UNIVERSITY OF CALIFORNIA

Los Angeles

Who Trains the Trainer?

An Investigation of the Preparation of Science Teacher Educators

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Education

by

Charles Changwon Seo

2021

ABSTRACT OF THE DISSERTATION

Who Trains the Trainer?

An Investigation of the Preparation of Science Teacher Educators

by

Charles Changwon Seo

Doctor of Education

University of California, Los Angeles, 2021

Professor Megan Loef Franke, Chair

The quality of science education in the United States has been progressively declining as shown through standardized test scores and postsecondary science degrees. K-12 science education relies on qualified science teachers. Although education policy has driven reform, such as the Next Generation Science Standards (NGSS), to combat this trend, these efforts must transfer from the page to everyday practice. While the development of science teachers' pedagogical content knowledge is influenced by many factors, one common denominator among teachers is their preparation in teacher education programs (TEP). Therefore, knowledge and introduction of new standards like NGSS can be established in TEPs by science teacher educators (STE). However, this relies on STEs keeping abreast of new standards.

In the current dissertation, approximately 295 STEs across western states in the United States were surveyed regarding their own background and their knowledge of NGSS. Findings indicated no significant associations between STEs' demographics and their survey responses.

The overall findings support that STEs are not yet familiar with NGSS and that no specific background or institutional attributes predicted STEs' understanding of NGSS. This lack of mastery regarding NGSS by STEs makes it harder for NGSS to be incorporated by their pupils, the next generation of science teachers. Therefore, STEs need greater institutional and government support regarding introduction of new standards and ongoing development of policy. These supports would allow STEs to stay abreast of policy reforms, the introduction of new standards, and innovations in instructional practices. This could include a focus on STEs in policy development and implementation efforts, on-going professional development (PD), and coaching to support and facilitate STEs’ professional growth.

The dissertation of Charles Changwon Seo is approved.

Mark P. Hansen

Rashmita S. Mistry

William A. Sandoval

Megan Loef Franke, Committee Chair

University of California, Los Angeles

2021

DEDICATION

This work is dedicated to my family.

To my father, who didn’t get to see this finished, for giving me a love of learning, a zest for life, and a generous heart.

To my mom, for teaching me what it means to be strong and persevere.

To my brother, for showing me how to love and care for others.

To my aunt, who also departed, for feeding me, clothing me, and looking out for me as her own.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

NGSS = the Next Generation Science Standards

DCI = Disciplinary Core Ideas

SEP = Science and Engineering Practices

CCC = Cross Cutting Concepts

PCK = pedagogical content knowledge

PD = professional development

STE = science teacher educator

TEP = teacher education program

ACKNOWLEDGMENTS

First and foremost, I would like to thank Dr. Megan Franke, my committee chair, for her leadership, guidance, and support. I appreciate her kind, honest feedback that helped shape this work and challenged me to grow through the process. I am grateful to my committee members, Dr. Mark Hansen, Dr. Rashmita Mistry, and Dr. William Sandoval for their expert insights and thoughtful feedback that helped refine this study.

Sincere thanks to Joanna Lim, who sacrificed many nights in support of my project, meticulously combed through my manuscript, and saw me to the finish line.

I would like to acknowledge Dr. Lynn Kim-John, Sherre Vernon, and Erin Kim, my mentors and friends, who always push me to be better and do better.

Thank you to Edwin Garcia, Bryley Bergh, and Tannis Norton for their support of this project.

No acknowledgement would be complete without thanking my mom, brother, late father, and late aunt for their unconditional love and unfailing encouragement. This would not have been possible without their support.

VITA

EDUCATION

2003	B.S. Biology University of California, Irvine Irvine, CA
2007	Single Subject Teaching Credential Point Loma Nazarene University San Diego, CA
2013	M.S. Chemistry *Effects of Implementing an Inquiry-Based Laboratory Curriculum on Students' Understanding of Science and Attitudes toward Science* California State University, Los Angeles Los Angeles, CA

EXPERIENCE

2006-2010	Chemistry Teacher Camino Nuevo Charter High School, Temple Campus Los Angeles, CA
2012-2013	Graduate Assistant, Teaching Associate California State University, Los Angeles Los Angeles, CA
2013-2014	Lead Teacher Camino Nuevo Charter High School, Miramar Campus Los Angeles, CA

2014-2016	Academic Director Southlands Christian Schools Rowland Heights, CA
2016-2019	Science Department Chair, STEM Dean Village Christian School Sun Valley, CA
2019-2021	Assistant Principal Larchmont Charter School Los Angeles, CA
2021	Administrative Director, Instruction Granada Hills Charter Granada Hills, CA

Chapter 1: Introduction

Statement of the Problem

K-12 students rely on their science teachers to deliver high quality science instruction. While the development of science teachers' pedagogical content knowledge (PCK) is influenced by many factors, one common denominator among teachers is that they spend time preparing to become a teacher in teacher education programs (TEP). In many of these programs, preservice science teachers enroll in science methods courses to learn science-specific content and pedagogy. These courses are instructed by science teacher educators (STE). The PCK of STEs impacts the preparation of prospective science teachers. This is especially true when education reform efforts reach a tipping point, such as when new policies and standards like the Next Generation Science Standards (NGSS) are introduced and implemented.

STEs are vital to the improvement of science education. However, there is a gap in the literature about STEs, their practice, and how they are prepared to implement changes to their practice in response to policy changes. If we are to improve student achievement in science and make advances in science education, then it is important to understand STEs because of their instrumental role in the process.

Background of the Problem

The quality of science education in the U.S. is cause for concern, as evidenced by performance on science assessments and relative decrease in postsecondary science degrees. Results from the 2015 Program for International Student Assessment (PISA) showed that American students are performing worse than their Asian counterparts in math, science, and reading. The PISA, which is administered every three years, is taken by 15-year old students in

71 developed and developing countries. The average scores (out of 1000) for US students were 470, 496, and 497, respectively. Thus, the US ranked 38th out of 71 in math and 24th out of 71 in science. By comparison, Singapore scored the highest in all three areas with scores of 564 in math, 556 in science, and 535 in reading. Science scores for American students have trended similarly since 2009.

At the collegiate level in 2015, the US ranked 38th out of the 40 most advanced countries in students obtaining a bachelor's degree in science. The results are from the 2015 Science, Technology and Industry Scoreboard,[1] which is reported by the Organization for Economic Cooperation and Development (OECD),[2] the same group that sponsors the PISA. The report showed that in 2012, only 16% of undergraduate degrees were awarded in Science, Technology, Engineering, and Math (STEM). In the highest-ranking country, South Korea, 32% of students earned STEM degrees. Bachelor's degrees have almost tripled in the past 40 years; however, the relative percentage of students who are earning degrees in STEM fields are at, or below, where they were (Maltese & Tai, 2011).

Even by our own American standards, students are not showing proficiency in science. Locally, on the 2015 National Assessment of Educational Progress (NAEP),[3] only 24% of California's fourth and eighth graders scored proficient in science, ranking us 48th and 46th respectively in the country.

Students' interest and motivation to learn science is not keeping up with those in other fields, which suggests that changes may be necessary in science education (Swarat, Ortony, &

---

[1] http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2015/science-and-engineering_sti_scoreboard-2015-9-en;jsessionid=4uuf712aq0sjj.x-oecd-live-02

[2] https://www.oecd.org/about/

[3] A study by the Institute of Education Sciences compared the overlap between NGSS and NAEP Frameworks in Science, Technology, and Engineering Literacy (TEL), and Math. The study found that NGSS-based assessments are moderately aligned with the NAEP.

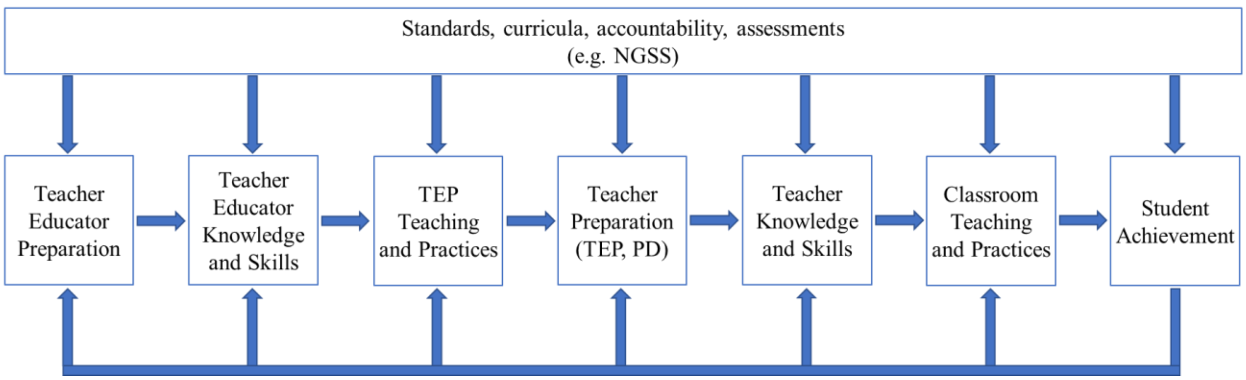
Revell, 2012). In fact, the results of surveys of science and math education support a need for shifts in science classroom instruction (Banilower et al., 2013; Weiss et al., 2003). At the most foundational level, a transformation may be needed in the classroom regarding teaching practices, learning practices, and teachers' approach to content because the current situation is not working to encourage students to pursue STEM fields to meet the demands of a well-trained workforce. While the reasons students are not pursuing STEM are unclear, one explanation might be that we are not teaching science classes in a manner that students enjoy and find success nor are we inspiring the confidence to take higher level (i.e., Advanced Placement) courses (Bennett & Hogarth, 2009; Jenkins & Nelson, 2005). An alternative rationale could be that science curriculum is not engaging students, especially because science has become more about learning and regurgitating theory and facts rather than inquiry and scientific practices (Freedman, 1997; Swarat et al., 2012; Tytler & Osborne, 2012). Gopnik (2016) elaborates on these science teaching problems through a poignant metaphor:

> Imagine if we taught baseball the way we teach science. Until they were twelve, children would read about baseball technique and history, and occasionally hear inspirational stories of the great baseball players. They would fill out quizzes about baseball rules. College undergraduates might be allowed, under strict supervision, to reproduce famous historic baseball plays. But only in the second or third year of graduate school, would they, at last, actually get to play a game. If we taught baseball this way, we might expect about the same degree of success in the Little League World Series that we currently see in our children's science scores. (p.187)

In order to effectively teach science, science teachers require a set of knowledge and skills. The initial point at which teachers systematically acquire knowledge and skills is primarily through teacher education. This sequence is depicted in Figure 1, which was adapted from Yoon, Duncan, Lee, Scarloss & Shapley (2007). This model, originally presented in professional development (PD) literature, has been modified; the PD component was changed to "teacher preparation" to include TEPs, because TEPs and PD are the two primary ways in which teachers learn and grow in their practice. Teacher educator components, such as teacher educator preparation, teacher educator knowledge and skills, and TEP teaching and practices, were added to the model and will be addressed in the next section.

Figure 1

Effects of Teacher Preparation on Student Achievement



(adapted from Yoon, Duncan, Lee, Scarloss & Shapley, 2007)

Standards, curricula, accountability, and assessments act as moderators on each component of the model. On a micro scale, these moderators influence what and how teachers teach day-to-day. On a macro level, they determine how students, teachers, and schools are held accountable through state assessments. A perennial challenge in education is keeping current with changes brought by education reform. When new standards and assessments are introduced, such as NGSS, it is important to understand how teacher educators are preparing new teachers to incorporate these standards into their curriculum and practice to ensure that students are receiving the highest quality of education. Preservice science teachers need to be appropriately prepared to teach science. STEs who are tasked with preparing preservice teachers also need to be prepared for this task, especially when standards and policies change.

Addressing the Problem Through Teacher Educators

The original model of Figure 1 (as diagrammed by Yoon et al., 2007) does not explicitly mention teacher educators' knowledge, skills, and practices, which would directly influence the preparation of preservice teachers and thereby ultimately impact student achievement. The modified version (Figure 1) depicts a more complete picture with the addition of teacher educator counterparts: teacher educator preparation, teacher educator knowledge and skills, and TEP practices and skills. However, little is known about teacher educators, the mechanisms that keep them current in research-based pedagogy and content, and their content knowledge and practices. Education reform efforts like NGSS are limited if teacher educators are not equipped to prepare teachers.

Research around teacher educators was catalyzed by the *Journal of Teacher Education*'s Major Forum in 2013, which focused on the preparation of teacher educators (Knight et al., 2014). Since this conference there have been renewed efforts to understand who teacher educators are, the qualifications that authorize them to prepare prospective teachers, the systems in place that ensure continued education to be current in content mastery and pedagogy, and the extent to which "teacher educators themselves actually use the constructivist views of learning they promote" (Cochran-Smith et al., 2015, p. 113). Because California has adopted NGSS, assessing STE knowledge of NGSS and its incorporation into the preparation of preservice teachers will help inform how effective TEPs are in preparing science teachers.

While teachers develop their knowledge and skills throughout their careers, it makes sense to focus here on preservice teacher education. Preservice teacher preparation is not limited to occasional workshops but rather has the benefit of providing prospective teachers with structured learning experiences that target content-specific pedagogy prior to entering classrooms as full-time teachers. Furthermore, teachers in the workforce have already developed habits that would have to be dismantled in order to incorporate new practices (Kennedy, 2016), which suggests that trying to prepare teachers through PD at a later time is more difficult than developing the same skills and practices in preservice programs.

