; Schwarz & Gwekwerere, 2007). As a result, it is expected that most science teachers, including PSTs, would choose to implement guided integration tasks over “doing science” tasks in their classrooms due to their guided nature – since instructional scaffolding can minimize the risk of ‘‘losing some students’’ who perceive these tasks to be very difficult. This last point is discussed in the next chapter when I address my second research question and analyze the findings in order to explore different ways in which PSTs effectively supported the academic language demands of their students, particularly ELs. More specifically, in the next chapter, I present findings of PSTs’ support in terms of enabling students to access and use the academic language in the science classroom beyond the TAGS framework.

## Chapter VI: Research Findings Set 2

As discussed previously, English learners (ELs) represent a substantial number of the students currently attending K-12 schools in the U.S. (National Center for Education Statistics, 2016). In the past 10 years, the number of English Learners (ELs) or multilingual learners in the United States has grown significantly. As a result, almost all states in the country have seen a recent increase in the number of ELs attending K-12 schools (NRC, 2012). This study encourages teachers to plan their science content and language instruction around a comprehensive EL framework rather than simply adopting a list of disconnected instructional practices (Heineke et al., 2019; Lyon et al., 2018; MacDonald, Miller, & Lord, 2017). Given the central role of discourse in the current *NGSS* framework, I attempt to

examine how preservice secondary science teachers supported the language demands of tasks (at the lexical, syntactic, and discursive levels) implemented as part of their edTPA lesson series. Therefore, I continued my investigation of 20 preservice secondary science teachers by examining their understanding of academic language and the effective types of instructional supports they implemented to scaffold ELs' academic language use during cognitively demanding tasks in their secondary science classrooms.

## Finding Set 2.1: Preservice Teachers Participants' Use of Academic Language Supports by Quadrants

As indicated at the end of my previous chapter, current educators recommend the implementation of guidance and instructional scaffolds in order for PSTs to successfully teach inquiry in science education (Moog & Spencer, 2008; Schwarz & Gwekwerere, 2007). In this chapter, I discuss my second research question and analyze the findings in order to explore different ways in which PSTs effectively support the academic language demands of their students, particularly ELs. Precisely, I investigate PSTs' support in terms of enabling students to access and use the academic language in the science classroom according to the TAGS framework.

To answer the second set of research questions, I examined the types of support preservice teacher participants reported using to help their students, including ELs, meet the academic language demands of their lessons. More specifically, I investigated the types of support they most frequently used at the lexical, syntactic, and discursive levels during their edTPA lesson cycle. As addressed in my Finding Set 1 chapter, I placed each PST's lesson series in one of the four quadrants of the TAGS framework. I found that 10 PSTs' lessons were placed in Quadrant I (Q.I): These lessons both integrated science content (disciplinary

core ideas and/or crosscutting concepts) and practices; and engaged students in cognitively demanding tasks in order to promote students' scientific sensemaking. On the other hand, I found that 10 PSTs' lessons could be thought of as isolated in science content and practices and low in cognitive demand: They were placed in Quadrant III (Q.III) of the TAGS framework (see again Table 5.1). In this chapter, I organized the findings both according to the TAGS quadrants in which the PSTs were placed and in terms of the presence (or not) of ELs in their classroom instruction.

**Use of Academic Language Supports by PSTs in Q.I**

I begin by presenting findings related to the 10 participants who were placed in Q.I according to the TAGS framework. It is important to highlight that half of these PSTs had ELs in their classroom instruction. I found that these 10 preservice teacher participants described using a wide range of instructional supports to scaffold students' academic language use. Nevertheless, the number of common types of support they implemented changed considerably by language level: from eight (for teachers who taught ELs) and seven (for teachers who taught non-ELs) at the lexical level, to four (both groups) at the syntactic level, to 13 (for teachers who taught ELs) and 12 (for teachers who taught non-ELs) at the discursive level (see Table 6.1). It is important to mention that I defined an instructional support as common for a specific language level if at least six different preservice teachers (majority of ten) mentioned a support within a given quadrant and at least three different preservice teachers (majority of five) mentioned a support for the intra-quadrant EL/non-EL groups in one or more instances during the edTPA lesson series (i.e., lesson plan and/or instruction commentary).

Table 6.1

*Comparison of Preservice Teachers' Common Support Strategies Used in edTPA Portfolios (Lesson*

*Plans and Commentaries) Within TAGS Quadrant I Placement for Those With and Without ELs*

| | Lexical Level | | Syntactic Level | | Discursive Level | |
|---|---|---|---|---|---|---|
| | **PSTs With ELs** | **PSTs Without ELs** | **PSTs With ELs** | **PSTs With out ELs** | **PSTs With ELs** | **PSTs Without ELs** |
| Chunking | | | | | ● | ● |
| Differentiation | | | | | ● | ● |
| Facilitating discussions | ● | ● | ● | ● | ● | ● |
| Guided notes | ● | | | | ● | ● |
| Hands-on activity | ● | ● | | | ● | ● |
| Home language | | | | | ● | ● |
| Individual instruction | | | | | ● | ● |
| Modeling | ● | ● | ● | ● | ● | ● |
| Peer collaboration | ● | ● | | | ● | ● |
| Providing clear directions | | | | | ● | |
| Sentence frames | | | ● | ● | ● | ● |
| Structured reading | | | | | ● | ● |
| Visuals and realia | ● | ● | ● | ● | ● | ● |
| Word learning strategies | ● | ● | | | | |
| Word walls | ● | ● | | | | |

*Note*: A ● indicates a type of support discussed or used by a majority of preservice teacher participants (3 or more).

As stated before, at the lexical level, preservice teacher participants who had ELs discussed implementing eight types of instructional support to help EL students learn and use academic language and those who did not have ELs, seven types. Moreover, those supports for vocabulary development were grouped into three of the five categories discussed in my Theoretical Framework described above: (1) providing a meaningful context for language use, (2) attending to language comprehension, and (3) providing opportunities for language production. More specifically, in the category of providing a meaningful context for language

use, a total of seven PSTs, consisting of four for those who taught ELs and three for those who did not teach ELs, discussed the importance of engaging students in a *hands-on activity* before presenting formal scientific terms. Then, whenever the new terms discussed, students were able to resort to their actual experiences and conceptual knowledge to understand and appropriately use them. For example, Zander discussed engaging his physics students in an initial investigation to complete an engineering challenge in which they will design, test, and refine a bumper/crumple zone that reduces the impact force during a collision event:

> *We did a lab with I circulate between student groups as they create and evaluate their bumper designs using pipe cleaners during the process. I started by asking a basic question, "How many pipe cleaners is this?". Where they said, "Oh, the bumper design thing." And then once we completed the notes, they're like, "Oh, that was like the design part that we, that was used to provide more resistance in our prototype. We used four pipe cleaners in our design."* [Zander, Instruction Commentary, University B, PST without EL]

Also, at the lexical level, PSTs indicated using instructional supports, such as *word learning strategies, visuals and realia*, and *guided notes,* to establish comprehensible input. Within this category, nine PSTs, including five for those with ELs and four for those without ELs, stated they used *word learning strategies*. For example, Jasmine discussed the importance of teaching students to interpret the meaning of new words using their knowledge of root words and home language cognates (Lesson Plan, University D, PST without EL), while Priscila stated clearly defining key vocabulary terms (Lesson Plan, University R, PST without EL). In addition, eight PSTs, five with ELs and three without ELs, reported they provided *visuals and realia* in one of two ways: using pictures or physical objects to

demonstrate the meaning of unfamiliar words and/or encouraging students to make drawings to enhance their understanding of newly adopted vocabulary. In addition, a total of six PSTs, comprised of four with ELs and two without ELs, provided students with structured *guided notes* as a way to record new vocabulary and take notes.

