SCIENCE TEACHER PERSPECTIVES

ON PROFESSIONAL DEVELOPMENT.

by

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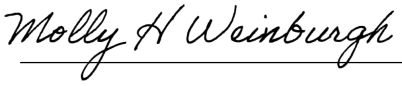

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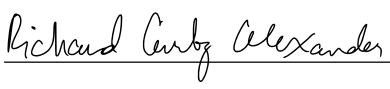

For the College of Education

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Problem

Science Teaching is Complex

Teaching and learning are complex human activities that are impacted by social, cultural, and historical influences on the individuals (Magnusson et al., 1999; van Driel et al., 2001). Teachers are expected to play active roles as facilitators, coaches, mentors, and designers of experiences that support students as they create new knowledge for themselves (Narayan et al., 2013). Research into shared teacher knowledge has focused on teachers in similar contexts such as teaching subject areas, school sites, or levels of teaching experience because understanding individual teacher knowledge is complicated (van Driel et al., 2014).

Science teaching and learning is made more complex because science teachers bring their attitudes, beliefs, identities, and personal experiences into the classroom (Jones & Leagon, 2014; Loughran, 2014). Science teachers are effective when they possess a variety of knowledges that allow them to deliver instruction in a range of contexts, meet the needs of students, and help students to learn and understand science (Magnusson et al., 1999). Abell (2008) summarized, "Science teachers must also have knowledge about science learners, curriculum, instructional strategies, and assessment through which they transform their science knowledge into effective teaching and learning" (p. 79). Therefore, teaching science presents challenges that may not be the same as other disciplines such as mathematics or language arts (Luft et al., 2003).

Science Teacher Professional Development

Science teachers develop science content and pedagogy knowledge over time, and professional development (PD) should support science teachers' professional learning needs throughout their careers as educators (Schneider & Plasman, 2011; Zhang et al., 2015). The

purpose of science teacher PD varies and may include: 1) altering teachers' attitudes and beliefs about science teaching (Jones & Leagon, 2014); 2) refining science content and pedagogy knowledge (Borko, 2004); 3) implementing innovative curriculum, instruction, technologies, or assessments (Borko, 2004; Gale et al., 2022; Hammond et al., 2018; Luft et al., 2019; Penuel et al., 2007); 4) improving student outcomes in science (Luft et al., 2019); or 5) a combination of goals relating to science teaching. Thus, science teachers participate in PD throughout their careers to improve their science teaching and improve student learning in science (Luft et al., 2019). Science teacher educators seek to understand how science teachers develop their knowledge and teaching expertise over time as they progress through various work experiences (Schneider & Plasman, 2011). For example, classroom science teachers need to learn a variety of new content, concepts, and skills to stay current in the field of science teaching, and new science teachers are expected to quickly imitate experienced science teachers (Davis et al., 2006; Eun & Lim, 2009). Science teachers require continuous opportunities for PD experiences with emerging scientific and technological innovations to prepare students for the 21st Century (Luft & Hewson, 2014). Educational reforms and science curriculum changes may leverage science teacher PD to support the implementation of new content and pedagogies (Bodzin et al., 2014; Borko, 2004; Chai, 2019; Gale et al., 2022; Higgins & Spitulnik, 2008; Penuel et al., 2007; van Driel et al., 2001; Zhang et al., 2015). Examining how science teachers acquire and implement knowledge and skills can inform science teacher educators how to design PD and learning (Higgins & Spitulnik, 2008).

Research on science teacher knowledge, attitudes, and beliefs is important for understanding science teacher PD, although the relationship between teacher attitudes and beliefs with PD experiences is complex (Gale et al., 2022). There is a considerable amount of research

on teacher satisfaction with PD, defining successful PD, and attempts to assess the effectiveness of PD (Chaipidech et al., 2021; Desimone, 2011; Penuel et al., 2007; Zhang et al., 2015). A PD experience may be more effective in generating change if science teachers are provided time during the PD to understand, design, and reflect on innovative curriculum changes (Penuel et al., 2007). However, Zhang et al. (2015) acknowledged "research on effective PD is largely disconnected from research on teacher knowledge" (p. 473). Penuel et al. (2007) suggested if PD is relevant to science teachers' classroom practices, then teachers are more likely to focus on student learning.