The Next Generation Science Standards

If the goal is to improve student achievement in science, investigating pre-service teacher education is necessary but not sufficient on its own to bring widespread change. Every component of the teacher preparation model (Figure 1) is affected by local, state, and national education policies. TEPs need to be examined in light of standards, curricula, assessments, and accountability that are imposed on education systems. This study focuses on what STEs in TEPs know about new standards, specifically NGSS.

Until now, there have never been national science standards. Although only 20 states and the District of Columbia had adopted NGSS by 2021,[4] many more states are interested in adopting the standards. Previously, individual state standards determined what was taught. In California, for example, the California State Science Standards outlined scientific knowledge that was considered essential for K-12 science education. However, even individual standards are being developed from the National Research Council Framework for K-12 Science Education, the foundation of NGSS, as is the case of 24 other states that have not officially adopted NGSS.

[4] http://ngss.nsta.org/About.aspx

Statement of Project

The purpose of the project was to study STEs in hopes of understanding what they know about NGSS and what role their backgrounds and institutions might play in their level of knowledge and understanding. To address this, I investigated the extent to which STEs' understanding of NGSS varied according to the characteristics of both their professional background and the institution in which they work. Professional background included their experience as K-12 teachers, the highest degree they earned, the number of years they taught methods courses, etc. In examining institution type, characteristics such as public versus private, level of research activity, and size of TEP were examined. In trying to understand how STEs learn about NGSS, I hoped to gain insight on whether their professional experiences, as well as the types of institutions in which they work, are factors in their likelihood of being equipped to prepare preservice teachers for the new standards.

Research Questions

1. What do STEs know about NGSS?
2. What is the relationship, if any, between STEs' professional background characteristics and their knowledge of NGSS?
3. What is the relationship, if any, between STEs' institutions and their knowledge of NGSS?

Research Design

The study design employed survey research methods to assess STEs' knowledge of NGSS and associations with their professional and institutional backgrounds.

The Significance of the Research for Solving the Problem

The results of the study are useful for schools of education and TEPs, professional development groups, educators, and policy-makers. Because of the mediating effect that teacher educators have on teacher preparation, teacher quality, classroom practices, and student achievement, the findings of this study have the ability to make lasting changes in the education system, specifically regarding teacher educators and science education.

Chapter 2: Literature Review

Introduction

K-12 teaching has been reduced to a semi-profession (Mehta, 2013) and has lost public trust (Kirst, 2010). Public perception of K-12 teachers in the U.S. shows a duality of attitudes towards the teaching profession. Teachers are praised for their important work of investing in the hearts and minds of students. However, in the same breath that they are praised, teaching is disparaged in a way that no other profession is.

The idea that "those who can't, teach" presumes that teaching is easy and that anybody can teach. This myth is perpetuated by politicians and business executives who visit schools and do the "work" of teachers by reading to students in order to gain favor from the public (Rose, 2014). Yet they would never take on the pretense of being a surgeon for a day because it requires a specific set of knowledge and skills that is out of their reach. Teaching, too, requires a specific set of knowledge and skills. However, because most Americans spend at least twelve years in compulsory education, teaching suffers a misfortune not experienced in other professions: everyone thinks that they can teach because they, as students, have spent countless hours in classrooms observing the teaching process. However, the notion that anyone can teach is far from the truth.

In this chapter, I explain the importance of teacher education and the role of teacher educators in the development of preservice science teachers. I start by presenting the case against teacher education, in order to argue the essential role of teacher educators in preparing teachers. I present what constitutes effective teacher education programs (TEPs) to discuss the challenges that some programs face, as well as teacher education in general. Because the crucial actors of these programs are the teacher educators, I explain what we know about teacher educators, including who they are, how they are prepared by obtaining specific qualifications, what they should be able to do, and what they actually practice in the classroom. Finally, I provide a summary of science education reform to provide context for how we arrived at the Next Generation Science Standards (NGSS). Understanding NGSS is important in determining the needs for preparing science teacher educators.

Teacher Education

Not everyone agrees on the importance of TEPs. In much the same way that the teaching profession is disparaged, teacher education is also denigrated. Murray, Swennen, and Shagir (2009) write:

> The status of teacher education within higher education has long been recognized as uneasy and given a sometimes marginal status. In some countries the field of teacher education has been measured against 'traditional' academic disciplines and found wanting. These struggles for legitimacy have occurred in part because the knowledge base of teacher education is what Furlong (1996, p. 154) calls the 'endemic uncertainty' of professional knowledge. (p. 31)

Opponents of TEPs argue that they are an unnecessary barrier to entry into the teaching profession (Darling-Hammond, 2010). Especially because of teacher shortages, those who oppose TEPs believe that eliminating this hurdle is necessary to ensure that schools have teachers. Unfortunately, a result of the under preparation of teachers is that students who most need qualified teachers are inequitably impacted; underprepared teachers with emergency credentials are often assigned to schools in poor underserved communities. Another sequela is the perpetuation of this disdainful cycle by casting teachers into the realm of semi-professionals and erasing the significance of teacher educators.

However, proponents argue that when teacher education is done well, student achievement is subsequently amplified. Research shows that well-prepared, qualified teachers with high scores on teacher licensing exams had a stronger effect on student achievement than race or socioeconomic status (Clotfelter et al., 2007; Ferguson, 1991). Polikoff (2013) found that teachers' classroom instruction was enhanced by their preservice education. Studies have shown that the teacher is the most important factor in student achievement (Hattie, 2003) and that student achievement is negatively impacted when taught by inexperienced teachers holding temporary credentials (Clotfelter et al., 2007).

The results are not surprising considering the complexity inherent to teaching (Lampert, 2001; Grossman, 2009). Teachers are tasked with engaging in a multitude of difficult tasks, such as differentiating instruction so that every student is able to demonstrate a minimum level of subject competence. Regardless of the varying levels of skills and needs with which each student starts a class, the teacher is expected to ensure that all students are engaged in meaningful learning activities. In order to help students achieve learning outcomes, teachers must be capable classroom managers, curriculum developers, and content experts.

What these roles and skills (i.e., effective teaching practices) entail have been shaped by decades of research. Various frameworks for the teaching profession and teacher evaluation forms outline the skills and strategies that effective teachers are able to execute (for example, Danielson, 2007; National Board for Professional Teaching Standards, 2013). Examples of skills include engaging students through activities and grouping, using assessments to monitor student learning, asking quality questions, and facilitating discussions. Prospective K-12 teachers begin to acquire these skills in TEPs.

However, TEPs are criticized for inadequately preparing preservice teachers to utilize these skills. Smith and Gess-Newsome (2004) concluded that "what happens in methods classes depends largely on the beliefs and knowledge of the instructor in much the same way that what and how science is taught in schools depends on the personal theories of classroom teachers" (p. 107). Because there is no agreed upon curriculum for teacher preparation, teacher educators teach content and strategies as they see fit.

Examination of TEPs reveals a probable cause of these criticisms. TEPs struggle to define the curriculum, especially regarding the appropriate balance of theory and practice (Darling-Hammond, 2010; Grossman, Hammerness, & McDonald, 2009). This difficulty stems from the assumption that university coursework emphasize theory while leaving the practical aspects of teaching to be developed in the field.

In theory courses, preservice teachers acquire knowledge about the purpose of school and how students learn. This facilitates the development of "conceptual tools," thereby building a framework to guide what they will do in the classroom. Theory courses include educational psychology, history of education, and philosophy of education. On the other hand, in methods courses, preservice teachers learn the "practical tools" that they will enact in the classroom, such as teaching strategies and classroom management practices. However, even in methods courses, teachers spend more time talking about teaching methods rather than practicing them (Ball et al., 2009). According to one teacher educator:

> When I first started observing teacher education, I was surprised at how poorly the teaching was done. For example, the teacher educators that I observed would spend their time lecturing to their students about how lecturing was not effective. (Goodwin et al., 2014, p. 292)

One of the challenges for TEPs is to decompartmentalize theory and methods courses. By integrating theory into methods courses and methods into theory courses, preservice teachers have opportunities to practice teaching methods that are shaped by what they learn in theory courses. A study by Boyd et al. (2009) supported this integration of theory and methods with their finding that teachers who were in TEPs that provided opportunities to practice teaching were more effective in their first year of teaching.

Efforts are underway to change how to bridge the theory-practice divide in TEPs. Conklin (2015) targeted the preparation of teacher educators by proposing a conceptual framework to tailor TEP coursework to the needs of K-12 teachers. She argued that this approach would allow teacher educators to address not only what K-12 teachers should know and be able to do, but also how they might be able to implement effective teaching. She addressed the "what" (i.e., theory) by incorporating Grossman, Smagorinsky, & Valencia's (1999) conceptual tools and practical tools:

> Conceptual tools are the theories, principles, and frameworks that help guide teachers' decision making in their teaching practice, whereas practical tools are concrete instructional practices, strategies, and resources that teachers can use in their classrooms. (Conklin, 2015, p. 325)

The "how" (i.e., practice) is accomplished through using practices – such as modeling and debriefing – that teacher educators should make explicit through their own practice in preparing preservice teachers.

A more direct approach to bridge the theory-practice gap is to organize teacher education around practices. This approach, called "practice-based" teacher education, is defined as "professional training that attempts to focus novices' learning more directly on the work of teaching rather than on traditional academic or theoretical topics that may have only marginal relevance to the realities of the classroom" (Forzani, 2014, p. 357). A further advancement has been the development of core practices, which are specific high-leverage teacher strategies that occur frequently across grade levels and disciplines (Grossman et al., 2009). Examples of core teaching practices include developing classroom culture and leading classroom discussions.

Kloser (2014) made a case for the need to identify core science practices referencing the fact that compared to science teachers around the world, U.S. science teachers show more variance in practices (Roth & Garnier, 2006). This suggests a lack of standardized practices in TEPs, which allows teacher educators to focus on areas of teacher development as they see fit rather than a narrower prescribed set of practices. If TEPs reached a consensus of core practices, then perhaps there would be higher adoption of high-leverage practices. Using Delphi methodology, Kloser (2014) identified the following core science practices (in descending rank order):

- engaging students in investigations
- facilitating classroom discourse
- eliciting, assessing, and using student thinking about science
- providing feedback to students
- constructing and interpreting models
- connecting science to its applications
- linking science concepts to phenomena
- focusing on core science ideas, crosscutting concepts and practices
- building classroom community

These core science practices align well with NGSS. With the introduction of NGSS, we have an opportunity to improve science education through standardizing these core practices in TEPs. Preservice science teacher educators would have the opportunity to practice and develop their implementation of these core science practices through coaching and feedback in TEPs.

In her research, Darling-Hammond (2006) examined institutions that were known to have exemplary TEPs and found features common to all of these programs. These features are:

- a clear common vision of good teaching
- well-defined standards of professional practice and performance
- a strong, core curriculum
- extended clinical experiences
- extensive use of case methods
- explicit strategies to challenge students’ assumptions about learning

- and strong relationships within university faculty.

The identification of these common features provides a starting framework by which TEPs can work towards to ensure a minimum standard of preparation for preservice teachers, regardless of the TEP.

Much work needs to be done in order to professionalize teacher education and lift it to its proper place of importance. Professionalizing teacher education would include standardizing the content and training for prospective teachers so that upon completion all first-year teachers would be equally equipped to deliver high quality instruction. The implication for teacher educators is the expectation to deliver appropriate, streamlined content and ensure that preservice teachers have the requisite skills to be successful starting from the first teaching assignment, regardless of the teacher educator or the TEP.

Darling-Hammond (2005) made a compelling argument for the importance of professionalizing teacher education by using medical education reform as a model. Up until the early 1900s, doctors were trained primarily through apprenticeships and early medical schools served as a supplement. Medical schools systematized that knowledge but were criticized because they "relied heavily upon textbooks, used didactic teaching methods, and required students to simply "parrot" back information" (Darling-Hammond, 2005, p. 449). Opponents of medical schools argued that the education favored theory over practice. Flexner (1910), who published a report about the state of medical education, argued that medical schools be housed in universities so that medical knowledge (i.e., theory) would be coupled with clinical work (i.e., practice). Eventually, the standards were set for the medical profession, as well as the necessary training, and were followed by standards of accreditation, licensing, and board certification exams. Teacher education stands to benefit from following this approach, much like other occupations that followed this process to become professions (e.g., law, engineering, nursing, accounting, etc.).

In a time when opponents of TEPs are calling for lowering standards, arguing to reduce professional status, and even suggesting that teacher credentialing be eliminated altogether (Walsh, 2001), proponents of teacher education are pushing back. They argue that teacher education needs more than modifications and changes to a few things that are not working, calling for transformation rather than reform (Grossman et al., 2009; Loughran, 2011).

Teacher Educators

The term teacher educator is used broadly in the literature to describe anyone who educates teachers. By the broadest definition, this includes professional developers who provide in-service training to teachers who are working in schools, most of who have completed coursework and passed credentialing exams. In my discussion of teacher educators, I focus only on those who work with preservice teachers through coursework in university TEPs.