Further, PSTs discussed using four types of instructional support at the lexical level that belonged to the third category of facilitating language production: *facilitating discussions*, *peer collaboration*, *modeling*, and *word walls*. Accordingly, nine participants, consisting of five with ELs and four without ELs, described *facilitating discussions* to define the meaning of new words. Moreover, all 10 PSTs reported that they used *peer collaboration* to provide students with various opportunities to apply new vocabulary in context. For example, Miles described regularly providing students low-stakes opportunities to practice new language:

> *It's like pair sharing or doing warm-ups where you provide the language for them and say, "Hey, in your warm-up, can you describe what we learned yesterday? Here are some words that you should include." So it's there for them to access and to use, but if they do it wrong or they forget what it is, they can just go back and look it up. It's low risk. It's not a big deal. So it gives them a chance to practice without further nervousness.* [Miles, Instruction Commentary, University D, PST with EL]

Furthermore, seven PSTs, including four with ELs and three without, specified *modeling* the use of academic vocabulary by purposely including academic terms in their own dialogue. Finally, eight participants, involving five with ELs and three without, presented *word walls* in a way that students could cite key terminology while engaging in talking or writing throughout the lesson.

On the contrary, at the syntactic level, most PSTs reported four types of instructional support that fell into two categories: (1) ensuring comprehensible input and (2) facilitating language production. In fact, eight PSTs, five with ELs and three without, described using *visuals and realia* to support both language comprehension and production. In regard to comprehensible input, participants also mentioned using drawings or illustrations to help students unpack the significance of complex sentences. Regarding language output, PSTs stated they provided students with opportunities to start or enhance sentences with drawings. For example, Mickey clarified that students could include both a picture and words to formulate their hypothesis before beginning an investigation:

> *Instead of having them just only write out the hypotheses, they could also draw a picture to describe the model explaining the phenomenon. Because maybe a few might have a better idea or sense of it, but not be able to explain it well in words. So starting with an image first.* [Mickey, Instruction Commentary, University C, PST with EL]

Moreover, PSTs noted three additional strategies in which they promoted students' production of language at the syntactic level. All 10 candidates noted using *sentence frames* to assist students in articulating oral or written tasks. For example, Eliza explained how she would support students in writing a hypothesis using differentiated sentence frames:

> *I would give them a sentence frame. And a sentence frame can be modified to differentiate for the spectrum of English language learners and from English language learners to native speakers. And you can give them a variety of sentence frames to help them write a hypothesis, kind of looking like, "Given X evidence, this is the behavior."* [Eliza, Instruction Commentary, University B, PST with EL]

Eight of the 10 PSTs, including five with ELs and three without, specified that they also used *modeling* to support students' creation of specific scientific and mathematical representations, such as graphs, tables, and equations. For example, Leo described modeling how to set up and solve an equation (Lesson Plan, University B, PST without EL) and Mickey reported demonstrating how to graph results (Lesson Plan, University C, PST with EL). Finally, nine PSTs, comprising five with ELs and four without ELs, reported *facilitating discussions* in small groups or whole class settings by encouraging students to write hypotheses and develop claims in complete sentences and unpack the significance of complex sentences.

As mentioned before, the number of common types of support implemented to scaffold oral and written discourse was considerably greater than the other two previous levels: lexical or syntactic. In total, PSTs implemented 13 common types of support at the discursive level covering all five categories: (1) providing a meaningful context, (2) ensuring comprehensible input, (3) facilitating students' production of spoken and written discourse, (4) using students' home languages and linguistic practices, and (5) more general strategies. In fact, nine participants, consisting of five with ELs and four without ELs, reported *implementing a hands-on activity* in a way to deliver a relevant context for language use at the discursive level. As an example, Rachel indicated engaging her students in a physical simulation so they could experience how changing (increasing) the wolf population would affect the elk population in the Yellowstone National Park ecosystem (Lesson Plan, University D, PST with EL).

All 10 PSTs described using at least one type of support that would help promote comprehensible input at the discursive level. All participants reported that they used some

form of *structured reading*, including collaborative reading, jigsaw reading groups, or a method for scientifically annotating texts. For example, Kim indicated using strategic reading methods to highlight the significance of key terms in the text during classroom discussions:

> *To address these misunderstandings, I would spend time highlighting the definition of the terms and their proper usage after the reading on lesson day two or just prior to the manipulative activity on featured in video 2. For example, rather than just having students organize them into the different categories in the text mining table on their reading guide, I would also have students provide their own definitions for the terms to reinforce the meanings of the terms and the context in which they should be used.* [Kim, Instruction Commentary, University D, PST without EL]

Moreover, all 10 PSTs also stated that they used *visuals and realia* to effectively encourage written or oral discourse. Additionally, six participants, including four with ELs and four without ELs, noted the significance of *providing clear directions* by certifying that the language they used was clear and concise. For example, Sophie indicated how she would support students during scientific inquiry activities by asking a series of clarifying questions:

> *When students ask questions [during an activity], I gauge where their understandings are by asking follow-up questions until we reach a question that is hard for them to answer. In this case, students were asking about the instructions for a station that they were having trouble understanding and had been at since the start of the clip. One student says she does not understand anything, and the next student says that instructions say decrease the temperature in the question, but the instructions say increase the temperature. I walk through the instructions with the students and pause*

> *to ask questions about the instructions in order for the group to be able to understand them.* [Sophie, Instruction Commentary, University B, PST with EL]

Lastly, six PSTs, three with ELs and three without ELs, provided students with a structured format for *guided notes* – for recording new vocabulary, taking notes, and answering questions – in order to facilitate their participation in classroom discussions. For example, Rachel reported using guided notes in order to encourage students to specifically document important data (in a structured format) shared by their peers during classroom discussion:

> *Students who are not at the discussion table are still engaged in the discussion because they have been instructed to take notes on a sheet of binder paper that includes the statement/question and at least 3 bullet points that their peers have shared during the discussion of that statement/question - so you should have 3 bullet points at least for that last statement.* [Rachel, Instruction Commentary, University D, PST with EL]

Next, all participants also discussed using multiple types of support to assist students in producing oral or written discourse. All 10 PSTs implemented *facilitating discussions*; included some type of *peer collaboration*, such as think-pair-share and small group investigations and/or presentations; and provided *sentence frames* in order to scaffold students' participations in classroom discussions, oral presentations, and written tasks. In addition, eight PSTs, including five with the ELs and three without ELs, introduced *modeling* discourse for their students, mostly for larger, more formal tasks.