Science Teachers as Learners

Research on PD over the last 25 years suggests PD designers consider teacher needs when creating PD experiences (Loucks-Horsely et al., 2003; Zhang et al., 2015), however there is little research to document science teacher perspectives on PD. Eraut (1995) placed some responsibility at the school level for working collaboratively with teachers to jointly create teacher goals for PD, yet teachers are often required to attend schoolwide PD sessions that may be perceived as "trivial or *post hoc*" (p. 257) and not designed to meet the individual needs of teachers. A one-size-fits-all approach to teacher PD is unlikely to result in improved teacher classroom practices (Garet et al., 2001). Loughran (2014) noted the shift from "developing" teachers through learning to a "professional learning model in which teachers have more autonomy over their learning" (p. 811), although science teacher autonomy and PD are rarely found together in science education research. Luft and Hewson (2014) promoted a view of science teacher PD as a process of professional learning in which science teachers take responsibility for actively learning. Nixon et al. (2017) advocated for science teachers to be lifelong science learners. If teachers are treated as adult learners in personalized teacher-centered

PD experiences, then teachers might be more inspired to teach and view learning to teach as a lifelong professional aspiration (Chaipidech et al., 2021; Thomas et al., 2019; Treagust et al., 2014).

During the course of a teaching career, a science teacher's perspective towards PD and their PD needs are likely to change as teachers transition from novices to experts in the community of the teaching profession (Higgins & Spitulnik, 2008; Lave & Wegner, 1991; Schneider & Plasman, 2011). Luft and Hewson (2014) cited a need for research to understand how the PD needs of science teachers may change as they progress through different professional roles or time in their career. Luft et al. (2019) noted an absence in research on "scaffolded and coherent professional learning opportunities … in science education professional development literature" (p. 67). Induction and mentoring programs may provide opportunities for science teachers to learn from more experienced teaching peers and may help new teachers become part of a professional teaching and learning community (Davis et al., 2006; Treagust et al., 2014). Although most science teachers participate in an induction program during their first few years of teaching, these programs usually do not focus on science content knowledge or quality science instruction (Davis et al., 2006; Luft et al., 2003; Luft et al., 2011; Luft & Zhang, 2014). Understanding how science teacher attitudes, beliefs, identity, and self-efficacy change over a teacher's career could lead to more effective models of professional learning and a deeper understanding of science teaching and learning (Jones & Leagon, 2014).

The Need for Science Teacher Voices

A novel perspective from classroom science teachers is needed to address the status of science teacher PD in the 21st Century. The voices of science teachers could generate novel methods for science teachers to learn, develop, grow, and change as educators. Notably absent

from science education research are studies describing what science teachers want to learn in PD, how science teachers prefer to participate in PD, or why science teachers choose to participate in professional learning opportunities. Loucks-Horsely et al. (2003) recommended PD designers use teacher interviews, surveys, and observations to understand science teacher needs and goals for PD. However, there was no discussion in Loucks-Horsely et al. (2003) about what teachers reported they want from PD. Also missing from the research on teacher PD are reports of teacher voices providing input on their professional learning. Gale et al. (2022) emphasized "the important role that teachers play as advocates and agents of curricular innovation" (p. 300), and yet little research has explored how science teachers can advocate for their professional learning.

There is immense value in analyzing complex and interrelated structures within school settings to reveal nuances that would otherwise remain hidden from public view (Brandt et al., 2010). Retelling stories and reflections from a science teacher's perspective situates the narrative in an authentic lived experience. Viewing teachers as individuals acknowledges their unique understandings and honors their voice as an educator. Too often, the teaching profession is represented by a single interview, a quote lifted out of its original context, or from a large survey with numerical averages. While these sources of information can be useful at times, this research provides the opportunity to capture the daily life of a classroom science teacher as only the teacher can describe. While narrative research does not lend itself to generalizations or assumptions about other teachers' experiences, sharing the stories of science teachers' personal journeys may provide insights into how some science teachers negotiate their professional responsibilities. Retelling someone else's story is a relational experience that connects us not only as researchers and teachers, but as humans living life in proximity to one another. Narrative

research provides an opportunity for individuals to be in relation with one another, to live through experiences together, and to learn from one another.

The purpose of this research is to explore high school science teacher experiences with PD and ways teachers describe their priorities for teaching and learning in relation to their PD needs. This target group of teachers is significant because high school science teachers are a unique subset of teachers with distinctive PD needs in content, pedagogy, and technology, yet there is scant research about PD from the perspective of high school science teachers. Considering science teachers as individuals with unique opinions and ideas about their learning and development as educators could impact the practices of science educators and designers of PD. Brandt et al. (2010) predicted the resulting "grand narrative" from this type of educational research could blend the researcher's motivations and the teachers' narratives into something larger and more powerful than the individual actors could produce.