Teacher educators need to play a large role in the transformation of teacher education. Although there is an increasing body of literature about teacher educators, we know little about them. In fact, as recently as 2014, Knight posed questions that illuminated how little we know, such as, “Who are teacher educators and what are the current knowledge, skills, dispositions they possess?” (p. 268) and “What practices characterize the work of teacher educators? (p. 268). Much of what we know about teacher educators are self-studies or studies that seek to understand teacher educator identity.

There are two main pathways to becoming a teacher educator: the academic pathway and the practitioner pathway (Davey, 2013). Those who take the academic pathway pursue a doctorate and become professors. However, this pathway is criticized because the preparation received by these teacher educators is in research, not in teaching (Cochran-Smith, 2003; Zeichner, 2005). Goodwin et al.'s (2014) study of doctoral degree-holding teacher educators, gave credence to this criticism as only 11.3% (n=293) of participants had earned their degree in teacher education. The practitioner pathway is taken by teacher educators who first pursue careers as K-12 teachers. After gaining experience and success in teaching K-12, they become teacher educators. Because the typical teacher educator on this pathway does not start in academia, they differ from their academic pathway counterparts in that they lack strong research background.

Regardless of the pathway by which they become teacher educators, members from both groups find themselves in their role by happenstance (Goodwin et al., 2014; Zeichner, 2005). They were not planning to become teacher educators nor were they prepared in any formal capacity for the work that they do. In a study of "university-based, doctoral-prepped, practicing teacher educators" (Goodwin, 2014, p. 287), three-quarters "fell into the profession" (p. 291), not having previously considered becoming teacher educators until after completing their doctoral programs.

Standards for Master Teacher Educators outline what teacher educators should know and be able to do (The Association of Teacher Educators, ATE, 2008). The nine standards, or domains, are teaching, cultural competence, scholarship, professional development (PD), program development, collaboration, public advocacy, teacher education profession, and vision. However, the standards are voluntary and do not represent consensus among teacher educators (Goodwin, 2014). While the standards are goals that teacher educators can work towards, teaching teachers is challenging.

For the many teacher educators who have K-12 experience, they quickly realize that the task of teaching teachers is not the same as teaching K-12 students. The transition from their role as K-12 teachers is not a self-evident process as it demands a different set of skills (Loughran, 2011). At the heart of what makes the work of teacher educators challenging is that they need to operate on multiple levels. On one level, this includes knowing and utilizing content knowledge and pedagogical content knowledge (PCK) for teaching preservice teachers. On another level, that content knowledge and PCK must be framed for teaching K-12 students. According to Davey (2013), teacher educators:

> …not only have to teach subject and curriculum content and skills but they also have to teach simultaneously *about* teaching these subjects and skills, and they do this by deconstructing the knowing *how*, the act, processes, and the nature of teaching itself. (pp. 112-113)

Murray and Male (2005) referred to this as the "second order" nature of teacher education, contrasting this with the "first order" work of K-12 teachers. In the first order, teachers rely on content knowledge and PCK within the discipline they teach. In addition to this, second order work demands that teacher educators develop pedagogies of teaching about teaching. The challenge of second order work is highlighted by Goodwin et al.'s (2014) finding that teacher educators "feel unprepared to implement teacher education pedagogies."

Another aspect of the challenging nature of the work of teacher educators is what Berry (2007) articulated as six types of tensions experienced in their practice: telling and growth, confidence and uncertainty, action and intent, safety and challenge, valuing and reconstructing experience, and planning and being responsive. Teacher educators are confronted with these tensions, which work as a check and balance to match what they want preservice teachers to know from their own practices as teacher educators. Conceptually, these are similar to the challenge of teacher education in integrating theory and practice. For example, the "planning and being responsive" tension addresses the implementation of a scripted curriculum with the ability to use unexpected learning opportunities that arise in practice. If a teacher educator follows a predetermined lesson, then preservice teachers miss out on opportunities to learn how to use organic learning opportunities in their work with K-12 students.

Preservice teachers start TEPs with deep-seated beliefs about teaching, having been "apprentice(s) of observation" during their time as students (Lortie, 1975). Apprenticeship of observation refers to the misconception that anyone can teach, which stems from the common experience of having observed countless hours of classroom instruction as students. Consequently, novice teachers' perceptions of teaching are not aligned to the reality of teaching as a complex practice. For this reason, it is all the more essential that science teacher educators provide preservice science teachers with opportunities to engage in core practices – both general to teaching and science-specific – so that they will have authentic opportunities to understand teaching as a complex practice as they grow their repertoire of instructional practices and routines. In practicing how to teach science, preservice science teachers will be better equipped to provide their students opportunities to engage authentically in core science practices. Loughran (2014) argued that doing so would have a "major impact on student teachers' developing views of science teaching and…challenge taken-for-granted assumptions and the deeply held beliefs of teaching… [that are] so difficult to change" (p. 812).

The challenges of second order work are exacerbated for science teacher educators. Science teacher educators, unlike teachers in other disciplines, have to navigate through an additional layer of complexity. This complexity is embedded in the criticisms of science education (discussed in the next section) that students are not provided with authentic opportunities to learn science. Rather than learning science, they learn *about* science. This is attributed, in part, to the difficulty of teachers to teach in a way that they have not experienced themselves (Richardson, 1996). They are unable to translate inauthentic experiences of learning about teaching to the practices required of them as teachers. Compounding this challenge, science teachers are unable to teach science because their experiences of science education have also been learning about science. Russell and Martin (2014) argued that science teacher educator programs “must always struggle to avoid the criticism that its version of learning to teach science has become an inauthentic representation of the teaching of science in schools” (p. 886). This aspect of science education parallels teacher education.

Knight (2004) drew three conclusions that are true for both teaching science and learning to teach science: students come to class with prior knowledge, not as blank slates; students’ prior concepts are resistant to change; and students’ knowledge is not coherently organized into a framework. It is the work of science teacher educators to help preservice teachers actively create a framework for their pedagogy, content, and PCK through tapping into their prior knowledge in authentic learning experiences. To do this well, science teacher educators need to use PCK about “curriculum, instruction, and assessment for teaching science methods courses and supervising field experiences, as well as his/her knowledge about preservice teachers and orientations to teaching science” (Abell et al., 2009, p. 79).

Even knowing what we know, science teacher educators remain reluctant to change their teaching practices to reflect what research suggest. Russell and Martin (2014) pointed out that “experienced teachers and teacher educators…ask of new teachers what they have not attempted themselves are ignoring the reality that we learn to teach more by what is modeled than by what is told” (p. 886).

Science Education Reform

The challenge of teaching science is rooted in the dual nature of science as content and science as a process. Science education has largely been driven by an emphasis on content – the facts and knowledge of the disciplines. Even as far back as 1957, when the U.S. response to the Russian's launch of Sputnik was to increase focus on science and reinvigorate science education, science education was deemed content-oriented, outdated, and "functionally inert outside of class" (Hurd, 1991, p. 33).

Not much has changed in how science is taught in U.S. schools. Science education has been reduced to a body of knowledge, neglecting the scientific endeavor and practices. Science classrooms focus on learning vocabulary, memorizing facts, reproducing explanations from textbooks, and participating in laboratory experiments that follow cookbook-style recipes (Abrahams & Reiss, 2012; Berland & Reiser, 2009; Osborne & Dillon, 2008).

Munby et al. (2000) reflected on the relationship of science and science education:

> …when science is removed from contexts that match and support its goals of inquiry and experiment, its character can change. School science is distinct from experimental science because it is practiced in an institution whose goals are not the goals of science, and so school science becomes an inauthentic representation of experimental science. (p.208).

This sentiment aligns with reform efforts, which have consistently recommended that science education shift towards authentic science experiences in which students are not merely learning about science but rather learning science by engaging in scientific practices.

Over the last several decades, this goal for science education has remained constant. However, each attempt conveyed this differently. For example, *Science for All Americans*, which was written by the American Association for the Advancement of Science (AAAS, 1989), focused on scientific literacy, reducing the content covered and highlighting themes that appear across science disciplines. In designing *Project on Scope, Sequence, and Coordination of Secondary School Science*, the National Science Teacher Association (NSTA, 1989) accounted for how students learn. Consequently, the goal was to restructure the science curriculum to an integrated science model, as opposed to traditional, compartmentalized science courses. Whereas traditional science teaching relied on students' memorization of facts, the recommendation was to provide students with opportunities to make sense of science by introducing concrete experiences through which students would connect their learning to scientific phenomena. In the early 1990s, the National Center for Improving Science Education developed frameworks for science curriculum and instruction for elementary, middle, and secondary levels that emphasized scientific habits of mind (Bybee & McInerney, 1995).

The *Framework for K-12 Science Education* developed by the National Research Council (NRC, 2012) and NGSS together represented the change in science education detailed in decades of reform efforts. They integrated the ideas and research-basis of previous reform documents. The *Framework*, which is the parent document of NGSS, provided the vision, rationale, guidelines, organizational structure, and research basis for what science education ought to look like. NGSS, on the other hand, were standards that provided goals that could be more readily aligned to student learning. However, neither the *Framework* nor NGSS provided details of how to teach science. Rather, they made explicit the core ideas (content), scientific practices (skills), and crosscutting concepts (interrelated themes) of science.

NGSS was created through a collaborative effort by the NRC, NSTA, AAAS, and Achieve. It was organized into three dimensions of science learning, which were derived from the *Framework*. Disciplinary Core Ideas (DCI), the first dimension, are the essential ideas in science disciplines that students should understand. They are articulated in developmental progressions for different grade levels and subject. This feature allows students to build more sophisticated understandings of core concepts over the course of their K-12 education, as the same ideas are revisited with increasing depth at subsequent grade bands. DCIs were intentionally designed with a limited number of core ideas so that students could more deeply learn the most essential ideas and have time to engage in science practices.

Science and Engineering Practices (SEP), the second dimension, detail the practices used in science inquiry and engineering design. The DCIs are intended to be learned in tandem with SEPs because "students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined" (NRC, 2012, p. 218). The eight SEPs are: asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information.

Cross Cutting Concepts (CCC), the third dimension, represent ideas that bridge disciplinary boundaries. They are not new to NGSS, as they have been mentioned in previous reform documents by different names (e.g., *Science for All Americans*, AAA, 1989; *National Science Education Standards*, NRC, 1996). However, in past iterations, there were never instructional supports to guide their implementation. CCCs are designed to unify DCIs to make the study of science more cohesive across disciplines. The seven CCCs are: patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change.

NGSS was developed by 26 lead states. Currently, 20 states and the District of Columbia have officially adopted NGSS, while 24 other states have developed individual standards similarly derived from the *Framework*. However, even with the support that it has garnered, NGSS is not a silver bullet that will ensure that science education will be different. It is not a curriculum. Rather, it is a set of content standards and science practices that provide goals by which classroom instruction can be guided. NGSS does not guarantee that scientific practices will be used in the way that they were envisioned and recommended. Without a proper understanding of the standards or curricular and pedagogical supports needed to enact a new type of science instruction, frustrated teachers will likely default to teach content that is familiar to them (e.g., teach to the test, rely on textbook for curricular decision-making), revert to more natural teaching strategies/practices (e.g., lecture), and deliver inauthentic student learning experiences in science (e.g., confirmation labs in which students conduct experiments by following a recipe to confirm what they already know).

Windschitl & Stroupe (2017) outlined a strategy for implementing NGSS in what they call the "three-story challenge." The premise of their approach is that each actor in the process – K-12 student, preservice teacher, and teacher educator – has unique responsibilities in process of science education. These actors operate on distinct, but interconnected, levels (i.e., stories). By understanding the learning goals of participants at each level, appropriate opportunities can be designed to achieve them. The authors argue that these goals should not be narrowly aligned to only NGSS, but that they should also be shaped by the precedent documents that informed the creation of NGSS. By using this approach, the focus of aligning classroom experiences – both in K-12 classes and teacher education classes – lies not in the goals themselves, but rather the means by which these goals can be achieved as outlined in NGSS. This is congruent with the movement in teacher education to drive instruction based on core practices, rather than allowing theory to drive learning.

Examples of the goals for the K-12 student level include understanding, using, and interpreting scientific explanations of the natural world as well as generating and evaluating scientific evidence and explanations. These goals were taken from the *Framework*, the guiding document in the development of NGSS, but were originally articulated in an earlier iteration called *Taking Science to School* (NRC, 2007).

At the teacher level, one of the goals is to “create opportunities for students to learn [and] participate in science” (p. 253). Again, the emphasis is on teaching practices because “if we shifted our professional focus toward the instructional conditions and teaching moves that enable students to participate in and understand science through engagement with NGSS-related tasks, we could more effectively influence learning” (Windschitl & Stroupe, 2017, p. 254).

Therefore, the goal of the teacher educator level is to “create cycles of opportunity for novices to take up practices that are linked to student learning and support equity” (p. 253). In order to effectively carry this out, teacher educators need to understand the content and practices that are implemented at the student level, be able to execute the goals of the second level, and operate at their own teacher educator level.

Ultimately, for substantial shifts in science education to occur, science teacher educators, who arguably play the most important role in influencing this change, need to alter how preservice science teachers are prepared. Science teacher educators carry the responsibility to teach NGSS to preservice teachers, thereby equipping them to teach and apply NGSS practices in their K-12 classrooms.