Furthermore, seven PSTs, including four with ELs and three without ELs, described supporting discourse by incorporating students' *home languages* and recognizing their

linguistic practices. Even though these three PSTs did not have any ELs in their classroom, they actually mentioned the effectiveness of introducing students' home languages as an instructional extension to a hypothetical scenario where they would have ELs. In fact, most of those participants with multilingual students offered learning materials in students' home language (Sophie, Lesson Plan, University B, PST with EL) or promoted the use of technology devices in order for students to translate documents themselves (Mickey, Lesson Plan, University C, PST with EL). Moreover, most actually reported deliberately grouping students who were in the beginning stages of learning English with more advanced English speakers or bilingual students. For example, Eliza discussed how she reorganized small groups in a way that her beginning English speakers would be able to both talk with each other in Spanish and interact with more fluent English learners:

> *I spread out the three ELs to different table groups. While they were still next to each other so they could still look over their shoulders and ask questions and such, they were with students who speak other languages in their small groups – ELs as well as a couple native English speakers.* [Eliza, Instruction Commentary, University B, PST with EL]

Lastly, most participants reported using three additional general strategies to support EL learning at the discursive level. More specifically, eight PSTs, consisting of four with ELs and four without ELs, mentioned *differentiation* in order to provide different tasks or learning options for students with different needs. For example, Rachel implemented intellectually demanding work as well as offered extra challenging questions to more capable students to promote a deeper conceptual understanding of the material:

> *By defining these roles with this particular student and other high-achieving students before class, I will ensure that these students collaborate with their peers throughout the class period rather than working individually. I will challenge these more capable peers by providing students with cognitively demanding questions that are high on Bloom's Taxonomy. Students will be challenged to analyze, synthesize, and evaluate given in formation to develop or apply population growth models to solve additional questions about concepts of resources availability in an ecosystem. These questions will deepen students' understanding of fundamental concepts and also promote curiosity about how academic topics from the classroom can be applied to real-life scenarios.* [Rachel, Instruction Commentary, University D, PST with EL]

Moreover, seven participants, including four with ELs and three without ELs, discussed *individual instruction* as a way to offer targeted instruction to a specific student instead of the whole class. In addition, six PSTs, including three with ELs and three without ELs, *chunked* a task into more manageable stages. For example, Miles addressed specific needs of individual learners within a particular group of students (e.g., English learners) in order to explore their conceptual understanding of the subject by chunking the whole task into shorter, more attainable units:

> *The class includes reclassified English language learners, advanced ELs, intermediate ELs, and early beginning ELs. I am able to routinely check in with the students with lowest language proficiency but since there are many other students with varying degrees of language fluency, I have ensured that students feel comfortable asking when they need help constructing sentences or understanding any*

*portion of an assignment*. [Miles, Instruction Commentary, University D, PST with EL]

**Use of Academic Language Supports by PSTs in Q.III**

I continued my analysis by looking at the findings related to the 10 participants who were placed in Q.III according to the TAGS framework. Again, it important to highlight that half of these PSTs had ELs in their classroom instruction and half did not. Overall, I found that these 10 preservice teacher participants described a more limited range of instructional supports to scaffold students' academic language use when compared to the participants placed in Q.I. Still, as with the PSTs in Q.I, the number of common types of support PSTs in Q.III used varied substantially by language level: from three (for those PSTs with ELs) and two (for those PSTs without ELs) at the lexical level, to two (both groups) at the syntactic level, to six (for those PSTs with ELs) and four (for those PSTs without ELs) at the discursive level (see Table 6.2). As mentioned previously, I defined an instructional support as common for a specific language level if at least six different preservice teachers (majority out of 10 for the total number of participants in each quadrant) mentioned the support in one or more instances during the edTPA lesson series (lesson plan and/or instruction commentary).

Table 6.2

*Comparison of Preservice Teachers' Common Support Strategies Used in edTPA Portfolios (Lesson*

*Plans and Commentaries) Within TAGS Quadrant III Placement for Those With and Without ELs*

| | **Lexical Level** | **Syntactic Level** | **Discursive Level** |
|---|---|---|---|

| | PSTs With ELs | PSTs Without ELs | PSTs With ELs | PSTs Without ELs | PSTs With ELs | PSTs Without ELs |
|---|---|---|---|---|---|---|
| Chunking | | | | | | |
| Differentiation | | | | | | |
| Facilitating discussions | | | | | ● | ● |
| Guided notes | | | | | | |
| Hands-on activity | | | | | ● | ● |
| Home language | | | | | | |
| Individual instruction | | | | | | |
| Modeling | | | | | ● | |
| Peer collaboration | | | | | ● | ● |
| Providing clear directions | | | | | | |
| Sentence frames | | | ● | ● | ● | |
| Structured reading | | | | | | |
| Visuals and realia | ● | ● | ● | ● | ● | ● |
| Word learning strategies | ● | | | | | |
| Word walls | ● | ● | | | | |

*Note*: A ● indicates a type of support discussed or used by a majority of preservice teacher participants (3 or more).

As introduced above, a majority of preservice teacher participants in Q.III reported using three types of instructional support to help EL students learn and use academic language at the lexical level. In fact, those supports were divided into two of the five categories addressed in my Theoretical Framework described above: (1) attending to language comprehension and (2) facilitating language production. More precisely, in the category of attending to language comprehension, six PSTs, including five with ELs and one without ELs, noted the significance of providing *word learning strategies.* In addition, seven PSTs, consisting of four with ELs and three without ELs, discussed offering *visuals and realia* to students by using pictures or physical objects to help clarify the definition of unfamiliar words and/or increase students' knowledge of newly introduced terms through drawings.

In the same language level of vocabulary development, PSTs mentioned using one instructional support to encourage and facilitate language production: *word walls*. In fact, six participants, including three with ELs and three without ELs, reported presenting *word walls* in order to enable students to refer to important vocabulary terms as a way to better understand their meanings. For example, James reported providing students with authentic problems along with a list of key vocabulary terms so they could feel more comfortable using relevant vocabulary and improving their conceptual understanding:

> *This review will support all students in developing a deeper conceptual understanding of protein synthesis. Throughout the class period, students will be presented with additional real-life problems that gradually include less scaffolding and additional vocabulary terms (such as DNA, RNA, and proteins). In addition to helping students understand proteins, students will also inherently be practicing speaking and writing new vocabulary. During class, students will also be able to reference a word wall instead of being expected to memorize all new terms.* [James, Instructional Commentary, University C, PST without EL]

Similar to the lexical level, the majority of PSTs discussed implementing two types of instructional support at the syntactic level that fell into two categories: (1) ensuring comprehensible input and (2) facilitating language production. Seven PSTs, including four with ELs and three without ELs, noted using *visuals and realia* to support language comprehension. In terms of language comprehension, PSTs highlighted the importance of using drawings or illustrations to assist students in understanding the significance of complex sentences. Furthermore, participants also described implementing an additional strategy through which they encouraged students' production of language at the syntactic level. Seven

PSTs, consisting of four with ELs and three without ELs, stated they used *sentence frames* to better prepare students in communicating through oral or written work. For example, Anderson provided linguistic scaffolding for students by asking them to write one sentence for evidence to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media:

> *A student asks, "Is there a sentence frame?" and I display a helpful frame on the LCD screen so it is available for all students who may benefit from a more structured response. Students know that they are not expected to use the sentence frames and many do not. However, those who do find sentence frames helpful feel comfortable to kindly remind me to display one.* [Anderson, Instruction Commentary, University C, PST without EL]

As previously indicated, the number of common types of support employed by PSTs in Q.III to scaffold oral and written discourse was greater than the other two previous language levels discussed but relatively smaller in number when compared to the participants placed in Q.I. I found that PSTs in Q.III implemented six common types of support at the discursive level across three categories: (1) providing meaningful context, (2) ensuring comprehensible input, and (3) facilitating students' production of spoken and written discourse. Seven PSTs, including four with ELs and three without ELs, documented *introducing a hands-on activity* in order to create an effective context for language development at the discursive level. As one example, George reported introducing a long-term research project to create a holistic action plan for an endangered species, which will incorporate ecological principles as the semester progresses (Lesson Plan, University B, PST with EL).