This research study offers the potential to fill a void in scholarly literature describing high school science teachers' experiences with PD and inform the field of science education about how science teachers negotiate PD as they move through their careers. Ultimately, no research exists to document science teachers views about PD, and the information gained from asking teachers about their perspectives on PD is of value to science teacher educators, campus and district administrators, science specialists, and even other science teachers. Furthermore, understanding science teacher perspectives on PD may lead to more effective models of professional learning and a deeper understanding of science teaching and learning (Jones & Leagon, 2014). Giving voice to science teachers' experiences with PD and advocating for the field of science teaching gives this research both purpose and potential to make a lasting

contribution to the field of science education (Brandt et al., 2010; Madison, 2020; Rosaldo, 1993).

Research Question

If researchers document science teacher voices regarding their experiences and perspectives on PD, then science education researchers can begin to collaborate with science teachers to reimagine PD experiences. The first step towards change begins with simply asking science teachers about PD and listening to their responses. The following research question framed the research in time and space: *How do teachers from the same high school science department describe their experiences with PD?*

Definitions

The vast scope of PD includes preservice learning about content, methods, and teaching and continues throughout one's teaching career (Luft & Hewson, 2014). PD has traditionally been delivered through in-person workshops, courses, and sessions, but novel forms of both hybrid and virtual PD sessions have become increasingly popular (Hammond et al., 2018). Informal interactions science teachers have with their peers or administrators in the school setting such as faculty meetings, in the break room, or during planning periods may provide opportunities to learn about teaching and learning (Higgins & Spitulnik, 2008). Using the phrase "science teacher professional learning" implies science teachers are committed to understanding their craft, rather than the need for science teachers to passively be developed (Loughran, 2014). Luft and Hewson suggested PD programs should seek to emphasize professional learning instead of filling teachers with knowledge and skills (2014). Although PD has many definitions, for the purpose of this research, PD is broadly defined as any activity teachers complete outside of their classroom teaching with students that contributes to their professional knowledge.

Chapter 2: Literature Review

A review of scholarly literature from academic peer reviewed sources provides a foundational understanding of the role of PD in relation to science teaching. Five major areas of scholarship are presented here: Science teaching as a discipline, science education in the U. S., professional development of teachers, types of professional development for science teachers, evaluation of PD, and PD needs over time. This literature review offers context for investigating secondary science teacher experiences with PD and the ways in which teachers' career histories impact their perceptions of PD.

Science Teaching as a Discipline

Understanding why science teacher PD is important includes an exploration of the unique nature of science teaching, science teacher knowledge and beliefs, and the variety of learning experiences that can be described as effective science teacher PD (Borko, 2004; Higgins & Spitulnik, 2008; Luft et al., 2003; Luft & Hewson, 2014; Penuel et al., 2007). Exploring science education as a discipline includes defining what is "science" and the history of the subject itself. The "nature of science" further complicates how science education has evolved through time (Lederman et al., 2013). Science teaching and learning is complex because science teachers bring attitudes, beliefs, identities, and personal experiences into the classroom (Jones & Leagon, 2014; Loughran, 2014).

Science Teacher Knowledge

Science teachers are effective when they possess a variety of knowledges that allow them to deliver instruction in a diverse contexts, meet the needs of students, and help students to learn and understand science (Magnusson et al., 1999). Researchers have identified what science teachers should know and be able to do (Zhang et al., 2015). Abell et al. (2009) explained

"science teachers must also have knowledge about science learners, curriculum, instructional strategies, and assessment through which they transform their science knowledge into effective teaching and learning" (p. 79). Teacher knowledge is most commonly understood in three different forms: content knowledge, pedagogical content knowledge, and technological and pedagogical content knowledge.

Content Knowledge

The expectation that science teachers should have an expert level of understanding science knowledge is not surprising. Science teachers need "a rich and flexible knowledge of the subjects they teach" to support student learning (Borko, 2004, p. 5). This type of subject-specific knowledge is referred to as *content* knowledge (CK). Science education research indicates science teachers refine their CK as they spend time in the profession and higher levels of CK are often associated with increased confidence in teaching ability (van Driel et al., 2014). Teachers must refine their content knowledge (Borko, 2004; Davis et al., 2006; Dubois & Luft, 2014; Luft & Zhang, 2014).