Conclusion

Teacher education is essential for the preparation of highly qualified teachers. We are entering into an era in which teacher education research suggests a new approach to the methodology teacher educators use to prepare preservice teachers, namely practice-based pedagogy. Simultaneously, the introduction of NGSS demands an approach to teaching science in a more authentic manner by focusing on scientific practices. The alignment and convergence of these two events suggests that science teacher educators will need to be prepared to teach NGSS and to reframe their approach to preparing preservice science teachers.

What remains unclear is what science teacher educators know about NGSS. The little that we know about this process gives credence to the importance of understanding how science teacher educators are prepared to equip preservice teachers to teach NGSS. My research sought to investigate what science teacher educators know about NGSS and what associations may exist between science teacher educators' level of knowledge of NGSS and their professional background and their institution of employment. We must understand science teacher educators as well as the systems that are in place to help them grow professionally, because their PCK impacts the preparation of preservice science teachers.

Chapter 3: Methods

Background

The Next Generation Science Standards (NGSS) provides content standards for what students should know in science classes (e.g., learning progressions for disciplinary core ideas), outlines what students should be able to do, and what classes that utilize science practices might look like (e.g., students engaging in discourse through scientific modeling and argumentation). In NGSS, these practices are one of the dimensions, called the Science and Engineering Practices (SEP). However, NGSS does not articulate how teachers might facilitate students' use of SEPs to acquire content. This marriage of content and practice is one of the defining features of NGSS; if not used, much of the objective of NGSS is nullified. Because this type of teaching is not prevalent in science classrooms (Banilower et al., 2013; Weiss et al., 2003), students who are accustomed to traditional science teaching need to be prepared to approach and engage in scientific practices. Teachers, too, need to learn how to teach science in a way that they may not have been taught in their own education. As teacher education programs (TEP) are presumably attempting to incorporate NGSS in science methods courses, I sought to understand what science teacher educators (STE) in these programs know about NGSS and the relationships that their professional experiences and the institutions at which they work might have with their knowledge of NGSS.

Research Questions

1. What do STEs know about NGSS?
2. What is the relationship, if any, between STEs' professional background characteristics and their knowledge of NGSS?

3. What is the relationship, if any, between STEs' institutions and their knowledge of NGSS?

Research Design

The purpose of this study was to explore STEs' knowledge of NGSS and factors that might predict STEs' understanding of NGSS. Because a goal of the study was to understand STEs' knowledge of NGSS, quantitative data collection allowed for measurement of their knowledge, as well as investigation of the existence of any patterns across this population. A survey was created to capture STEs' understanding of NGSS, which was drawn from the work of Lee et al. (2019). Demographic questions were informed by a study conducted by Goodwin et al. (2014). Using a survey to gather data was appropriate because the goal was to reach a relatively large group of STEs, which would have been time- and cost-prohibitive had interviews been used instead. In addition, the breadth of data collected by survey was informative because so little was previously known about this population.

Site and Population

I systematically built a database of STEs based in western states of the United States. Contact was established either through my personal network of colleagues and mentors or through culling information directly from TEPs, either by website or program administration, culminating in the identification of 295 STEs. Because teacher credentialing in these states vary (e.g., baccalaureate vs. post-baccalaureate process), preservice teachers start in these programs with different levels of science expertise, providing a range of backgrounds.

Data Collection Methods

The survey (see Appendix A) has two components. The first component consists of demographic questions about STEs' professional background and the characteristics of the institutions where they work. These questions were based on a study conducted by Goodwin et al. (2014), which studied teacher educators, what they should know, and what they should be able to do. In their study, variables such as years teaching, years in education, and primary use of professional time were used to determine correlations between teacher educators and what they value.

The second component measures STEs' understanding of NGSS. NGSS questions were created based on the work of Lee et al. (2019). There were eight NGSS questions, which chronicle a unit of study. Each question represented one of the SEPs (e.g., Asking Questions and Defining Problems, Developing and Using Models, etc.). For each question, participants read two dichotomous scenarios and then decided how NGSS-aligned each scenario is with respect to the other. The answer choices were "Only [scenario] A is NGSS aligned," "[Scenario] A is more aligned, but [scenario] B is somewhat aligned," "[Scenarios] A & B are equally NGSS aligned," "[Scenario] B is more aligned, but [scenario] A is somewhat aligned," and "Only [scenario] B is NGSS aligned."

The SEP items asked participants to choose a response from a set of categories about the scenarios being consistent with the NGSS. The correct answers were created using the science unit that the scenarios were drawn on, as well as SEP descriptions and learning progressions in the NGSS. A key was created (see Appendix A) and used to score the NGSS questions. While they were designed with one correct answer – one category choice was correct – it became clear in the analysis that many respondents chose the category closest to the correct category. Thus, in order to give respondents more credit and diversify the scores, the closest category received a half a point. The maximum possible score that could be earned on the NGSS questions was eight.

The survey was created using Survey Monkey and distributed by email. While some emails were sent on my behalf, the majority were sent directly by me to teacher educators at post-secondary institutions' (i.e., colleges and universities) TEPs across Arizona, California, Nevada, Oregon, and Washington in order to collect a representative data set. Targeting these institutions across these western states provided a large sample size for the survey. The survey was sent to 295 people, representing 75 postsecondary institutions. Although 104 people engaged with the survey by answering at least one question, 83 people answered all of the NGSS questions and 80 people completed all 26 questions used in the analyses. The survey was open from June 2020 to April 2021.

Participants were incentivized by entry into a raffle: a drawing for one (1) $250 gift card, one (1) $100 gift card, and three (3) $50 gift cards. Participation in the study was not required in order to be entered in the drawing.

Measures

The following list outlines the sets of survey items that correspond to their respective research questions in order of the research questions:

- Survey questions 1-8 were designed to understand what teacher educators know about NGSS (RQ1).
- Survey questions 9-18 gathered information about STEs' professional background in order to determine if there is a relationship between their background and their knowledge of NGSS (RQ2).

- Survey questions 19-26 pertain to STEs' institutions, which were compared with their knowledge of NGSS for the presence of a relationship (RQ3).

Data Analysis Methods

The survey data was analyzed through the use of descriptive statistics, chi-square analysis, and cross-tabulation analysis. Descriptive statistics, i.e., frequencies, were used to examine STE background information, including their professional experience (e.g., type of courses taught, experience as K-12 educator) [questions 9-18], their institution's attributes (e.g., public vs. private; level of research activity, other; etc.) [questions 19-22], and their relationship to their institution (e.g., full-time vs. part-time; number of years at their institution, etc.) [questions 23-26]. Data from these background questions were used to describe the population of STEs. In addition, I examined whether understanding of NGSS was associated with these background characteristics. Most of the questions that rely on descriptive analysis were multiple choice; two questions asked participants to type in their answer (e.g., the academic discipline in which they earned their highest degree).

A second analysis, chi-square analysis, was conducted with data from questions related to the SEPs, which examined the relationship between these responses and participants' background information. For example, what was the relationship, if any, between science teacher educators' institution and their level of understanding of NGSS?

In order to test the extent to which STE background predicted understanding of NGSS, a third analysis of the data was done using cross-tabulation analysis. For example, how likely were science teacher educators at "very high research activity" institutions to respond a certain way to one of the NGSS questions?

When totaling responses from the SEP questions, composite score ranges from two to six, which includes half points. I could have treated this as interval data but I left it as categorical in the analysis to mirror what they were tasked to do: decide among a set of categorical choices. I did run ANOVAs that corresponded to the Chi-Square analysis and the results were exactly the same except in one case that is shared in the findings.

The analysis was able to integrate the data to show a consistency, or lack thereof, between broadly applicable data from the survey study. Findings that were incongruent raised questions for further exploration.

Ethical Issues

The survey instrument did not collect any information that could later be used to identify an individual. All data collected was coded to protect participants' identities. In the unlikely case that participants' identities and responses leak, there could be risks that might affect receiving promotions, securing tenure, or, at worst, being terminated from their position.

Reliability and Validity

The survey instrument was not tested for validity. However, part of it was created based on a survey used by Goodwin et at. (2014). Although their survey was not publicly available, their analysis revealed the demographic data that was collected for their survey. The survey instrument was piloted and revised prior to distribution.

Summary

Not much is known about teacher educators, including STEs. We do not know their background, let alone understand how they are prepared in light of policy changes and education reform, such as NGSS. By using a survey, this study examined the extent to which STEs that teach science methods courses in TEPs understood NGSS and the relationship of STEs' backgrounds on that understanding.

Chapter 4: Results

Introduction

The purpose of this survey study was to learn what science teacher educators (STE) know about the Next Generation Science Standards (NGSS), specifically the Science and Engineering Practices (SEP). The focus of the study was on SEPs, rather than the Disciplinary Core Ideas or the Crosscutting Concepts, because the SEPs best represent the philosophy of NGSS, namely that students are participating in practicing science. The SEPs also require the largest shifts in science teachers' thinking and practice. Responses were analyzed using descriptive statistics and Chi-Square tests to determine how STEs' professional background and institutions might play a role in their understanding of NGSS.

Surveying teacher educators provided a range of information about who STEs are as a group and how they understand NGSS. In this chapter, I share what was learned from the STEs in three sections: what we learned about them as a group, how they responded to NGSS scenarios, and the relationship between who they are and their responses to NGSS scenarios.

Demographic Results

The survey was sent to 295 people. There were 104 participants who started the survey and answered at least one question. The NGSS scenario questions were completed by 83 people. Eighty people answered all 26 of the survey questions.

The pool of teacher educators in this sample was more experienced than not (see Appendix B, Table 6). Just under a quarter of the participants had 21 or more years of experience as teacher educators and nearly half (48.8%) had more than 10 years of experience. In contrast, 27.7% of participants had been teacher educators for five or fewer years.

Degrees

Participants' highest degree and highest science degree resulted in different outcomes. The largest group of participants' highest degree was a Ph.D. (66.3%) (see Appendix B, Table 7); all doctorates combined made up 81.4% of respondents. However, when examining the subject area of the highest degrees earned, only 11.3% were in a science field, with the highest represented fields being Education (36.3%) and Science Education (28.7%) (see Appendix B, Table 8). This is not surprising considering that the subjects of the survey are teacher educators. By the same reasoning, it is also unsurprising that participants' highest degree in a science field trends in the opposite direction from those with doctorates (11.3%), followed by masters (26.3%), and then bachelor's degrees (38.8%) (see Appendix B, Table 9). Nearly a quarter of participants' highest science degree was a minor (7.5%) or none (16.3%). This is a striking discovery considering that they are responsible for preparing preservice science teachers yet have not earned a postsecondary degree in a science field.

Courses

The majority of participants (60%) taught methods courses at least once every academic year, while 10% taught methods courses once every 2-3 years, and 16.3% only once every 4+ years (see Appendix B, Table 10). The NGSS was introduced in 2013, which means that STEs who sometimes teach methods courses have had no more than 2 years to have taught NGSS at the time they took the survey. In other words, 30% of participants would have had limited opportunity to explicitly teach NGSS.

Given that STEs were the target population, it makes sense that Elementary Science Methods (55.0%) and Secondary Science Methods (53.8%), which were evenly distributed, were the most common courses taught by participants (see Appendix B, Table 11). This was followed by practicum courses, which were taught by nearly a third (31.3%) of respondents. Since STEs who teach practicum courses support preservice teachers in the field, they represented an important group of STEs in this study. In theory, this group of participants could better understand the SEPs because they would be able to work with teachers on implementing science-specific pedagogy.

Eighty percent of participants had experience teaching K-12. Of these, 23.8% had more than 10 years of experience as a K-12 teacher and over half (52.5%) spent 6 or more years in compulsory education (see Appendix B, Table 12). In my analysis, I collapsed years of experience into fewer groups: novice (STEs with up to 2 years of K-12 experience), emergent (3-5 years), established (6-10 years), and experienced (11 or more years). The reduction in categories focused in on more or less teaching experience as a way to maximize the cells for examining the relationships between experience and other outcomes.

Institutions

In examining attributes of participants' institutions, the majority (73.8%) work as teacher educators at a public institution (see Table 1); 28.7% reside at institutions with very high research activity (R1; see Table 1), while 63.8% are at institutions that engage in a lower volume of research, i.e., high (R2) or some (R3). And the largest group (38.8%) work at institutions that have more than 200 students in their Teacher Education Program (TEP) (see Table 1).

Table 1

Teacher Educators by Institution

	% of Teacher Educators (n=80)
Type of Institution	
Public	73.8
Private	23.8
Not Reported	2.5
Institution's Level of Research	
Very High	28.7
High	21.3
Some	42.5
Don't Know	5.0
Not Reported	2.5
Number of Students Enrolled in TEP	
<100	36.3
100-200	22.5
>200	38.8
Not Reported	2.5

Nearly a third (28.9%) of teacher educators in the study have been at their institution for more than 10 years (see Table 2). Of the participants, 8.8% have been at the same institution for 21 or more years. Those who more recently joined the institution and had been there for five years or less accounted for 43.9% of the participants. The majority of participants (80%) are full-time faculty and only a quarter do not spend any time conducting research. There were 21.3% of participants who use more than 50% of their professional time engaging in research and the remaining, just over half (51.2%), spend up to half of their time doing research.