Most PSTs in Q.III also reported implementing at least one type of support that would encourage comprehensible input at the discursive level. Eight participants, including four with ELs and four without ELs, noted that they used *visuals and realia* to successfully promote student comprehension of written or oral discourse. For example, Jackie described how she would enhance her own verbal explanations with visual references, "Not just saying it or pointing to something, but showing them physically what something means, or through demonstrations" (Jackie, Instruction Commentary, University C, PST with EL).

Further, almost all PSTs in Q.III described using several types of support in order to encourage students to produce oral or written discourse. Nine participants, including five with ELs and four without ELs, discussed *facilitating discussions*; regularly introducing discourse moves and some kind of teamwork, such as think-pair-share; and small group or whole-class inquiry activities and/or presentations. For example, Max mediated a whole class investigation by asking targeted questions regarding data collection and analysis for a lab activity the students conducted:

> *I ask students why their graphs don't look like mine. One student talks about how they could have been an error in the lab because they were the ones moving. I asked this to begin to develop students' thinking about their data collection. The student has identified an alternative explanation for their data. I follow that answer up with asking them how they collected the data to which they respond that they had someone walk forward and backward. I ask them what machine they used they respond that they used a motion sensor.* [Max, Instruction Commentary, University C, PST without EL]

Six participants, including four with ELs and four without ELs, offered *peer collaboration* with the purpose of scaffolding students' engagement in classroom dialogues, verbal displays, and written work. For example, Nadin described using peer collaboration in order for students to argue and justify their claims during a scientific inquiry activity:

> *I tell students to "talk to their families" about how willow trees affect the river. This is a procedure they are very used to, and gives students the chance to share, refine, and build on their ideas before sharing them out with the class.* [Nadin, Instruction Commentary, University C, PST with EL]

Finally, seven PSTs, including five with ELs and two without ELs, presented *modeling* discourse for their students, usually for larger formal assignments. For example, Jennifer used a combination of *chunking*, *sentence frames*, and *modeling* to describe how she helped her life science students create their first authentic piece of scientific writing – an argument on the causes of inheritance:

> *So we had pretty structured sentence frames for them. And it was kind of broken down into each paragraph, this is where the introductory paragraph or sentence goes, and we showed some examples, and then had them write their own. And then also showed them how to do correct citations, showed examples, and had them write their own. So a lot of show and now have them do.* [Jennifer, Instruction Commentary, University C, PST with EL]

## Finding Set 2.2: Preservice Teachers Participants' Use of Academic Language Supports by Presence or Absence of EL Students

### PSTS Within a Given Quadrant

In order to further address my second research question, I specifically compared the results from PSTs who had ELs and those who did not first within Q.I. and then within Q.III. For Q.I, the data show that the supports from both groups (PSTs with ELs and those without ELs) were very consistent across all three language levels (see again Table 6.1). This pattern is a good indication that the actual placement of PSTs in quadrants adequately captured the types of support offered across both groups. Said another way, these findings suggest that having ELs or not in the classroom was less important than being placed in one of the quadrants based on lesson series integration and the cognitive demand level of a task. In turn, as expected, PSTs' total edTPA scores had an important role in determining the types and/or range of instructional support provided by the participants. As mentioned above, there was little variation in terms of the types of support PSTs implemented within each of the three language levels across both groups in Q.I. Thus, even though PSTs without ELs did not have opportunities to actually teach ELs, those participants were still able to successfully scaffold their students using different strategies in order to make academic language accessible.

Still, there were a few minor differences between those PSTs in Q.1 who taught ELs and those who did not. I found that the majority of PSTs with no ELs implemented a few less supports when compared to the PSTs with ELs. More specifically, a minor variation between the two groups was noted at the lexical language level, where the PSTs with ELs used eight types of support whereas those PSTs without ELs used seven types, indicating that *guided notes* were actually not implemented by the majority of participants without ELs placed in Q.I. PSTs without ELs also did not use *providing clear directions* as a way to scaffold students' oral and written discourse when compared to PSTs who taught ELs. Indeed, PSTs with ELs implemented a total of 13 different types of support whereas the PSTs without ELs

implemented a total of 12 scaffolding strategies at the discourse level (see again Table 6.1). In addition, it is important to notice that there were no differences between the two groups were found in terms of language support at the syntax level. Therefore, both groups of participants were able to introduce the same number and types of language support: *sentence frames, facilitating discussions, modeling, and visuals*.

Similarly, in analyzing the results from PSTs' support in Q.III, the data indicate that the supports from both groups (those with ELs and those without ELs) were relatively consistent across all three language levels (see again Table 6.2). As seen in the previous analysis of Q.I, the data for Q.III show that both groups of participants (those with ELs and those without ELs) varied to a higher degree in terms of types of support for all students when compared to those PSTs from Q.I as compared to each other. Still, there was a bit more variation between PSTs within Q.III who taught ELs versus those who did not in comparison to those two groups within Q.I. A minor variation was observed at the lexical language level where those PSTs with ELs implemented three types of support while those without ELs used only two types, demonstrating that *word learning strategies* were not introduced by the majority PSTs without ELs in Q.III. Although both PSTs with ELs and those without in Q.III constantly and successfully supported their students' academic language, there was some variation seen in terms of types of support at the discourse level. In fact, the majority of participants without ELs were not able to implement as many types of language support as their counterparts with ELs. More specifically, PSTs without ELs did not use *modeling and sentence frames* to scaffold students' oral and written discourse in comparison to PSTs with ELs. In this case, at the discourse level, PSTs with ELs in Q.III introduced a total of six different types of support whereas PSTs without ELs implemented a total of four strategies.

Finally, at the syntax level, findings indicated that both groups were able to offer the same number (a total two) and types of supports: *sentence frames* and *visuals*.

Overall, within a given quadrant, these findings suggest that those participants who did not have ELs in their instruction were still able to adopt most of the same types of support across all three levels of language when compared to PSTs with ELs – given a few exceptions described above (see again Table 6.2). As a result, having ELs in the classroom did not substantially shape the way PSTs used their skills and academic language knowledge to address all their students' needs regarding language support. However, when compared to participants in Q.I, Q.III participants showed that there was a greater variation in terms of supports between both groups (PSTs with ELs and PSTs without ELs). As mentioned before, those PSTs without ELs were neither able to specifically implement *word learning strategies* at the vocabulary level nor *modeling* or as *sentence frames* at the discourse level. As a result, the actual placement of PSTs in Q.III, characterized by their relatively low total edTPA scores, lack of integration of content and practices, and the implementation of low-level cognitively demanding tasks, was reflected in their fewer scaffolds for students' academic language. In fact, as seen with Q.I participants before, quadrant placement captured PSTs' ability to make academic language accessible while implementing isolated low-level tasks.