Science education should provide students with an understanding of the epistemology of scientific knowledge, in other words, "the theory of knowledge, the study of how we go about knowing, justifying what we know, and the extent of what we know" (Delgado, 2015, p. 139). Teaching science presents challenges that may not be the same for other disciplines such as mathematics or language arts (Luft et al., 2003). For example, science teachers may find it difficult to use standards-based science instruction (Dubois & Luft, 2014) as "many teachers, novice and experienced, struggle to find time, resources, and confidence to weave science into a crowded curriculum" (Kiesel, 2013, p. 68). Thus, a PD experience that provides time for teachers

to understand, design, and reflect on innovative changes to science curriculum may be more effective at improving classroom practices (Penuel et al., 2007).

Scientific knowledge includes both conceptual understandings of scientific facts, ideas, and processes and the history, philosophy, and nature of science as a unique way of knowing about the world. In addition to learning science and learning about science, the act of doing science is a consideration in the scope of science education (Delgado, 2015). In 2012, the National Research Council (NRC) published *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* with revised kindergarten through twelfth grade science standards. The new standards were written with the following goals for U.S. students (NRC, 2012):

> To ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)

These standards also integrated engineering and technology with other sciences and focused on scientific literacy, inquiry-based experience, and how scientists apply research (Yoon et al., 2018). The *Framework* (NRC, 2012) report explained the standards would be useless without corresponding "curriculum, instruction, professional development, and assessment" (p. 19).

Pedagogical Content Knowledge

Pedagogical content knowledge (PCK) describes the variety of methods, processes, and practices teachers understand and use in the process of teaching and learning (Bos, 2011).

Research focused only on science teacher pedagogical knowledge is rare (van Driel et al., 2014). When teachers integrate their pedagogical knowledge (PK) and content knowledge (CK) into PCK, they are able to design opportunities for students to explore and interact with the content (Borko, 2004; Chai, 2019). There is disagreement among researchers in science education over the relationship between subject matter knowledge (SMK), CK, and PCK (van Driel et al., 2014). Regardless of the intricate relationships between the different types of knowledges required for effective teaching, teachers need to know their subject matter and know how to teach their subject (Luft et al., 2019).

Shulman (1987) believed "a knowledge base for teaching is not fixed and final … the proposed knowledge base remains to be discovered, invented, and refined" (p. 12). PCK is a distinctive type of knowledge found in the teaching profession and can be used as a construct to understand how effective science teachers assist students with learning science content (Magnusson et al., 1999; Peterson et al., 2021; Shulman, 1987). PCK for science educators considers a teacher's understanding of teaching, and science content, instruction, and assessment (Gunckel et al., 2018; Jin et al., 2015; Magnusson et al., 1999). Science teacher PCK encompasses a science teacher's knowledge and beliefs about teaching science, science curriculum, instruction and assessment methods and strategies, and students learning science content (Magnusson et al., 1999).

Science educators have researched the complexities of science teachers' enactment of PCK in their teaching and instruction (van Driel et al., 2014). Focusing on teachers' PCK can assist teacher educators in illuminating the nuances of teacher development of PCK as they participate in PD to foster PCK in specific areas (Gunckel et al., 2018; Magnusson et al., 1999; Schneider & Plasman, 2011). PCK research with preservice teachers has shown how PCK can

help early career teachers develop a deep understanding of science teaching and a commitment to lifelong learning in the profession (Loughran, 2014). As teachers develop their content and PCK over time, other components of knowledge and beliefs about instruction, assessment, and student learning transform as well (Abell, 2008; Magnusson et al., 1999). Other researchers conducted PD interventions aimed at improving science teacher PCK and evaluating the effectiveness of the interventions (van Driel et al., 2014). A focus on PCK for science teachers "can be helpful in untangling the complexities of what teachers know about teaching and how it changes over a broad span of time" (Schneider & Plasman, 2011, p. 533).

A teacher's knowledge, views, reasons, and goals for teaching science inform their planning, instruction, and assessment decisions (Magnusson et al., 1999). Alonzo and Kim (2016) classified the explicit knowledge of teaching, students, curriculum, and instruction as *declarative* PCK when teachers used their knowledge to inform their classroom actions and decisions. Science teachers possess *practical knowledge* consisting of a variety of life experiences, beliefs, and knowledge when they enter the teaching profession. In contrast, *tacit knowledge* described a science teacher's implicit understandings about science, schools, and teaching that may be taken for granted by an experienced teacher and may be difficult to formally articulate to others outside the community of teaching (van Driel et al., 2001). *Dynamic* PCK describes these implicit understandings teachers possess and use when the classroom need arises (Alonzo & Kim, 2016). van Driel et al. (2001) explained each teacher's practical knowledge is unique and develops over time as teachers learn from everyday teaching experiences and refine their formal knowledge and ideas about teaching. If science teachers' practical knowledge is ignored, then PD designed to reform curriculum and instruction in science

education may be ineffective (van Driel et al., 2001). Thus, science teachers need PD to support the nuances within PCK as they gain on-the-job experience and expertise in teaching.