Table 2

Teacher Educator Institutional Demographics

	% of Teacher Educators (n=80)
Time Working at Institution (years)	
<1	3.8
1	7.5
2	11.3
3	11.3
4-5	10.0
6-10	25.0
11-15	11.3
16-20	8.8
≥21	8.8
Not Reported	2.5
Status	
Full-Time	80.0
Part-Time	17.5
Not Reported	2.5
Time Spent on Research	
>50%	21.3
<50%	51.2
0%	25.0
Not Reported	2.5

As a group, participants generally work at public institutions that focus on teaching at least as much as research, and have a medium to large TEP. They are very experienced, regularly teach methods courses, and three-quarters of them spend time doing research. The variability in many of these categories were used to analyze how their experiences and institutions might relate to their responses to NGSS questions.

NGSS Responses

Table 3 summarizes participants' responses to the NGSS questions. In looking at responses across the scenarios, it was clear that some were more challenging than others for the teacher educator participants. However, in general, correct responses to the scenarios were less common.

Question 6, which represented SEP 4 (Analyzing and Interpreting Data), was the most correctly answered question for full credit. It was also the only question for which all participants received credit; in other words, all participants received full (61.3%) or partial credit (38.8%) for question 6. One explanation is that in both scenarios, students were explicitly described as analyzing data, which is part of that SEP's description (i.e., "Analyzing and Interpreting Data"). In both scenarios, students also met with other groups to compare their results.

The SEP survey item that yielded the least amount of credit across participants was question 5, which pertained to SEP 5 (Using Mathematics and Computational Thinking). This item may have been more challenging to participants because the activities in which the students engaged were very different between the two scenarios. In one scenario, students were using a computer simulation; in the other, students were creating a model. Another reason this could have been challenging is that participants may be less acquainted with this particular SEP, i.e., Using Mathematics and Computational Thinking, or were not familiar with PhET simulations. Partial credit was given to 53.8% of participants. Only 12.5% of participants received full credit, and 46.3% of participants received no credit.

Table 3

Teacher Educator Responses to NGSS/SEP Scenarios (n=80)

	Full Credit (%)	Partial Credit (%)	No Credit (%)
Q1 (SEP 1)	12.5	56.3	31.3
Q2 (SEP 3)	41.3	38.8	20.0
Q3 (SEP 7)	40.0	46.3	13.8
Q4 (SEP 2)	45.0	21.3	33.8
Q5 (SEP 5)	12.5	41.3	46.3
Q6 (SEP 4)	61.3	38.8	0.0
Q7 (SEP 8)	27.5	48.8	23.8
Q8 (SEP 6)	25.0	37.5	37.5

Table 4 provides participants' total NGSS SEP scores across the eight scenarios. With a possible composite score of 8.0, no participant received the maximum points. In fact, the highest score attained was 6.0 points by 10% of participants. The lowest score earned was 2.0 points by 2.5% of respondents. The average score was 4.4 points, the median was 4.5 points, and the mode was 5.0 points.

Table 4

Teacher Educators' Total SEP Scores

Total Points	% of Teacher Educators (n=80)
2.0	2.5
2.5	7.5
3.0	8.8
3.5	7.5
4.0	13.8
4.5	13.8
5.0	21.3
5.5	15.0
6.0	10.0

Relationship Between Demographics and NGSS Scores

To understand whether particular demographic characteristics were related to NGSS scores, I conducted a series of chi-square analyses and looked at patterns in crosstabs. I looked at all of the demographic variables from the survey that had variability in responses. Overall, these variables were not related to scores on the NGSS scenarios.

I ran independent chi-square tests on the distribution of NGSS scores on each of following: K-12 teaching experience, whether STEs' institution is public or private, STEs' institution's research activity, STEs' employment status, STEs' time spent in research, STEs' regularity in teaching methods course, STEs' experience teaching secondary science methods , and STEs' experience teaching elementary science methods (see Appendix B, Tables 13-20, respectively). None of these showed any statistically significant difference in the distribution of the demographic variables on understanding of NGSS.

Independent chi-square analysis on participants' highest degree held did produce a statistically different distribution on scores (chi-square = 17.96, df = 8, p = 0.022) (see Table 5). Interestingly, this was not in the direction one might initially expect. The relationship was not linear, rather 40% of participants whose highest degree was a Masters scored 6.0 points (the highest score) as compared to 6.2% of Doctorate holders. At the same time, the teacher educators with Masters degrees had the highest percentage of the lowest score, 2.0 points. Given the number of tests run and this rare finding, I hesitate to make much of this one significant finding.

Table 5

Total SEP Score Considering Highest Degree

Total Points	**% of Masters as Highest Degree (n=10)**	**% of Doctorate as Highest Degree (n=65)**
2.0	10.0	1.5
2.5	0.0	6.2
3.0	0.0	9.2
3.5	20.0	6.2
4.0	10.0	13.8
4.5	0.0	15.4
5.0	10.0	24.6
5.5	10.0	16.9
6.0	40.0	6.2

Pearson Chi-Square = 17.96, df = 8, p = .022

Chapter 5: Discussion

Introduction

A teacher educator will impact thousands of teachers, classrooms, and students every year. Due to this exponential influence, it is important that teacher educators stay abreast of current standards and effective teaching practices so that their students can benefit from the latest education reform.

The Next Generation Science Standards (NGSS), the most current science standards based on the National Research Council Framework that shape the state standards of 44 states and the District of Columbia (NRC, 2012), require shifts in current pedagogy for implementation. These shifts require teachers to create learning environments and activities that place students in the center of the learning experience (Reiser, 2013). For example, rather than the teacher asking driving questions, students might ask questions that drive investigations, which they are then expected to design and carry out. In this way, classroom science incorporates authentic scientific practices. The NGSS specifies these as Science and Engineering Practices (SEP). My study focused on the SEPs, one of the three dimensions of NGSS and the dimension that is associated with the largest shift in a science teachers' practice.

I sought to figure out what science teacher educators (STE) know about NGSS and how their experiences, such as their background as K-12 teachers, their highest degree attained, type of institution in which they work as well as other factors, might influence their knowledge of the NGSS SEPs. In this chapter, I summarize the study's findings and provide a discussion of their significance and implications for practice. I discuss the limitations of the study and reflect on how my thinking and practices have changed through this experience and provide recommendations for future research.

Summary of Findings

Based on the variation of responses to the eight NGSS items, STEs as a group do not understand NGSS well. The fact that the highest score earned on the eight SEP questions was 6.0 points was surprising. From a sample of 80 STEs, I expected at least one participant to have answered all of the SEP questions correctly. A concerning result is that several STEs earned 2.0 or 2.5 points, especially considering that they are responsible for preparing preservice teachers to teach NGSS.

In looking across all of the relationships between the SEPs and characteristics of the STEs, I did not find any pattern that indicated that certain types of experience led to better scores on the SEP scenarios. For example, how regularly STEs taught methods courses, the type of methods courses they taught (elementary or secondary), and their years of experience as K-12 teachers did not show any relation to how they scored on the SEP questions. The fact that these measures did not relate to the participants' SEP scores was surprising. I predicted that by gaining experience in teaching science as well as by preparing preservice teachers to teach science, STEs would have a better handle on the most current standards and the urgency to learn them; however, the data did not support this.

Furthermore, neither their highest degree in a science field nor their field of study distinguished what STEs knew about NGSS. The institutions where STEs taught methods also did not distinguish STEs in relation to their scores on the SEP scenarios. I did not find a difference in SEP scores based on whether STEs taught at public institutions or private institutions. I expected the size of their institution's teacher education program (TEP) to have an impact, thinking that a larger TEP might provide more resources in ensuring that prospective teachers are better prepared in NGSS.

Just as the size of STE's TEP was not related, neither was the institution's level of research activity. STEs at institutions with high research activity (R1) and those who work at institutions that focus more on teaching than research (R3), as well as R2 institutions, did not perform differently on the SEP questions. Considering that university faculty at R2 and R3 institutions spend less time on research, which allows them more time for other responsibilities, such as teaching, I anticipated that STEs at R2 and R3 institutions might have scored higher on SEP questions. Other variables that were hypothesized to have a relationship with SEP score – including STEs' years of experience, their employment status, and how much or little research they engaged in – did not show any such relationship.

The only significant association found in the characteristics of the STEs and the SEP scores involved the highest degree held by STEs. The outcome was contrary to what was expected; while I expected to see STEs who held terminal degrees better grasp NGSS, more of the participants with Master's degrees scored higher than their counterparts who held a Doctorate. However, teacher educators with Masters also happened to score the lowest, too. Given the number of statistical analyses conducted, I hesitate to make much of this one rare, significant finding.

Analyses examined relationships with all of the aforementioned demographic variables and the SEP variable and generally found no association (except for the highest degree held). This leaves me to conclude that there is likely no relation to SEP scores, which means that background, experiences, and institution are not predictive of what STEs know about NGSS.

Significance of Findings

One significant finding is that people in science education do not understand the nature of scientific practice. Long before the NGSS popularized the scientific practices, i.e., SEPs, there have been efforts to make science education more grounded in science practices (Berland & Reiser, 2009; Passmore & Stewart, 2002; Windschitl et al., 2012). However, after years of attempting to infuse science practices into K-12 classrooms and methods courses, we are reminded how difficult it is for someone to shift their teaching practices. Cochran-Smith (2003) reminds us that the work of unlearning ideas and practices is difficult, yet necessary precursor to be able to abandon how we think about instructional practices and to subsequently change them.

Another significance of the findings of this study lies in the absence of relationships between STE's backgrounds and institutions with what they know about NGSS. It highlights how little we know about STEs and how they learn and grow in their own practice.

These findings reflect the lack of data regarding how teacher educators are themselves prepared to teach prospective teachers. This study exposes the gap in the literature about teacher educators. We do not have a grasp of who STEs are and how they become teacher educators. The requirements of becoming a teacher educator vary by state. For example, in California, a prerequisite is K-12 teaching experience. Understanding the challenges of K-12 teachers would only help teacher educators in their preparation of preservice teachers. In contrast, Nevada does not require this experience of its teacher educators.

In addition, it is apparent we need to know how STEs grow professionally as educators in learning about new standards, adopting best practices, and overall improving their own teaching practices. Cochran-Smith et al. (2020) pointed out that a doctorate in an education-related field is falsely assumed to be sufficient preparation for one to teach preservice teachers. She mentioned that the few programs that intentionally prepare teacher educators (e.g., Montclair State University; University of Colorado, Boulder) are the exception in that they explicitly address how teacher educators should be preparing preservice teachers. They echo the common sentiment that there is a lack of comprehensive effort to prepare teacher educators and maintain continual development of their knowledge and skills.

In the absence of a concerted effort in the preparation and ongoing professional development of teacher educators, there exist studies in which individuals participate in self-study (Cochran-Smith & Lytle, 2009). While these studies show a desire for ongoing growth, they betray a larger issue, namely the importance of systemic infrastructure to prepare STEs and support their continued professional growth. STEs are an important lever for the implementation of NGSS, yet we have not focused efforts to support STEs.

This study highlights the importance of a coherent implementation rollout. The work in creating the NGSS, a widely-accepted set of national standards, has pointed out a gap in its implementation efforts at a focal point of the educational process, i.e., teacher educator preparation. The statewide implementation plan did not include STEs. The findings suggest the need to involve STEs in statewide and regional planning of NGSS efforts as well as within their own institutions.

Implications and Recommendations for Practitioners

This study's titular question remains: "Who trains the trainer?" Perhaps more importantly, "how do we train the trainer" in the current education landscape where few teacher educators are explicitly prepared for their role in teacher education programs? We ought to build systems to ensure that education policy stays aligned with its implementation in teacher education. Until those systems are in place, we must actively work from within teacher education to build practices that will support teacher educators. I will share the implications of my study and provide recommendations aimed at state and regional approaches and institutional efforts to support teacher educators.

Statewide and Regional

The development of policy needs to start with a deep understanding of the integration of the practices that will take the reform from theory to classroom execution. In this case, my recommendation to policymakers is to build a statewide NGSS implementation plan that not only includes but emphasizes the involvement of STEs in their uniquely important role of preparing teachers. While California and various county offices of education have been engaged in rolling out the NGSS, STEs were not specifically recruited to these efforts. Searches for NGSS resources that are specific to STEs return empty. Thus, current implementation plans ought to be updated to include a concerted effort to support and utilize STEs. This should be guided by a strong understanding of the vision and philosophy of NGSS, especially as the standards require a shift in teaching practices (Reiser, 2013), which has been a challenge for classroom teachers to individually adopt. As described by Windschitl and Stroupe (2017), this poses an additional layer of challenges for STEs because it necessitates that they deeply know NGSS and personally make requisite shifts in their own teaching practices so that they are able to exemplify and teach them to preservice teachers (see Figure 1, p.4).

Another statewide recommendation is to create a network for STEs, which would allow for an exchange of ideas, questions, and experiences. When preparing to distribute my survey, I was unable to locate a centralized forum to find STEs. I started with contacts I had in the field and later searched through individual postsecondary institutions' websites to create a list. An

STE network would not only allow for the propagation of ideas and best practices, but could also allow for collaboration and research.

Along those lines, the state could also support STEs by sharing resources for science methods courses. Specifically, providing NGSS resources that are endorsed by experts could be invaluable for STEs in the absence of a formal preparation program. Exemplars would allow for individual STEs to use these resources as models when planning their methods classes. Professional learning communities could also use this material in designing curriculum. Demonstration of specific strategies for implementing and embedding into practice would showcase the challenging shifts that need to be made, not only in the K-12 classroom, but also the additional shifts that STEs must make in science methods courses. Ideally, this would lead to an alignment of how NGSS and its practices are modeled for preservice teachers.