**PSTs With ELs Vs Without ELs: Interquadrant Analysis**

As a final way to address my second research question, I investigated whether the instructional supports differed by PSTs with ELs and without ELs irrespective of their quadrant placement. In general, considering both TAGS quadrants together for analysis (PSTs with ELs in both Q.I and Q.III versus PSTs without ELs in both Q.I and Q.III), the data indicated that the different types of academic language support offered to students

differed slightly across both groups of PSTs (see Table 6.3). Overall, the variation was pretty consistent across all three language levels: lexical, syntactic, and discourse. Each level will be covered and analyzed next in this chapter.

Table 6.3

*Comparison of Preservice Teachers' Common Support Strategies Used in edTPA Portfolios (Lesson Plans and Commentaries) for PSTs With ELs and PSTs Without ELs*

| | **Lexical Level** | | **Syntactic Level** | | **Discursive Level** | |
|---|---|---|---|---|---|---|
| | **PSTs With ELs** | **PSTs Without ELs** | **PSTs With ELs** | **PSTs Without ELs** | **PSTs With ELs** | **PSTs Without ELs** |
| Chunking | | | | | | |
| Differentiation | | | | | ● | |
| Facilitating discussions | ● | ● | ● | ● | ● | ● |
| Guided notes | | | | | | |
| Hands-on activity | | | | | ● | ● |
| Home language | | | | | ● | |
| Individual instruction | | | | | | |
| Modeling | ● | | ● | | ● | |
| Peer collaboration | ● | ● | | | ● | ● |
| Providing clear directions | | | | | | |
| Sentence frames | | | ● | ● | ● | ● |
| Structured reading | | | | | ● | ● |
| Visuals and realia | ● | ● | ● | ● | ● | ● |
| Word learning strategies | ● | ● | | | | |
| Word walls | ● | ● | | | | |

*Note*: A ● indicates a type of support discussed or used by a majority of preservice teacher participants (6 or more).

In order to examine the different types of instructional supports between these two groups of participants, I began with the lexical language level of analysis. The findings suggest that there was a slight variation across the two groups: The majority of PST

participants with ELs implemented a total of six types of supports to scaffold their students' vocabulary use: *facilitating discussions, modeling, peer collaboration, visuals and realia,* and *word learning strategies*. Moreover, these six types of support attempted to address students' language production and comprehension. On the contrary, the data showed that the PSTs without ELs used a total of five types of support, falling into the same two categories described previously: *facilitating discussions, modeling, peer collaboration, visuals and realia,* and *word learning strategies*. Therefore, the main difference between these two groups was that the majority of PSTs (six or more) from both quadrants (Q.I and Q.III) who had no ELs did not include *modeling* at the lexical level as a way to support academic language demands of their students.

Next, in order to continue the analysis across both groups (PSTs with ELs and PSTs without ELs), I examined the findings at the syntax language level. Once again, the data showed that a small variation between groups. The majority of participants with ELs implemented a total of four types of support to scaffold their students' academic language syntax: *facilitating discussions, modeling, sentence frames,* and *visuals and realia*. In addition, those four types of support fell into the same two categories as the ones at the lexical level (see again Table 6.3). In contrast, PSTs without ELs used a total of three types of support within the same two categories: *facilitating discussions, sentence frames,* and *visuals and realia*. As a result, the key difference between these two groups was that the majority of PSTs (six or more) from both quadrants (Q.I and Q.III) with no ELs in the classroom did not offer modeling at the syntax level as a way to support academic language demands of their students. In fact, when comparing both groups, this similar pattern was identified at the lexical level of academic language support.

Continuing with my analysis of the types of academic language support implemented across both groups, I investigated the range of scaffolding strategies at the discourse level. Overall, the data indicated that the difference in terms of academic language support between the two groups was more substantial at the discourse level, suggesting there was a greater variation across groups (PSTs with ELs and those without ELs). The majority of participants with ELs used a total of nine types of support to scaffold their students' academic oral and written discourse: *differentiation, facilitating discussions, hands-on activity, home language, modeling, peer collaboration, sentence frames, visuals/realia,* and *structure reading*. Moreover, those nine types of support were grouped into five categories (see again Table 6.3). On the other hand, PSTs without ELs implemented a total of six types of support falling into three categories: *facilitating discussions, hands-on activity, peer collaboration, sentence frames, structured reading,* and *visuals and realia*. Therefore, the main difference between these two groups rested upon the fact that the majority of PSTs (six or more) from both quadrants (Q.I and Q.III) without ELs did not include *differentiation, home language,* or *modeling* as types of academic language support during classroom discourse.

In sum, the findings indicate that the majority of PSTs from both quadrants without ELs implemented fewer supports than the PSTs with ELs across all three language levels, particularly at the discourse level. Still, when considering participants in Q.I and Q.III across both groups (PSTs with EL and PSTs without ELs), the number of common types of support employed to scaffold oral and written discourse was greater than the other two previous language levels discussed (i.e., lexical and syntax). Finally, the fact that all PSTs included the largest number of supports at the discourse level is important given the centrality of discourse

in current reform-based instruction and the *NGSS* framework, as explained in the previous chapters.

# Chapter VII: Discussion

## Summary of Findings

As stated in the Introduction, English learners (ELs) account for more than nine percent of the students currently enrolled in K-12 classrooms in the U.S. (National Center for Education Statistics, 2016). The current science education reform movement in the U.S. emphasizes the importance of providing opportunities for equitable science learning for all students, including ELs (NRC, 2012). Indeed, it is important to highlight that the *NGSS* encourages teachers to engage their students in advanced and varied language use to promote reasoning and sense-making in science and engineering (NGSS Lead States, 2013). In short, teachers working with ELs are expected to teach the core content, science and engineering practices, and language essential to communicate their discipline as specified in the *NGSS* (Bunch, 2013; Quinn et al., 2012).

As a result, teacher education programs need to better instruct preservice science teachers to teach for a diverse student population in U.S. classrooms (National Academy of Sciences, 2011). Teacher education programs are beginning to focus more intently on preparing their preservice science teachers to effectively teach ELs. Science preservice teachers must learn how to move beyond general strategies to implement disciplinary-specific principles and practices (Lyon, Tolbert, Stoddart, Solis, & Bunch, 2016) aligned with the *NGSS* (NGSS Lead States, 2013). These PSTs must also understand how to include the diverse cultures, languages, and experiences of ELs as resources for content-specific learning.

Previous studies of efforts to prepare preservice secondary science teachers to effectively teach ELs have highlighted the importance of integrating disciplinary language and literacy practices into preservice coursework and experiences (Heineke et al., 2019; Lyon et al., 2016, 2018). In addition, previous studies reinforce the need to integrate science content with *NGSS* practices, as well as implement cognitively demanding tasks in the classroom (Tekkumuru, 2015). As such, this present study builds on the current literature by qualitatively analyzing two cohorts of preservice science teachers' understanding of academic language demands and appropriate supports for ELs in science while implementing reform-based instruction aligned to the *NGSS* framework.