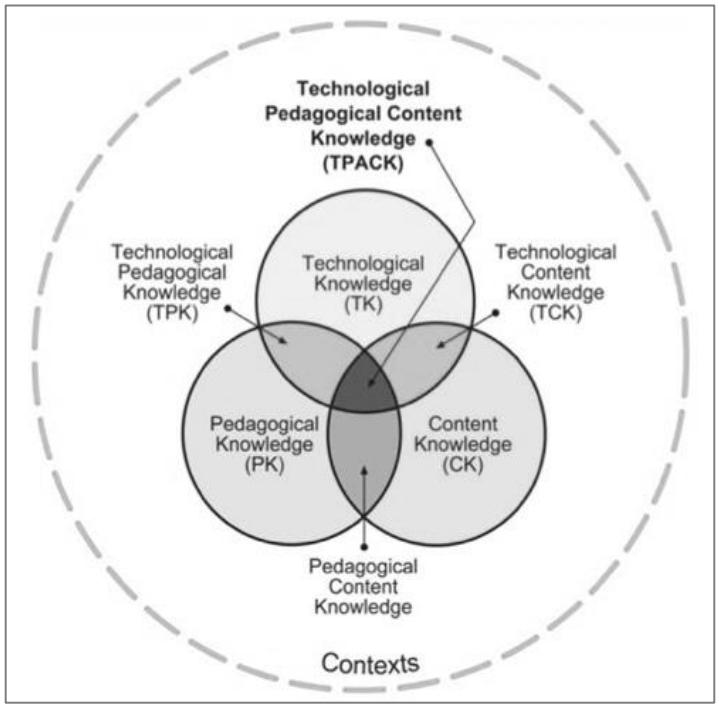
Technological Pedagogical Content Knowledge (TPACK)

PD can support teachers' use of technology to enhance science instruction. Integrating technology into science education may provide the opportunity for students to investigate scientific phenomenon, although effective technology integration by teachers is complex (Delgado, 2015; Higgins & Spitulnik, 2008). Higgins and Spitulnik (2008) acknowledged, "Technology can provide pedagogical supports for the classroom teacher, greater access to information, and deepen understanding through the use of models" (p. 512). In this sense, technology is more than an instructional tool used by teachers or students to complete tasks; technology is infused in teaching and learning as a conceptual tool for understanding (Bos, 2011).

Teachers who effectively weave content, pedagogy, and technology into their instruction are dynamic educators with a focus on student learning outcomes (Koehler & Mishra, 2009). Technology knowledge (TK) requires an awareness of content and changes in pedagogy in order for learning to occur with technology; therefore, TK should not be treated as an additional layer over PCK for teachers to master (Bos, 2011). Mishra and Koehler (2006) designed the technological, pedagogical, and content knowledge (TPACK) framework to inform research and assist teachers with technology integration into teaching and learning. The TPACK Framework combines traditional PCK with technical knowledge (TK) and identifies the complex ways these three different knowledges interact as teachers use technology in their instruction. It is important to clarify that Mishra and Koehler's (2006) TPACK Framework (Figure 1) assumes TK, PK, and CK interact simultaneously and synergistically; therefore, TPACK should be treated as a single

unit of knowledge rather than a sum of each sub-knowledge type (Bos, 2011). van Driel et al. (2014) cautioned that adding different types of knowledges into PCK could lead to lists of knowledge that might be used to evaluate teaching without considering the complex interactions between various knowledge components. Although the TPACK Framework was not specifically designed for science teaching, TPACK can be used to guide and assess PD involving technology, pedagogy, and content-specific components (Chaipidech et al., 2021; Higgins & Spitulnik, 2008).

Figure 1. The TPACK Framework and its Knowledge Components



Science Education in the United States

Over the last thirty years, improvement efforts in science education have attempted to transition science instruction from its traditional emphasis on lecturing-style teaching over a dense amount of content towards innovative instructional methods that use scientific inquiry, model scientific practices, promote scientific literacy, and inspire students to pursue careers in science (Higgins & Spitulnik, 2008; NRC, 2012; NRC, 2013; van Driel et al., 2001). Educational

reforms often leverage science teacher PD to support the implementation of new content, curriculum, and pedagogies (Bodzin et al., 2014; Borko, 2004; Chai, 2019; Gale et al., 2022; Higgins & Spitulnik, 2008; Penuel et al., 2007; van Driel et al., 2001; Zhang et al., 2015).