Regional education policymakers and science education leaders could consider creating opportunities for collaboration among STEs. Although county offices of education in California have created partnerships with Schools of Education and built Science Communities of Practice have made efforts towards including STEs, they still lack emphasis on STEs. Next steps could be to promote more collaboration of STEs by allowing opportunities to observe one another across institutions. STEs might be encouraged to engage in cycles of lesson study that would allow for feedback on NGSS practices in one another’s science methods courses.

Institutional

University leadership has the opportunity to bolster the growth and development of STEs by providing more individualized support, such as access to instructional coaches. Expert NGSS practitioners could provide one-on-one feedback and perhaps co-teach in order to model effective practices to teach NGSS. For larger universities that have multiple STEs, the institution might consider organizing, and perhaps even incentivizing, NGSS-specific professional development opportunities.

Based on my findings, all STEs need much more work, and support, towards developing a deeper understanding of NGSS and the nature of science practices. This will require more than mere exposure to, or knowledge of, the NGSS. Rather, STEs will need to have access to models of what this looks like in the K-12 classroom as well as in methods courses. This is in line with Windschitl and Stroupe's (2017) three-story challenge, which describes the uniquely difficult demands on STEs, especially in light of the shifts in teaching and learning required by NGSS. In order to be effective, STEs need to understand what is expected of students, i.e., the standards – science content, instructional practices, and the connections between disciplines – and know what science teachers need to know. By addressing these, STEs can help science teachers make instructional shifts so that they will be able to teach in a way that engages students to learn through science practices.

Limitations of this Study

The lack of findings may be due to the measure itself and the fact that the survey design did not distinguish well between those who understood NGSS and those that did not. No matter how I looked at the data – by item, by subsets of stronger items, etc. – the measure did not help to separate the participants nor reveal any relationship. The fact that no participant earned a full score (8.0 points) and that those who had high scores still missed items cast doubt on the validity of the measure. Ultimately, the SEP measure may not be fine-tuned enough to differentiate STEs who are knowledgeable about NGSS from those who are not.

Another limitation of this study is that it relied solely on a single quantitative measure with a potentially limited outcome measure. The data from the survey's NGSS questions would benefit from a follow-up conversation about the rationale for why participants chose certain responses. A mixed-methods approach that included interviews of STEs around their SEP answers would have provided a more nuanced understanding of their grasp of NGSS and given insight into factors contributing to lack of understanding. Detection of these weaknesses would provide research targets for future improvement.

A final limitation worth mentioning is that in some of the analyses, the group size was small. In these cases, the group differences would have to be larger to power a statistically significant result.

Recommendations for Future Research

Although this study raised questions about several hypothesized relationships between STEs and their understanding of NGSS, it was not able to identify what factors do contribute to understanding NGSS. This presents a challenge for TEPs when hiring STE to teach methods courses and necessitates that we find other ways to identify who to hire as STE. Future research could examine how people come to understand NGSS and what causes the shifts in their thinking that allow for shifts in their teaching practices.

There is still a gap in what we know about teacher educators. Studying this group of people, how they are prepared, and how they are able to continue to grow in content knowledge and practices, especially as new standards are introduced, would provide insight into this important group of educators. It would be impactful to understand their needs and areas for support.

In specific, STEs have additional challenges facing the overall decline of science education in America. A better understanding of the preparation of science teachers, from STEs in TEPs to ongoing PD, will move K-12 education forward. Although important reform, such as NGSS, is being made by academic associations such as the National Research Council, the practical implementation must be as important as the theoretical crafting. Specific attention to STE incorporation of new standards will result in exponential influence as knowledge trickles down to science teachers and then students themselves.

Reflection

As I continue my work as a high school administrator, I am daily reminded of the importance of every participant at every level of the educational endeavor. Seeing teachers give their very best encourages me as a school leader. However, at times my work can be discouraging as well because I always want to see students and teachers succeed. Such discouragement comes when I meet teachers who do not agree with the rationale for NGSS or when observing science classrooms in which teachers seem to be blatantly disregarding the NGSS for a more traditional, teacher-centered approach to instruction.

This frustration is not centered on the teachers themselves. Rather, through my study, I was constantly reminded of the meta nature of teaching. Research on learning and the brain has revealed that students learn by constructing knowledge according to the various schema they have already learned. When teaching a child to tie a shoe, merely explaining the steps or demonstrating the actions is not sufficient; the child must be actively involved in the process. Similarly, if NGSS is merely explained to K-12 science teachers without actively engaging them in the processes that will shift their teaching, the expectation that their students would be able to learn and think differently would be unfair. While STEs might be asked to embed these practices in their work of preparing preservice science teachers, they will not be subject to the same level of scrutiny. If we want to make sure that NGSS does not become a missed opportunity, it is important that we provide support for STEs, because as complex as teaching is, teaching to teach is even more so.

I can't help but wonder if my study provided some benefit to the advancement of NGSS through raising my participants' awareness as they examined what they know, and perhaps more importantly what they don't know, about NGSS. At the least, I hope that the dichotomous SEP scenarios reminded the STEs who saw my survey that NGSS requires material changes to their planning and practices. As such, I wonder if science education might benefit from an NGSS training program – similar to compliance initiatives such as first aid training – for educators at all levels, including STEs.

I realize that my study focused on preparing preservice teachers for NGSS in TEPs and that in-service professional development is an important learning space for teachers. This challenge is real: it has been eight years since NGSS was introduced and teacher buy-in remains a big hurdle.

Still, the more I dig into my own understanding of NGSS, the more I am excited about what it represents for the future of science education. I envision a near future in which students are not merely learning about science, but rather are engaged in the scientific endeavor throughout their K-12 education.

Appendix A: Survey

Thank you, in advance, for responding to my survey. I am a graduate student at UCLA working towards an Ed.D. in Educational Leadership. This survey is being distributed to higher education institutions across the Western States. I hope to learn about your experience as a teacher educator.

The survey consists of 8 NGSS scenarios followed by some demographic questions and will take approximately 15 minutes.

You will have the option to share your contact info at the end of the survey to be entered into a drawing for one of five (5) Amazon Gift Cards ranging from $50 - $250. Participation in the study is not required in order to be entered into the drawing. Thank you, again.

NGSS SEP Questions

1. In a unit of study in science, 5th-grade students will be learning about what happens to their garbage after they dispose of it. The teacher starts the unit by observing a pile of garbage that was prepared by the teacher. After students are given a chance to examine the garbage, the teacher engages them in a quick write of their observations. For homework, students engage in a similar exercise with their garbage at home. Students share their observations and comparisons of their home trash with the teacher's trash.

*The table below describes two possible scenarios that can take place next. After reading the scenarios, decide which scenario is more aligned to NGSS with respect to the Science and Engineering Practices (SEP), "**Asking Questions and Defining Problems**."*

ASKING QUESTIONS AND DEFINING PROBLEMS	
(A)	**(B)**
The teacher directs students to ask questions that they might have about the trash. In groups, they share their questions. Afterward, each group shares their questions with the whole class.	The teacher calls on students to share questions they might have until all student questions have been asked.

1	**2**	**3**	**4**	**5**
Only A is NGSS aligned	A is more aligned, but B is somewhat aligned	A & B are equally NGSS aligned	B is more aligned, but A is somewhat aligned	Only B is NGSS aligned

2. The driving question for the unit is "What happens to our garbage?" Students will engage in an experiment to answer the driving question. The teacher guides the class in a discussion about the parameters of the lab, including the length of the study (5 weeks), materials that can or cannot be used, and what students might want to be thinking about to answer the driving question. Throughout the unit, students will work in groups of four.

   *The table below describes two possible scenarios that can take place next. After reading the scenarios, decide which scenario is more aligned to NGSS with respect to the Science and Engineering Practices (SEP), "**Planning and Carrying Out Investigations**."*

PLANNING AND CARRYING OUT INVESTIGATIONS	
(A)	**(B)**
Students review lab materials and a timeline that includes the steps that they will take over the coming weeks. The teacher checks for understanding by calling on groups to share.	The teacher tasks each group with selecting materials they will use to carry out the investigation. Each group shares their ideas with the class.

1	**2**	**3**	**4**	**5**
Only A is NGSS aligned	A is more aligned, but B is somewhat aligned	A & B are equally NGSS aligned	B is more aligned, but A is somewhat aligned	Only B is NGSS aligned

3. In order to study what happens to garbage, students work in their groups to assemble landfill bottles that serve as a model for their investigation. Half of the class create open system landfill bottles, while the other half create closed system ones. The teacher tells the class that they will be investigating their landfill bottles over several weeks to observe changes to their garbage over time, including changes in mass and what happens to various materials when they are crushed.

   Students crush various materials (e.g., soda can, a piece of paper, a cookie, etc.) which are provided by the teacher (not from their landfill bottles). Students examine properties of each material (i.e., color, texture, reflectivity, and weight) before and after crushing.

   *The table below describes two possible scenarios that can take place next. After reading the scenarios, decide which scenario is more aligned to NGSS with respect to the Science and Engineering Practices (SEP), "**Engaging in Argument from Evidence**."*

ENGAGING IN ARGUMENT FROM EVIDENCE	
(A)	**(B)**
The teacher engages students in a discussion with their groups to answer the question: "When materials are crushed in a landfill bottle, do the materials change?" After each group shares their responses with the class, a representative from each group argues why their answer is best.	The teacher engages students in Think-Pair-Share, to the following question: "When materials are crushed in a landfill bottle, do the materials change?" The teacher then instructs students to complete a "Claim, Evidence, Reasoning" worksheet in which students support their answers.

1	**2**	**3**	**4**	**5**
Only A is NGSS aligned	A is more aligned, but B is somewhat aligned	A & B are equally NGSS aligned	B is more aligned, but A is somewhat aligned	Only B is NGSS aligned

4. The teacher prepares an activity to engage students in examining a sub-question, “What happens to materials that we can’t see anymore?” In this activity, students weigh sugar and water, prior to adding the sugar to the water. After all of the sugar dissolves, students weigh the mixture, record the results, and see that the total weight of the water and the sugar was the same before and after the sugar was dissolved.

   *The table below describes two possible scenarios that can take place next. After reading the scenarios, decide which scenario is more aligned to NGSS with respect to the Science and Engineering Practices (SEP), “**Developing and Using Models**.”*

DEVELOPING AND USING MODELS	
(A)	**(B)**
The teacher prompts students to discuss in their groups what happened to the sugar after it was no longer visible. The group discussion is followed by a task given to each group to draw a diagram to help visualize what they observed.	The teacher provides each group with a molecular model set to help them visualize what happens as sugar is dissolved in water. After students have had a chance to work with the models, the teacher uses the models to explain what happened to the sugar after it was no longer visible.

1	**2**	**3**	**4**	**5**
Only A is NGSS aligned	A is more aligned, but B is somewhat aligned	A & B are equally NGSS aligned	B is more aligned, but A is somewhat aligned	Only B is NGSS aligned

5. A few days later, students investigate another sub-question: "What is that smell?" In this study, students study gases, as they think about how smell travels. Students explore properties of gases through creating models of how smell travels through the air, examining air in balloons and air in a sealed syringe as its plunger is moved, and access a computer simulation.

   *The table below describes two scenarios. After reading the scenarios, decide which scenario is more aligned to NGSS with respect to the Science and Engineering Practices (SEP), "**Using Mathematics and Computational Thinking**."*

USING MATHEMATICS AND COMPUTATIONAL THINKING	
(A)	**(B)**
In their groups, students explore a PhET simulation, called "Phase Changes." The simulation allows users to adjust the amount of air that is added to a chamber, observe the speed and direction of particles, and shows changes in pressure. After discussing in small groups, they write their thoughts in their science notebooks.	In their groups, students create models of gas particles and how they travel. Students describe and estimate what might happen to particles if more are added to their model, and the effect on the speed and direction of the air, as well as changes in pressure. After discussing in small groups, they write their thoughts in their science notebooks.

1	**2**	**3**	**4**	**5**
Only A is NGSS aligned	A is more aligned, but B is somewhat aligned	A & B are equally NGSS aligned	B is more aligned, but A is somewhat aligned	Only B is NGSS aligned

6. Students check on their landfill bottles every two weeks after they were first assembled, for a total of 3 observations. At each point in time (i.e., assembly, time point 2, and time point 3), students first make predictions about what they might observe. They then record the following observations for each garbage material in their landfill bottle: smell, color, texture, and reflectivity. In addition, they record the weight of their landfill bottles, indicating whether their bottle was an open or closed system. The teacher reminds students of the driving question: "What happens to our garbage?"

   *The table below describes two possible scenarios that can take place next. After reading the scenarios, decide which scenario is more aligned to NGSS with respect to the Science and Engineering Practices (SEP), "**Analyzing and Interpreting Data.**"*

ANALYZING AND INTERPRETING DATA	
(A)	**(B)**
Students analyze the data using questions that were provided to frame their thinking on changes that they've observed over time. Within their groups, students discuss what patterns they observed in properties of materials and weights of their bottles. Groups are allowed to meet with other groups to compare open and closed systems.	Students analyze the data, which they use to compare with their predictions. Once every group has had a chance to write down their thinking, groups are given time to meet with other groups to share and compare their results and their interpretation.