In order to prepare preservice secondary science teachers to teach ELs, teacher education programs must provide appropriate coursework and experiences in principles and strategies that are effective in supporting ELs' learning of science. As indicated previously, all four TEPs included in this study were located in California, a state where 22% of public-school students are designated as ELs (California Department of Education, 2014). The TEPs were similar in that they included (a) science methods courses that focused on reform-based science instruction, (b) courses that specifically addressed teaching linguistically and culturally diverse students, and (c) intensive classroom-based practicum experiences. Moreover, these four TEPs' post-baccalaureate credential programs were relatively small and followed a cohort model.

In this study, I investigated a defined area of science teacher education: preservice secondary science teachers' understanding of academic language and of ways to support ELs in both the content and language of science during instruction – while providing opportunities to integrate challenging science content and practices. As a result, I examined

the lesson series of 20 preservice science teachers from four universities by qualitatively analyzing their edTPA portfolios (lesson plans and instruction commentaries, specifically). I initially analyzed and coded the written commentaries (instructional) and lesson plans using five cycles of analysis: (1) five a priori codes constructed from the principles on effective teaching of ELs, (2) the level of academic language/linguistic demand and types of instructional support preservice teachers implemented, (3) each of the eight *NGSS* science and engineering practices, (4) the integration or isolation of science content and practices and the level of cognitive demand of instructional tasks, and (5) the placement of each participant within one of the TAGS quadrants to further address my research questions.

To address the first part of my first research question, I investigated the instructional tasks of the PSTs in terms of how successfully they integrated their edTPA lessons (content and practices), also considering if the integration differ between those preservice teachers who taught ELs and those who did not teach ELs. Thus, I was able to better understand the degree of integration/isolation of PSTs' lessons in terms of disciplinary content and *t* science and engineering practices. As a result, I found that 10 of the PST participants could be placed in Q.I since they were able to integrate science content (particularly core ideas and/or crosscutting concepts) and SEPs while engaging their students in cognitively demanding work to promote students' scientific reasoning. On the other hand, I also found that the other 10 PST participants could be placed in Q.III since they were not able to completely integrate science content and SEPs while engaging their students in low-level intellectual work that limited the development of students' scientific reasoning.

One of the major findings was that the PSTs' instructional task integration and appropriate placement in the TAGS quadrants were highly dependent on how successful they

were during their performance assessment, as specified by their total edTPA scores and high-quality instruction. In fact, the participants who scored high on the edTPA (i.e., those ranked in the top five scores in each group of PSTs with ELs and those without ELs) were placed in Q.I: Their instruction showed a high level of integration between science content and practices. In contrast, those participants who ranked in the bottom five edTPA scores in each group (PSTs with ELs and those without ELs) were placed in the Q.III: They were not able to successfully integrate the subject content and *NGSS* practices during instructional tasks. In addition, I found few differences between participants who had ELs in their classroom and those who did not. As such, for those PSTs who had ELs in their classrooms, there was no pattern in quadrant placement for those who had few in comparison to those who had many.

In reality, it is important to note that when teachers choose tasks for their ELs, they are usually decontextualized and low in cognitive demand, containing very few words, are very repetitive, and require students to "solve" or "find" the answer rather than provide opportunities for students to engage in rich content communication and practices that allow them to justify their thinking (de Araujo, 2017). In fact, there is a need to design and implement reform-based tasks because the integration of content and language is key for the success of ELs, enabling PSTs to better understand the connection between language and reform-based content knowledge. Moreover, reform-based instruction claims that ELs regularly engage in the types of reform-minded, academically rigorous tasks that are often reserved for non-EL students (Iddings, 2005). As a result, PSTs need to offer all students the same opportunities to engage in cognitively demanding work, and the use of scaffolding tools to maintain student engagement in intellectually demanding tasks (Kang et al., 2016).

To address the second part of my first research question, based on the second dimension of the TAGS framework, I examined the different levels of cognitive demand work that PSTs implemented in their EdTPA tasks. In fact, I explored the instructional tasks of the participants in relation to how successfully they used the *NGSS* science and engineering practices to engage their students in cognitively demanding work. As with part one of my first research questions, I found that the 10 PST participants who implemented lesson series that fell within Quadrant I of the TAGS framework implemented high intellectual level tasks, including those that encouraged open inquiry and/or guided instruction during most of their lesson series. Science PSTs' implementation of cognitively demanding work during instructional tasks was again connected to how well the participants performed in the edTPA tests: The participants who ranked in the top-five edTPA scores in each group (PSTs with ELs and those without ELs) were placed in the Q.I, which essentially specified that they used high-level tasks (open inquiry or guided) and successfully employed several *NGSS* practices in the science classroom. On the contrary, I found that those participants in Q.III implemented low-level tasks (scripted or memorization) and used few *NGSS* practices in the science classroom. These PSTs continuously introduced memorization and scripted tasks, preventing students from attending to scientific ideas or principles and minimizing their participation in science reasoning. These PSTs had low edTPA scores (i.e., bottom 5 in each group).

Generally, PSTs with high edTPA scores, regardless of whether or not they had ELs in their classrooms, implemented lessons that were placed in Q.I: They offered students opportunities to integrate science content (disciplinary core ideas and/or cross-cutting concepts) and practices as well as engage students in cognitively demanding tasks in order to

promote students' critical scientific sensemaking. In fact, given the adoption of the *NGSS* (NGSS Lead States, 2013) and the push for rigorous and equitable science instruction (Windschitl, Thompson, & Braaten, 2018), preservice science teachers of ELs must learn how to integrate lessons and make cognitively demanding work accessible and understandable to ELs so that all students can benefit from this reform-based instruction model. In conclusion, PSTs with low edTPA scores, again, regardless of whether or not they had ELs in their classroom, implemented lessons placed in Q.III.

To answer the second set of research questions, I examined the types of support preservice teacher participants stated using to help their students, including ELs, meet the academic language demands of the lessons. More specifically, I examined the types of support they most frequently reported using at the lexical, syntactic, and discursive levels during their edTPA lesson cycle. I divided the supports into five categories: providing meaningful context, ensuring comprehensible input, facilitating students' production of spoken and written discourse, using students' home languages and linguistic practices, and more general strategies.

In terms of the total number of supports identified across the data, I found that participants described types of instructional support at the discursive level the most often and supports at the syntactic level the least often, with discussion of supports at the lexical level falling in between. Participants' focus on types of instructional support at the discursive level was important for two reasons. First, supporting students' discourse aligns with the goals of conceiving of academic language as spanning three levels in the first place. As such, complex language use should be a priority in instruction for ELs (O'Hara et al., 2017; Zwiers et al., 2014). Second, such a focus resonates with the recommendations set by the *NGSS* (NGSS

Lead States, 2013): Teachers implementing reform-based science instruction should engage all students, including ELs, in learning the language and content of science through reasoning and sense-making (Quinn et al., 2012). Second, I found that PSTs discussed a number of instructional supports at the lexical level but identified few supports at the syntactic level. Although I am not recommending science teachers focus extensively on the teaching of grammar, I argue that greater attention to supports at the sentence level is needed. PSTs should be explicitly introduced to a number of other supports at the syntactic level since students cannot build discourse (e.g., arguments and explanations) without using sentences.