Global and Federal Influences on Science Education

The history of reforms in the U.S. science education demonstrates the field has been influenced by external political fears and educational theories related to teaching and learning (Rudolph, 2019). Bybee (2002) cautioned that current issues in society and politics should not impact what is taught in science courses, however contemporary issues have historically impacted science curriculum and instruction. The 20th Century efforts to reform science curriculum in the United States began in the late 1950s in response to the growing tensions with the Soviet Union over the Cold War (Rudolph, 2002).

Race to Space and Sputnik

Science curriculum reforms in the United States were in response to public and political pressure for the United States to produce more scientists and engineers to be globally competitive (Lazarowitz, 2007; Rosenthal, 1990). Both the federal government and research scientists became actively involved in science education reform as those in the United States reacted to losing to the Soviet Union in the "race to space" with the successful Soviet launch of *Sputnik* (Akin & Black, 2007; Mayer, 1970; Rudolph, 2019; van den Akker, 1998). High school biology, chemistry, and earth science curriculums were revised by nationally renowned scientists with funds from the National Science Foundation (NSF) (Akin & Black, 2007; Lazarowitz, 2007; Mayer, 1970; Rudolph, 2019). High school science curriculum shifted towards scientific inquiry and what real scientists do in the laboratory instead of science for everyday living (Lazarowitz, 2007; Rudolph, 2019; van den Akker, 1998).

Scientists who contributed to the NSF curriculum projects believed science was more than memorizing facts and vocabulary and should include information about the history of the sciences and the nature of science (DeBoer, 2014). van den Akker (1998) described this era of science education in the United States as an "alphabet soup" curriculum written in response to public concerns about the country's competitiveness in science and technology. The implementation of teaching science as an inquiry process varied depending on how teachers presented the new curriculum. Woodruff and Kahle (2014) explained that teacher PD during this period focused on improving science teacher content knowledge and pedagogy, which led to an elevation of the teaching profession. The result of the science education curriculum reforms of the 1960s was a shift away from everyday application of science towards replicating the ways scientists solve problems and discover new knowledge (DeBoer, 2014).

In the late 1970s, the NSF funded several large-scale evaluation studies of science curriculum development from the previous decade. The consensus from research and evaluations in the 1970s illustrated the curriculum reforms from the last two decades had not drastically improved how science was taught in U.S. classrooms. Science curriculum reformers shifted their focus to the role of science in society and citizens being environmental stewards during this period. The socially conscious and environmentally concerned reform efforts of the 1970s were eventually replaced with a more rigorous approach to science education (DeBoer, 2014). During this period, science education research experienced a paradigm shift from students learning through doing science towards understanding how students learn science (Amin et al., 2014).

A Nation at Risk and No Child Left Behind

In the 1980s, another push for science and educational reform began after *A Nation at Risk* was published in 1983 (DeBoer, 2014; van den Akker, 1998). The U.S. focus on competing

in a global economy resulted in accountability measures for education (Akin & Black, 2007; DeBoer, 2014) and preparing students for careers in science, technology, engineering, and mathematics (STEM). Science education research in the 1990s demonstrated teachers were simply preparing students for the next grade level, there was an overuse of textbooks for instruction, and scientific inquiry was rarely observed in science classrooms (van den Akker, 1998).

PD in the 2000s focused on professional learning communities (PLCs) as vehicles for school improvement, and this period marked the beginning of standards-based reform in U.S. education (DeBoer, 2014; Gordon, 2004). In 2001, the federal government enacted the *No Child Left Behind Act* (NCLB) which impacted local education districts in several areas including student assessment, school-level report cards, teacher qualifications, and district accountability (McGuinn, 2015). NCLB increased the federal government's control over public education and increased accountability measures and testing requirements for students in reading and mathematics. Teachers lost autonomy in their classrooms as stakeholders increased teaching standards and student achievement measures (Woodruff & Kahle, 2014). Although science assessment was eventually required in three grade levels, some science educators blamed NCLB for an overemphasis on reading and mathematics and a decreased concern for science education (DeBoer, 2014).

Sparapani et al. (2014) expressed concern that nationally mandated education reforms may not result in changes in teachers' classrooms. More importantly, macro level policy decisions rarely considered the impacts for teachers working directly with students in the classroom (van den Akker, 1998). The balance between the act of *doing* science and the process

of understanding *how* science works was often lost in the translation of curriculum documents into textbooks and ultimately classroom practice (Abd-El-Khalick et al., 2004).