1	**2**	**3**	**4**	**5**
Only A is NGSS aligned	A is more aligned, but B is somewhat aligned	A & B are equally NGSS aligned	B is more aligned, but A is somewhat aligned	Only B is NGSS aligned

7. The teacher elicits students' thinking by facilitating a discussion about what new questions they might have to help them answer the driving question, "What happens to our garbage?" Eventually, the class comes up with the sub-question, "What causes changes in landfill bottles?" to try to understand what happens with food in their bottles.

   In this investigation, each group of students prepares one agar plate. Some groups swab food materials; other groups swab non-food items. The agar plates are stored in a warm location for 3 days.

   *The table below describes two possible scenarios that can take place next. After reading the scenarios, decide which scenario is more aligned to NGSS with respect to the Science and Engineering Practices (SEP), "**Obtaining, Evaluating, and Communicating Information**."*

OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION	
(A)	**(B)**
The teacher uses a slide show to provide information about decomposers. After the presentation, students answer questions related to the information presented. The teacher also asks students to work in groups to develop any questions they might have about the presentation and/or how it might relate to their investigation of the agar plates.	The teacher gives students an article that provides information about decomposers. Students are instructed to read the article independently. Following the reading, students work in pairs to answer questions related to the article. They then discuss in their groups how the article relates to the investigation of the agar plates.

1	**2**	**3**	**4**	**5**
Only A is NGSS aligned	A is more aligned, but B is somewhat aligned	A & B are equally NGSS aligned	B is more aligned, but A is somewhat aligned	Only B is NGSS aligned

8. After learning about decomposers, specifically microbes, students are tasked with making a connection between their new learning, how it connects to the landfill bottles, and particularly how their new learning might get them closer to answering the driving question. The activity with the agar plates and the new learning relates to how the food in the landfill bottles changes.

*The table below describes two possible scenarios that can take place next. After reading the scenarios, decide which scenario is more aligned to NGSS with respect to the Science and Engineering Practices (SEP), "**Constructing Explanations and Designing Solutions**."*

CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS	
(A)	**(B)**
To support students in constructing an explanation for why the food in the landfill bottles changes, the teacher provides a worksheet that has prompts asking students to make a claim, provide evidence from their learning, and explain their reasoning.	To support students in constructing an explanation for why the food in the landfill bottles changes, the teacher posts multiple sample responses on the board. In groups, students are asked to rank the examples and provide a rationale.

1	**2**	**3**	**4**	**5**
Only A is NGSS aligned	A is more aligned, but B is somewhat aligned	A & B are equally NGSS aligned	B is more aligned, but A is somewhat aligned	Only B is NGSS aligned

Demographics

Teacher Educator Demographics

9. Are you a teacher educator, one who prepares preservice teachers?
    a. Yes
    b. No

10. How long have you been a teacher educator?
    a. Less than 1 year
    b. 1 year
    c. 2 years
    d. 3 years
    e. 4-5 years
    f. 6-10 years
    g. 11-15 years
    h. 16-20 years
    i. ≥ 21 years

11. What is the highest degree you have earned?
    a. Bachelor of Art (B.A.)
    b. Bachelor of Science (B.S.)
    c. Master of Art (M.A.)
    d. Master of Science (M.S.)
    e. Doctor of Education (Ed.D.)
    f. Doctor of Philosophy (Ph.D.)
    g. Doctorate, other
    h. Other

12. In what field was the degree (in #11) earned?

13. What is the highest degree you have earned in a science-field?
    a. Doctorate
    b. Master
    c. Bachelor
    d. Minor
    e. Other ___________________

14. In which science-field was the degree (in #13) earned?

15. Which of the following apply regarding your involvement in teaching a science methods course?
    a. I regularly teach a science methods course (i.e., at least once every academic year)
    b. I often teach a science methods course (i.e., once every 2-3 years)
    c. I sometimes teach a science methods course (i.e., once every 4+ years)
    d. Other____________________

16. Which of the following types of courses do you teach?
    (select all that apply)
    a. Foundations
    b. Elementary Methods
    c. Secondary Methods, general
    d. Secondary Methods, English
    e. Secondary Methods, Math
    f. Secondary Methods, Science
    g. Secondary Methods, Social Science
    h. Secondary Methods, other
    i. Practicum (field support)
    j. Other ___________________

17. Have you ever taught full-time as a K-12 teacher?
    a. Yes
    b. No

18. How long did you work as a full-time K-12 teacher? [only if answered yes to #21]
    a. Less than 1 year
    b. 1 year
    c. 2 years
    d. 3 years
    e. 4-5 years
    f. 6-10 years
    g. 11-15 years
    h. 16-20 years
    i. ≥ 21 years

Institution

19. In which of the following institutions do you currently work as a teacher educator?
    (if more than one, select responses based on primary assignment)
    a. Public
    b. Private

20. Which of the following best describes the institution in which you currently work as a teacher educator?
(if more than one, select responses based on primary assignment)
    a. Very high research activity (e.g., ASU, Columbia, Texas A&M, UCLA, etc.)
    b. High research activity (e.g., Azusa Pacific University, Boise State, Portland State, etc.)
    c. Some research activity, but primarily teaching focused
    d. I don't know

21. In which state is your institution located?
    a. Arizona
    b. California
    c. Colorado
    d. Idaho
    e. Montana
    f. Nevada
    g. Oregon
    h. Utah
    i. Washington
    j. Other ____________________

22. What is the approximate number of students enrolled in your institution's Teacher Education Program?
    a. <100
    b. 100-200
    c. >200

23. How long have you been working at this institution?
    a. Less than 1 year
    b. 1 year
    c. 2 years
    d. 3 years
    e. 4-5 years
    f. 6-10 years
    g. 11-15 years
    h. 16-20 years
    i. ≥ 21 years

24. What is your current status at this institution?
    a. Full-time
    b. Part-time

25. Which of the following best reflects the time you spend on research at this institution?
    a. More than 50%
    b. Some research, but less than 50%
    c. No time doing research

26. Approximately what percentage of your professional time do you spend on the following tasks at your institution?
    a. Teaching
    b. Administrative work
    c. Research
    d. Other

27. If you would like to be entered into the gift card drawing, please enter your email address. *(optional)*

NGSS SEP Questions Answer Key

Q1: 1 – Only A is NGSS aligned

Q2: 5 – Only B is NGSS aligned

Q3: 3 – A & B are equally NGSS aligned

Q4: 2 – A is more aligned but B is somewhat aligned

Q5: 2 – A is more aligned but B is somewhat aligned

Q6: 3 – A & B are equally NGSS aligned

Q7: 4 – B is more aligned but A is somewhat aligned

Q8: 2 – A is more aligned but B is somewhat aligned

Appendix B: Additional Tables

Table 6

Teacher Educators by Years of Experience as Teacher Educator

Time (years)	% of Teacher Educators (n=80)
<1	1.3
1	3.8
2	5.0
3	6.3
4-5	11.3
6-10	23.8
11-15	15.0
16-20	11.3
≥21	22.5

Table 7

Teacher Educators by Highest Degree Earned

Degree	% of Teacher Educators (n=80)
Doctor of Philosophy	66.3
Doctor of Education	13.8
Doctorate, other	1.3
Master of Science	7.5
Master of Arts	5.0
Bachelor of Science	1.3
Other (non-doctorate)	5.0

Table 8

Teacher Educators by Subject of Highest Degree Earned

Subject	% of Teacher Educators (n=80)
Science Education	28.7
Science	11.3
Education	36.3
Leadership/Admin	10.0
Math/Science/Eng Ed	7.5
Psychology	3.8
Missing	2.5

Table 9

Teacher Educators by Highest Science Degree Earned

Degree	% of Teacher Educators (n=80)
Doctorate	11.3
Master	26.3
Bachelors	38.8
Minor	7.5
None	16.3

Table 10

Teacher Educators by Frequency of Teaching Methods Courses

Frequency	% of Teacher Educators (n=80)
Regularly	60.0
Often	10.0
Sometimes	16.3
Other	10.0
None	3.8

Table 11

Teacher Educators by Teacher Education Program Courses Taught

Type of Course	% of Teacher Educators (n=80*)
Foundations	22.5 (18)
Elementary Methods	55.0 (44)
Secondary Methods, General	7.5 (6)
Secondary Methods, Math	6.3 (5)
Secondary Methods, Science	53.8 (43)
Practicum (Field Support)	31.3 (25)

*some participants taught more than one type of course

Table 12

Teacher Educators by Years of Experience as K-12 Teacher

Time (years)	% of Teacher Educators (n=80)
0	20.0
<1	1.3
1	1.3
2	5.0
3	6.3
4-5	13.8
6-10	28.7
11-15	12.5
16-20	1.3
≥21	10.0

Table 13

Total SEP Score Considering K-12 Teaching Experience

SEP Score	% Taught K12 (n=64)	% Did Not Teach K12 (n=16)
2.0	3.1	0.0
2.5	4.7	18.8
3.0	6.3	18.8
3.5	7.8	6.3
4.0	12.5	18.8
4.5	15.6	6.3
5.0	20.3	25.0
5.5	17.2	6.3
6.0	12.5	0.0

Pearson Chi-Square = 10.54; df = 8; p = 0.23

Table 14

Total SEP Score Considering Type of Institution

SEP Score	% from Public (n=59)	% from Private (n=19)	% of Total (n=78)
2.0	1.7	5.3	2.6
2.5	8.5	5.3	7.7
3.0	10.2	5.3	9.0
3.5	10.2	0.0	7.7
4.0	13.6	10.5	12.8
4.5	10.2	26.3	14.1
5.0	23.7	15.8	21.8
5.5	11.9	21.1	14.1
6.0	10.2	10.5	10.3

Pearson Chi-Square = 7.26; df = 8; p = 0.51

Table 15

Total SEP Score Considering Institution's Research Activity

SEP Score	% from Very High (R1) (n=23)	% from High (R2) (n=17)	% from Some (R3) (n=34)	% from Unknown (n=4)
2.0	0.0	0.0	5.9	0.0
2.5	13.0	5.9	5.9	0.0
3.0	13.0	5.9	8.8	0.0
3.5	4.3	17.6	5.9	0.0
4.0	26.1	5.9	5.9	25.0
4.5	8.7	17.6	17.6	0.0
5.0	13.0	5.9	32.4	50.0
5.5	13.0	23.5	11.8	0.0
6.0	8.7	17.6	5.9	25.0

Pearson Chi-Square = 25.15; df = 24; p = 0.40

Table 16

Total SEP Score Considering Teacher Educator's Employment Status

SEP Score	% of Part-Time (n=14)	% of Full-Time (n=64)	% of Total (n=78)
2.0	0.0	3.1	2.6
2.5	14.3	6.3	7.7
3.0	0.0	10.9	9.0
3.5	7.1	7.8	7.7
4.0	7.1	14.1	12.8
4.5	0.0	17.2	14.1
5.0	28.6	20.3	21.8
5.5	21.4	12.5	14.1
6.0	21.4	7.8	10.3

Pearson Chi-Square = 8.86; df = 8; p = 0.35

Table 17

Total SEP Score Considering Time Spent in Research

SEP Score	None (n=20)	<50% (n=41)	>50% (n=17)	Total (n=78)
2.0	5.0	2.4	0.0	2.6
2.5	5.0	9.8	5.9	7.7
3.0	5.0	7.3	17.6	9.0
3.5	5.0	9.8	5.9	7.7
4.0	5.0	7.3	35.3	12.8
4.5	5.0	22.0	5.9	14.1
5.0	30.0	19.5	17.6	21.8
5.5	15.0	17.1	5.9	14.1
6.0	25.0	4.9	5.9	10.3

Pearson Chi-Square = 23.82; df = 16; p = 0.093

Table 18

Total SEP Score Considering Regularity in Teaching Methods Course

SEP Score	Regularly (n=48)	Often (n=8)	Sometimes (n=13)	None (n=3)	Other (n=8)	Total (n=80)
2.0	4.2	0.0	0.0	0.0	0.0	2.5
2.5	4.2	0.0	15.4	0.0	25.0	7.5
3.0	6.3	12.5	7.7	33.3	12.5	8.8
3.5	12.5	0.0	0.0	0.0	0.0	7.5
4.0	16.7	0.0	7.7	0.0	25.0	13.8
4.5	12.5	12.5	15.4	33.3	12.5	13.8
5.0	16.7	50.0	23.1	33.3	12.5	21.3
5.5	18.8	12.5	7.7	0.0	12.5	15.0
6.0	8.3	12.5	23.1	0.0	0.0	10.0

Pearson Chi-Square = 26.77; df = 32; p = 0.73

Table 19

Total SEP Score Considering Experience in Teaching Secondary Science Methods

SEP Score	Yes (n=43)	No (n=37)	Total (n=80)
2.0	0.0	4.7	2.5
2.5	13.5	2.3	7.5
3.0	8.1	9.3	8.8
3.5	5.4	9.3	7.5
4.0	10.8	16.3	13.8
4.5	18.9	9.3	13.8
5.0	16.2	25.6	21.3
5.5	16.2	14.0	15.0
6.0	10.8	9.3	10.0

Pearson Chi-Square = 8.179; df = 8; p = 0.42

Table 20

Total SEP Score Considering Experience in Teaching Elementary Science Methods

SEP Score	Yes (n=44)	No (n=36)	Total (n=80)
2.0	0.0	4.5	2.5
2.5	11.1	4.5	7.5
3.0	16.7	2.3	8.8
3.5	5.6	9.1	7.5
4.0	19.4	9.1	13.8
4.5	5.6	20.5	13.8
5.0	22.2	20.5	21.3
5.5	8.3	20.5	15.0
6.0	11.1	9.1	10.0

Pearson Chi-Square = 14.582; df = 8; p = 0.07

References

Abell, S. K., Park Rogers, M. A., Hanuscin, D. L., Lee, M. H., and Gagnon, M. J. (2009). Preparing the next generation of science teacher educators: A model for developing PCK for teaching science teachers. *Journal of Science Teacher Education, 20,* 77-93.