Originally, I began my analysis looking at the findings related to the 10 participants who were placed in Q.I according to the TAGS framework, including half of these PSTs who had ELs in their classroom. In fact, I found that those PSTs informed using a wide range of instructional supports to scaffold students' academic language use. However, the number of common types of support PSTs implemented changed substantially by language level when both EL and non-El groups (PSTs with ELs and those without ELs ) were compared: eight (PSTs with ELs) and seven (PSTs without ELs) at the lexical level, four (both groups) at the syntactic level, and thirteen (PSTs with ELs) and twelve (PSTs without ELs) at the discursive level. As such, there was a slight variation in terms of the types of support PSTs implemented within each of the three language levels across both groups in Q.I. Thus, the PSTs from both groups were able to appropriately scaffold all their students through different strategies in order to make academic language accessible.

The data from Q.I participants indicated that the supports across both groups (those who taught ELs and those who did not) were consistent among all three language levels. As a result, this pattern suggested that the number and types of supports implemented by PSTs in

Q.I were highly influenced by the actual placement of PSTs in the quadrants and therefore PSTs' total edTPA scores, rather than the inclusion (or lack of) of ELs in the classroom to a less degree. In other words, participants' placement in quadrants was more significant and had a greater impact in terms of the types of support provided by PSTs across both groups (PSTs with ELs and those without ELs). More specifically, PSTs' placement defined by their total edTPA scores was basically a more prevalent factor in assuming that those participants had the appropriate resources to support all their students. In fact, the non-EL group (PSTs without ELs) was still able to effectively scaffold all their students through different strategies to make academic language accessible, even though they did not use the same number of supports as the participants from the EL group (PSTs with ELs). Overall, the findings from Q.I participants showed that there was almost no considerable difference in terms of types of support implemented by those PSTs when making a comparison between the EL and non-EL group (PSTs with ELs and those without ELs).

Further, elaborating on my second research analysis, I examined the findings related to the 10 participants who were placed in Q.III according to the TAGS framework. I found that preservice teacher participants reported a narrower range of instructional supports to scaffold students' academic language use when compared to the participants placed in Q.I. Nevertheless, the number of common types of support they implemented changed noticeably by language level when both EL and non-El groups (PSTs with ELs and those without ELs ) were compared: three (PSTs with ELs) and two (PSTs without ELs) at the lexical level, two (PSTs with ELs and those without ELs) at the syntactic level, and six (PSTs with ELs) and four (PSTs without ELs) at the discursive level. Moreover, both groups consistently supported their students' academic language, even though a greater variation was noted in

terms of types of support at the discourse level. In fact, the majority of participants from the non-EL group (PSTs without ELs) was not able to implement as many types of language support as their counterparts in the EL group (PSTs with ELs) at both lexical and discourse levels.

In Q.III, the data showed that the supports across both groups (PSTs with ELs and those without ELs) were fairly consistent among all three language levels. As seen in the previous analysis of Q.I, the data for Q.III indicated that both groups of participants varied in terms of types of support for all students when compared to the results from Q.I. In fact, the most noticeable difference was identified in terms of the number of supports implemented by PSTs when I compared across both quadrants. This way, the biggest and most dramatic difference in terms of language support provided by PSTs was noted between quadrants I and III, rather than between the EL and non-EL group (PSTs with ELs and those without ELs). Therefore, PSTs in Q.III used fewer number of language support types across all three language levels when compared to participants in Q.I.

Moreover, when analyzing Q.III specifically, both groups (PSTs with ELs and those without ELs) steadily supported their students' academic language, even though a greater difference between these two groups was found in terms of types of support at the discourse level. Similar to findings from previous studies (Meier et al., 2020), in quadrants I and III participants from both EL and non-EL groups (PSTs with ELs and those without ELs) did use a higher number of language support types while promoting discourse in the classroom compared to the other two language levels. Therefore, the findings from Q.III participants showed that there was no considerable difference in terms of types of support implemented by those PSTs when making a comparison between the EL and non-EL group (PSTs with

ELs and those without ELs), even though participants from the non-EL group (PSTs without ELs) implemented slightly fewer types of language support in relation to their fellow participants in the EL group (PSTs with ELs).

As with research question one, PSTs' use or lack of use of language supports was reflected in their total edTPA scores. In Q.III, having ELs in the classroom did not completely influence the way participants used their resources and academic language knowledge to address students' needs regarding language support since both groups (PSTs with ELs and those without ELs) were able to implement about the same number and types of support across all three language levels. Overall, the findings from both quadrants (Q.I and Q.III) showed that those participants who did not teach ELs were still able to implement many of the same types of support across all three levels when compared to the EL group (PSTs with ELs). However, when compared to participants in Q.I, Q.III participants exhibited a greater variation in terms of supports across both groups (PSTs with ELs and those without ELs) and implemented fewer number of supports in general.

## Implications

This study examined if and how preservice secondary science teachers contributed to ways to support ELs in both the content and language of science during instruction, as well as offered opportunities to integrate complex science content and practices. To do so, I investigated the lesson series of 20 preservice science teachers from four research universities by qualitatively analyzing their part of their edTPA portfolios. More specifically, I analyzed preservice secondary science teachers' integration of science practices with content, implementation of cognitively demanding tasks, and whether or not those situations differed between those preservice teachers who had ELs in their classroom and those who did

not. I also investigated preservice secondary science teachers' support of academic language demands, and whether or not those types of supports varied by those PSTs who taught ELs and those who did not.

Based on my recent findings regarding PSTs' knowledge and implementation of reform-based instruction, I recommend preservice secondary science teachers be given explicit opportunities to gain the knowledge and skills needed to effectively implement the *NGSS* science and engineering practices in their lessons, both as a tool to enhance students' thinking about the important science concepts that they support and as an integral part of the science understanding that students are asked to actively construct. This way, PSTs would gain a better understanding of the adoption of reform-based instruction in terms of identifying the importance of content-practice integration and application of instructional tasks that would promote a deeper conceptual knowledge. For example, in a methods course, PSTs might spend a week learning about each of the eight *NGSS* science and engineering practices, identifying practical applications of their implementation within high cognitive demand science lessons, and trying out such implementation and content integration in their placements. For example, when discussing *using mathematics and computational thinking*, PSTs could evaluate the high school mathematical content and practices in CCSS-M that are pertinent to the science phenomenon in their current unit; for this specific practice, knowledge of and ways to implement the CCSS-M mathematical content practices naturally embedded within it should also be emphasized. In fact, PSTs could collaborate by sharing their own experiences and reflections with their peers in future opportunities (Lee, Quinn, and Valdés, 2013).

Given the previous suggestion to contextualize reform-based instruction in science, some PSTs will essentially miss opportunities to effectively implement *NGSS* science and engineering practices, especially the ones that are considered to be language intensive. Even though I found that half of my participants were able to successfully engage students in the *NGSS* practices and content integration to support their understanding in reform-based instruction, there is still a need for teacher educators to more clearly articulate for preservice secondary science teachers to effectively integrate lessons and implement intellectually challenging work in the science classroom, particularly focusing on the adoption of the *NGSS* science and engineering practices. More specifically, TEPs should deliberately attend to how to appropriately support their students, especially ELs, in order to promote reasoning and sensemaking across different levels of cognitively demanding tasks in science. This way, PSTs should feel compelled to make every effort to effectively engage their students in the *NGSS* framework (practices and cross-cutting concepts) so as to move their conceptual understanding of the science forward.