School Science Standards

The 1980s and 1990s were the beginning of science education standards in the United States (Bybee, 2014). The first national science standards were published in 1993, however they were not a required national curriculum, so state science curriculum documents continued to be diverse (Abd-El-Khalick et al., 2004; DeBoer, 2014; Goldsmith, 1989). A review of U.S. science education standards from the last sixty years illuminates the shifting emphasis placed on science teacher education and learning within the realm of school science.

Science for All Americans and Benchmarks for Science Literacy

Science for All Americans (Rutherford & Ahlgren, 1991) was a result of Project 2061 by the American Association for the Advancement of Science (AAAS). The goal of *Science for All Americans* was to define scientific literacy and create learning goals for science, mathematics, and technology (DeBoer, 2014). *Science for all Americans* focused on establishing standards for science teachers and improving teacher educator programs. Science teacher PD was indirectly addressed in the *Science for All Americans* document. College science departments were tasked "to create and seek funding for the conduct on in-service workshops and institutes tailored to the needs of teachers who wish to attain the standard of excellence implicit in the recommendations presented in this report" (Rutherford & Ahlgren, 1991, p. 226 - 227). *Science for all Americans* was then used as the basis for the *Benchmarks for Science Literacy* (AAAS, 1993) which were the first national science standards for science education in the United States (Bybee, 2014; DeBoer, 2014). The *Benchmarks for Science Literacy* indicated teacher education was a

component of reforming the education system, however specific suggestions for teacher training and PD were not included in the document.

National Science Education Standards

The *National Science Education Standards* (NSES) (NRC, 1996) were unique because they used scientific inquiry as the focus for science teaching and learning (Osborne, 2014). The NSES vision included chapters outlining standards for science content, teaching, and assessment; standards for science education programs and systems; and standards for science teacher PD. Science teacher PD standards were described in the NSES as professional knowledges and skills and included learning science content through inquiry, integrating science content knowledge with pedagogical content knowledge, and understanding and ability for lifelong learning. The NSES (NRC, 1996) explained:

> In this vision, teachers of science are professionals responsible for their own professional development and for the maintenance of the teaching profession … Professional development for teachers should be analogous to professional development for other professionals. Becoming an effective science teacher is a continuous process that stretches from preservice experiences in undergraduate years to the end of a professional career. (p. 55)

Twelve years after the NSES were published for science education, the *Common Standards for K-12 Education* (NRC, 2008) were published as a vision for standards-based education in the United States. The *Common Standards* included the term "professional development" instead of "teacher education" and suggested teacher PD would be needed for education systems to shift to a standards-based model of teaching and learning (DeBoer, 2014). A systems approach to education reform was prevalent in the 1990s, which may explain why the NSES specifies science

teacher PD standards and the NGSS did not explicitly address science teacher PD (Woodruff & Kahle, 2014).

A Framework for K-12 Science and The Next Generation Science Standards

In 2012, the National Research Council (NRC) published *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* which served as a guiding document to revise K -12th grade science standards. The *Framework* described the following goals for U.S. students (NRC, 2012):

> To ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)

These guidelines integrated engineering and technology with other sciences and focused on scientific literacy, inquiry-based experience, and how scientists apply research (Yoon et al., 2018). The *Framework* explained how the revised science standards would be useless without corresponding "curriculum, instruction, professional development, and assessment" (NRC, 2012, p. 19). PD was considered an important mechanism in *The Framework* to ensure the revised science standards and expectations would result in substantial changes to science education in the United States and not merely unrealized curriculum policy (Bybee, 2014; Crawford, 2014).

The *Next Generation Science Standards* (NGSS) (NRC, 2013) were based on recommendations made in *The Framework* (NRC, 2012) and explicitly stated in the introduction, "The NGSS are not intended to be an exhaustive list of all that could be included in K-12 science

education" (p. xvii). The NGSS were student standards that were not intended to be a national curriculum. However, Bybee (2014) warned that the NGSS "imply dramatic changes in teacher education programs" (p. 217). Despite the possible need for teacher PD as a result of the changes for science teaching and learning in the NGSS, there were no specific recommendations or standards for science teacher PD in the NGSS. National organizations for science teachers, science education researchers, and other science education organization attempted to fill the void by preparing resources, guides, and documents to assist science teachers with the transition to the new standards such as the *Guide to Implementing the Next Generation Science Standards* (NRC, 2015). The table below (See Table 1) provides a summary of each of the major documents for science education in the United States and the emphasis placed each document placed on science teacher education and learning.