Abrahams, I. & Reiss, M. (2012). Practical work: It's effectiveness in primary and secondary schools in England. *Journal of Research in Science Teaching, 49*, 1035-1055.

American Association for the Advancement of Science. (1989). *Science for All Americans.* Washington, D.C.

Association of Teacher Educators. (2008). *The teacher educator standards*. Retrieved from https://www.ate1.org/standards-for-teacher-educators

Ball, D. L., Sleep, L., Boerst, T.A., & Bass, H. (2009). Combining the development of practice and the practice of development in teacher education. *The Elementary School Journal, 109*, 458-474.

Banilower, E.R., Smith, P.S., Weiss, I.R., Malzahn, K.A., Campbell, K.M., and Weis, A.M. (2013). *Report of the 2012 National Survey of Science and Mathematics Education.* Chapel Hill, NC: Horizon Research.

Bennet, J. & Hogarth, S. (2009). Would you want to talk to a scientist at a party? High school students' attitudes to school science and to science. *International Journal of Science Education, 31*, 1975-1998.

Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education, 93,* 26-55.

Berry, A. (2007). Reconceptualizing teacher educator knowledge as tensions: Exploring the tension between valuing and reconstructing experience. *Studying Teacher Education, 3*, 117-134.

Boyd, D. J., Grossman, P. L., Lankford, H., Loeb, S., & Wyckoff. (2009). Teacher preparation and student achievement. *Educational Evaluation and Policy Analysis, 31*, 416-440.

Bybee, R. W. (1995). *Science curriculum reform in the United States*. Retrieved from http://www.nas.edu/rise/backg3a.htm

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2007). Teacher credentials and student achievement: Longitudinal analysis with student fixed effects. *The Journal of Human Resources, 45*, 655-681.

Cochran-Smith, M. (2003). Learning and unlearning: the education of teacher educators. *Teaching & Teacher Education, 19,* 5-28.

Cochran-Smith, M., Grudnoff, L., Orland-Barak, L., & Smith, K. (2020). Educating teacher educators: International perspectives. *The New Educator, 16*, 5-24.

Cochran-Smith, M. & Lytle, S. L. (2009). *Inquiry as stance: Practitioner research for the next generation*. New York, NY: Teachers College Press.

Cochran-Smith, M., Villegas, A. M., Abrams, L., Chavez-Moreno, L., Mills, T., & Stern, R. (2015). Critiquing teacher preparation research: An overview of the field, part II. *Journal of Teacher Education*, *66*, 109-121.

Conklin, H. G. (2015). Preparing novice teacher educators in the pedagogy of teacher education. *Action in Teacher Education, 37*, 317-333.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.)*. Los Angeles, CA: Sage.

Danielson, C. (2007). *Enhancing professional practice: A framework for teaching*. Alexandria, VA: ASCD.

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

Darling-Hammond, L. (2010). Teacher education and the American future. *Journal of Teacher Education, 61*, 35-47.

Darling-Hammond, L. & Bransford, J. (Eds.). (2005). *Preparing teachers for a changing world: What teachers should learn and be able to do.* San Francisco, CA: Jossey-Bass.

Davey, R. (2013). *The professional identity of teacher educators: Career on the cusp?* New York, NY: Routledge.

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

Ferguson, R. F. (1991). Paying for public education: New evidence on how and why money matters. *Harvard Journal on Legislation, 28,* 465–498.

Flexner, A. (1910). *Medical education in the United States and Canada.* Washington, DC: Science and Health Publications, Inc.

Forzani, F. M.(2014). Understanding "core practices" and "practice-based" teacher education: Learning from the past. *Journal of Teacher Education, 65*, 357-368.

Freedman, M. P. (1997). Relationship among laboratory instruction, attitude towards science, and achievement in science knowledge. *Journal of Research in Science Teaching, 34*, 343-357.

Furlong, J. (1996). Do student teachers need higher education? In J. Furlong & R. Smith (Eds.), *The role of higher education in initial teacher education* (185–198). London: Kogan Page.

Garbett, D. (2011). Developing pedagogical practices to enhance confidence and competence in science teacher education. *Journal of Science Teacher Education*, *22*, 729-743.

Garet, M.S, Porter, A.C., Desimone, L., Birman, B. F. & Yoon, K.S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal, 38,* 915-945.

Goodwin, A. L., Smith, L., Souto-Manning, M., Cheruvu, R., Tan, M. Y., Reed, R., & Taveras, L. (2014). What should teacher educators know and be able to do? Perspectives from practicing teacher educators. *Journal of Teacher Education, 65*, 284-302.

Gopnik, A. (2016). *The gardener and the carpenter: What the new science of child development tells us about the relationship between parents and children*. New York: Farrar, Straus, and Giroux.

Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching: Theory and Practice, 15,* 273-289.

Grossman, P. L., Smagorinsky, P., & Valencia, S. (1999). Appropriating tools for teaching English: A theoretical framework for research on learning to teach. *American Journal of Education, 108,* 1-29.

Hamilton, M. L. (2004). Professional knowledge and self-study education. In J. J. Loughran, M. L. Hamilton, V. K. LaBoskey and T. Russell (eds.), *International Handbook of self-study of teaching and teacher education practices* (Vol. 1, pp. 375-420). Dordrecht: Kluwer Academic Publishers.

Hattie, J. (2003). *Teachers make a difference, what is the research evidence?* Retrieved from https://research.acer.edu.au/research_conference_2003/4/

Hurd, P. D. (1991). Why we must transform science education. *Educational Leadership, 49*, 33-35.

Jenkins, E. W. & Nelson, N. W. (2005). Important but not for me: Students' attitudes towards secondary school science in England. *Research in Science & Technological Education, 23*, 41-57.

Kirst, M. W. (2010). *The political and policy dynamics of K-12 education reform from 1965 to 2010: Implications for changing postsecondary education.* Stanford, CA: Stanford University, Reform and Innovation in the Changing Ecology of U.S. Higher Education Project.

Knight, R. D. (2004). *Five easy lessons: Strategies for successful physics teaching.* San Francisco, CA: Addison-Wesley.

Knight, S. L., Lloyd, G. M., Arbaugh, F., Gamson, D., McDonald, S. P., Nolan Jr., J. (2014). Professional development and practices of teacher educators. *Journal of Teacher Education, 65*, 268-270.

Lampert, M., (2010). Learning teaching in, from, and for practice: What do we mean? *Journal of Teacher Education, 61*, 21-34.

Lee, O., Goggins, M., Haas, A., Januszyk, R., Llosa, L., & Grapin, S. (2019). Making everyday phenomena phenomenal: Next Generation Science Standards-aligned instructional materials using local phenomena with diverse student groups. In P. Spycher & E. Haynes (Eds.), *Culturally and linguistically diverse learners and STEAM: Teachers and* *researchers working in partnership to build a better tomorrow* (pp. 211-228). Charlotte, NC: Information Age Publishing.

Lortie, D. (1975). *Schoolteacher: A sociological study.* Chicago: University of Chicago Press.

Loughran, J. (2011). On becoming a teacher educator. *Journal of Education for Teaching, 37*, 279-291.

Loughran, J. (2014). Professionally developing as a teacher educator. *Journal of Teacher Education, 65*, 271-283.

Loughran, J. J. (2014). Developing understandings of practice. N. G. Lederman & S. K. Abell (eds.) *Handbook of Research on Science Education*. Routledge. Accessed on February 11, 2018. https://www.routledgehandbooks.com/doi/10.4324/9780203097267.ch40.

Maltese, A.V. & Tai., R.H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students, *Science Education, 95*, 877–907.

Mehta, J. (2013). When professions shape politics: The case of accountability in K-12 and higher education. *Educational Policy, 28*, 881-915.

Merriam, S. B. & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation (4th ed.)*. San Francisco, CA: Jossey-Bass.

Munby, H., Cunningham, M. & Lock, C. (2000). School science culture: A case study of barriers to developing professional knowledge. *Science Teacher Educator, 84*, 193-211.

Murray, J. & Male, T. (2005). Becoming a teacher educator: Evidence from the field. *Teaching and Teacher Education, 26*, 125-142.

Murray, J., Swennen, A. & Shagir. L. (2009). Understanding teacher educators' work and identities. In *Becoming a teacher educator: Theory and practice for teacher educators,* eds A. Swennen, and M. van der Klink, 29–43. Dordrecht: Springer.

National Board for Professional Teaching Standards. (2013). *National board standards.* Retrieved from http://www.nbpts.org/national-board-standards

National Research Council. (2007). *Taking Science to School*. Washington, D.C.: The National Academics Press.

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

National Science Teachers Association. (1989). *Project on Scope, Sequence, and Coordination of Secondary School Science.* Washington, D.C.: National Science Teachers Association.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* Washington, DC: The National Academies Press. Retrieved from https://www.nap.edu/catalog/18290/next-generation-science-standards-for-states-by-states.

Osborne, J. & Dillon, J. (2008). *Science education in Europe: Critical reflections (A Report to the Nuffield Foundation)*. London: Kind's College.

Passmore, C., & Stewart, J. (2002). A modeling approach to teaching evolutionary biology in high schools. *Journal of Research in Science Teaching, 39,* 185-204.

Polikoff, M. S. (2013). Teacher education, experience, and the practice of aligned instruction. *Journal of Teacher Education, 64,* 212-225.

Reiser, B. (2013). *What professional development strategies are needed for successful implementation of the Next Generation Science Standards*. Paper presented at the

Washington, DC: Paper presented at the Invitational Research Symposium on Science Assessment. K-12 Center at ETS.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.) *Handbook of research on teacher education* (second edition, pp. 102-119). New York: Macmillan.

Rose, M. (2014). *Why School? Reclaiming education for all of us.* NY: The New Press.

Roth, K. & Garnier, H. (2006). What science teaching looks like: An international perspective. *Educational Leadership, 64*, 16-23.

Russell, T. (1997). Teaching teachers: How I teacher IS the message. In J. Loughran & T. Russell (Eds.), *Teaching about teaching: Purpose, passion and pedagogy in teacher education* (pp. 32-47). London: Falmer Press.

Russell, T. & Martin, A. K. (2014). Learning to Teach Science. In N. G. Lederman & S. K. Abell (eds.) *Handbook of Research on Science Education.* Routledge. Accessed on February 11, 2018. https://www.routledgehandbooks.com/doi/10.4324/9780203097267.ch43

Smith, L. & Gess-Newsome, J. (2004). Elementary science education methods courses and the National Science Education Standards: Are we adequately preparing teachers? *Journal of Science Teacher Education, 15*, 91-110.

Sneider, C., Stephenson, C., Schafer, B., & Flick, L. (2014). Exploring the science framework and NGSS: Computational thinking in high school science classrooms. *The Science Teacher, 81*, 53-59.

Stake, R. E. (2005). Qualitative case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research (3rd ed.)*. (pp.443-466). Thousand Oaks, CA: Sage.

Swarat. S., Ortony, A., & Revell, W. (2012). Activity matters: Understanding student interest in school science, *J Res Sci Teach* 49, 515–537.

Tobin, K. (2003). The challenges of attaining a transformative science education in urban high schools. In J. Wallace & J. Loughran (Eds.), *Leadership and professional development in science education: New possibilities for enhancing teacher learning* (pp.33-47). London: Routledge Falmer.

Tytler, R. & Osborne J. (2012). Student attitudes and aspirations towards science. In: Fraser B., Tobin K., McRobbie C. (eds) *Second International Handbook of Science Education. Springer International Handbooks of Education, vol 24.* Springer, Dordrecht.

Walsh, K. (2001). *Teacher certification reconsidered: Stumbling for quality.* Baltimore: The Abell Foundation.

Weiss, I., Pasley, J., Smith, S., Banilower, E., and Heck, D. (2003). *Looking inside the classroom: A study of K-12 mathematics and science education in the United States.* Chapel Hill, NC: Horizon Research.

Windschitl, M. A., Stroupe, D. (2017). The three-story challenge: Implications of the *Next Generation Science Standards* for teacher preparation. *Journal of Teacher Education, 68,* 251-261

Windschitl, M., Thompson, J., & Braaten, M. & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education, 96,* 878-90

Yoon, K.S., Duncan, T., Lee, S. W.-Y., Scarloss, B., & Shapley, K. (2007). Reviewing the evidence on how teacher professional development affects student achievement *(Issues & Answers Report, REL 2007–No. 033)*. Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional

Assistance, Regional Educational Laboratory Southwest. Retrieved from http://ies.ed.gov/ncee/edlabs.

Zeichner, K. (2005). A research agenda for teacher education. In M. Cochran-Smith & K. Zeichner (eds.) *Studying teacher education* (pp. 737-760). Mahwah, NJ: Erlbaum.

Zeichner, K. (2005). Becoming a teacher educator: A personal perspective. *Teaching and Teacher Education*, *21*, 117-124.