In terms of assuring that TEPs address their PSTs' needs to support the academic language of ELs, there were several courses that addressed 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 the four universities in this study. In general, PSTs had relatively ample opportunities to participate in courses on how to teach English learners science or how to help students develop academic language and literacy in science. As a result, based on the new science standards which focus on language use in the science classroom through implementing science and engineering practices, teacher education programs should aim to

effectively examine and address academic language and literacy development in science with their PSTs. Moreover, assuming that 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 will grow even more diverse, the importance of how to teach ELs science will remain a very crucial task for teachers.

In general, this study contributes to significant attempts to offer ELs better access to reform-based science teaching and learning. Based on the aim of the *NGSS* framework and the increasing number of EL students in US classrooms, this study advocates that teacher education programs dedicate more time and attention to providing PSTs with a thorough understanding of how to teach ELs by sharing with them a principle-based, disciplinary-specific framework. Such disciplinary frameworks must prioritize the understanding of academic language and instructional support as a way to help preservice teachers move beyond "just good teaching" to the effective teaching of ELs (Cohen & Lotan, 2014). In addition, such frameworks must also include attention to all three language levels (lexical, syntax, and discourse) to help ensure that instruction in academic language goes beyond the simple repetition of key vocabulary terms to the essential making of meaning (Bunch, 2013). In fact, this study encourages TEPs to recognize and expand their focus on providing PSTs the necessary knowledge and instructional resources to support the academic language demands of their students, especially ELs.

As indicated in this study, the participants had opportunities to engage in courses that focused on guiding principles for effective EL instruction. However, based on the findings discussed here, some PSTs were not able to properly engage their students in reform-based instruction and to provide supports across all three language levels, especially during

classroom discourse. Therefore, this study suggests that TEPs need to make sure that all PSTs equally and consistently understand how to efficiently apply the resources given and knowledge gained to support their students' language needs while engaging in ambitious science teaching. More specifically, in order to successfully accomplish that goal, TEPs must strategically monitor the development of those PSTs and attempt to better identify the main reasons as a way to support those that are struggling. In other words, TEPs must appropriately differentiate the curriculum to attend to those struggling PSTs, highlighting the need to provide extra opportunities and additional support in the same way K-12 teachers handle their challenging students. As a result, this study took one step closer toward offering ELs greater access to science by documenting how a select group of preservice secondary science teachers understood academic language and how they applied their understandings to the needs of ELs in terms of effective implementation reform-based instruction in science classrooms and supports across varying language levels.

## Limitations

In this study, I provided insight into an important area of science teacher education: preservice secondary science teachers' implementation of a reform-based instruction based on the *NGSS* framework and emphasis on cognitively demanding tasks; and their use of academic language and of ways to support ELs in both the content and language of science. To do so, I qualitatively analyzed specific parts (lesson plans and instruction commentaries) of the edTPA lesson series portfolios. I acknowledge that there is still much work to be done to understand the multiple intersections across the *NGSS* framework, academic language demands and supports, and ambitious teaching in the context of preservice science teacher preparation. I also recognize that the findings in this study are constrained by a few

methodological and practical limitations. Below, I discuss four limitations and related areas of potential research.

One limitation is that my data consisted solely of edTPA portfolios (e.g., commentaries, lesson plans) from my participants. In fact, edTPAs are expected to show PSTs' best and most effective teaching and lesson series (de Araujo, 2017). In other words, these portfolios did not necessarily reflect everyday teaching resources and instructional experiences in terms of disciplinary content, student engagement, and effective teaching practices. Therefore, future studies should attempt to include additional data, such as interviews with PSTs, additional classroom observations during their student teaching, and follow-up visits during their first year of teaching. Such data collection would enable detection of changes in these beginning teachers' understanding and implementation of the ways to support ELs' academic language and *NGSS* content and practices over time.

A second limitation and area for future research is the sample size. I focused my investigation on 20 PSTs from only two cohorts (2016-2017 and 2017-2018) attending the TEPs at those four research institutions. Even though this sample size is appropriate for a qualitative study, future research should attempt to gather data from a larger number and wider range of participants, including PSTs whose credentials are specific to other STEM areas. Increasing the sample size would allow for both quantitative and qualitative analyses as well. In fact, a larger number of participants from several universities would allow researchers to tease apart how preservice secondary science teachers' support of ELs and implementation of reform-based instruction are related to their depth of coursework preparation, their field placement experiences, and their scores on performance assessments.

A third limitation is related to the type and origin of the data collected during this study. All PST participants were enrolled in TEPs at research institutions only, specifically located in California. Therefore, future studies should collect data from non-research institutions, particularly smaller ones, as well as from institutions outside of California. By analyzing a data set that was more diverse in terms of demographics and TEP resources, researchers would be able to gain a more accurate picture of the average beginning teacher, since a high percentage of the beginning teachers graduate from these other institutions (NGSS Lead States, 2013).

A fourth and final limitation specifically addresses research methods consideration in which this present study did not look at or consider analyzing. As such, other factors than total edTPA scores could have been included in the analysis and thus possibly affected PSTs' performance and teaching effectiveness regarding attending to the needs of ELs. In order to address similar research questions, future studies could consider and include other factors, such as placement sites and school types, to further evaluate both PSTs and TEPs' performance, resources, and successful teaching practices.

## Conclusion

Overall, my findings show that preservice secondary science teachers can learn to recognize and appreciate their role in promoting science classrooms that support all students, especially ELs, to develop an understanding about academic language at the lexical, syntactic, and discursive levels. These findings indicate that helping preservice teachers appropriately support the learning of academic language in all of its complexity demands continuous and self-reflective determination from preservice teachers and teacher education programs as well. As previously mentioned, the recently adopted *NGSS* expects secondary

science teachers to engage their students in rich, complex practices and content so as to construct deep and integrated understanding (NGSS Lead States, 2013). The *NGSS* 3D framework (including the practices, cross-cutting concepts, and core ideas) offers authentic opportunities for PSTs to help students draw connections across the disciplines of science and engineering. As such, within the context of reform-based instruction, this study offers effective strategies and unique experiences of how preservice secondary science teachers should (and should not) integrate the *NGSS* science and engineering practices with science content in order to move toward with the ambitious goal of engaging students in reasoning and sensemaking in science classrooms.

In closing, this study suggests that these four teacher education programs were partially effective in supporting PSTs in developing standards-based instruction and in developing language, literacy, and EL instruction – in implementing ambitious teaching practices aligned with the *NGSS* framework, cognitively demanding tasks, and effective instruction for ELs. I conclude by recommending guidelines for teacher education programs be revised in order to better prepare reform-minded STEM teachers capable of teaching all students, especially English learners. As such, teacher educators and curriculum developers involved in teacher education programs should continue to consider how to address and integrate the topics of language, literacy, and EL instructions in their programs. Moreover, teacher educators participating in teacher education programs should also reflect on how to improve preservice teachers' knowledge of standard-based instruction through their programs as well. Consequently, teacher education programs must continue to work to provide appropriate coursework and experiences in principles and strategies that are effective in supporting preservice secondary science teachers to teach ELs. Finally, in order to

effectively achieve that goal, TEPs must systematically monitor the progress of those PSTs that are struggling and properly differentiate the curriculum by offering additional opportunities and support to those participants.

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