Table 1: Summary of U.S. Science Standards and Teacher PD

Year Published	U.S. Science Education Documents	Teaching & Instruction Focus	Science Teacher PD
1991	Project 2061: Science for All Americans	Science, mathematics, & technology. Science literacy – using science to think about personal & societal issues, nature of science (NOS)	Teacher education is needed, but no recommendations for science teacher PD.
1993	Benchmarks for Science Literacy		
1996	National Science Education Standards	Abilities needed for scientific inquiry, implies inquiry as a pedagogy for science teaching	Outlines PD standards for science teachers
2012	Framework for K-12 Science Education	Science, technology, & engineering education. Scientific practices with no decision making on issues and limited NOS.	Values teacher PD to reform science education.
2013	Next Generation Science Standards		Does not have explicit recommendations for science teacher PD.

Professional Development of Teachers

Traditional PD methods for teachers include courses, workshops, and lecture-style sessions, while more innovative teacher-centered PD methods include personalized coaching and mentorship opportunities, teachers teaching their peers, and teacher-led study and research groups (Penuel et al., 2007). The purpose of science teacher PD is usually to change classroom

practices and improve student outcomes (Penuel et al., 2007; Rubino-Hare et al., 2016). Traditional PD experiences have been described as tools to increase teacher capacity and meet societal demands. This production metaphor for PD implied a factory model of education where teachers and students were widgets to be manipulated in the system of schooling and ignored constructivist learning theories (Charles & Kolvoord, 2004). Charles and Kolvoord (2004) questioned the recommendations that teacher PD should be conducted like corporate training seminars and suggested teachers might have more intrinsic motivation for learning than other professions. Advocates for a constructivist approach to PD suggested teachers should be treated as adult learners in personalized teacher-centered PD experiences or participate in collaborative PD activities with their peers at school (Chaipidech et al., 2021; Higgins & Spitulnik, 2008). Participating in collaborative PD may be used to transform teachers' ideas about instruction and student achievement (Higgins & Spitulnik, 2008). For example, Penuel et al. (2007) found teachers may be more willing to make changes as a result of PD if they participate in a PD experience with other colleagues from their campus. Determining the effectiveness of PD should include multiple measures including both teacher self-report data and classroom observations to confirm changes in both teaching practice and student outcomes (Bodzin et al., 2014; Penuel et al., 2007).

Types of Professional Development for Science Teachers

Student-Centered Professional Development

When PD is relevant to science teachers' classroom practices, teachers are more likely to focus on student learning (Penuel et al., 2007). Science teachers today are expected to respond to student diversity when designing instruction to produce scientifically literate citizens who will make positive contributions to society (Lazarowitz, 2014). Science teachers may need PD to

alter knowledge, views, and beliefs about teaching science to students from a variety of cultural, linguistic, indigenous, and ethnic backgrounds (Abrams et al., 2014; Buxton & Lee, 2014; Jones & Leagon, 2014; McKinley & Gan, 2014). PD can support science teachers' understanding how to alter their curriculum, instruction, and assessment for students with learning differences and extraordinary science talent (McGinnis & Kahn, 2014). Some science teachers may require PD interventions to provide science learning experiences that are relevant for students' school environments such as in urban and rural school settings (Barton et al., 2014; Oliver & Hodges, 2014). Because "Students are the ultimate beneficiaries of any professional development program for teachers", student performance in science has been used by science education researchers to evaluate PD experiences (Luft & Hewson, 2014, p. 894). PD experiences may foster teacher use of assessments to improve both teacher instruction and student outcomes, including the use of technology tools to assess student use and understanding of technologies (Gunckel et al., 2018; Higgins & Spitulnik, 2008). Other research on science teacher PD has focused on the conceptual changes that occur when students learn science and teaching students through scientific inquiry (Loughran, 2014).

Instruction-Centered Professional Development

PD may be used to improve teachers' pedagogy and content knowledge, resulting in improved instruction and student outcomes on standards-based assessments (Hochberg & Desimone, 2010). Wickman (2014) suggested teachers should have decision-making authority over their curriculum and instruction, however science teachers have increasingly lost decision-making control over their curriculum, instruction, and assessment as school districts strive to meet accountability standards for science education. When teachers are provided with support in instructional practices and adapting instruction to meet student needs, there may be a positive

impact on teacher effectiveness and student learning (Jones et al., 2016). Science instruction includes a variety of pedagogical methods including but not limited to lectures, hands-on activities and laboratory exercises, and demonstrations. Science teachers need PD to refine their pedagogical and content knowledge and to effectively design science instruction so that students learn the science content (Kelly, 2014; Treagust & Tsui, 2014). PD may enhance science teachers' instructional methods with learning technologies such as online simulations, electronic probe ware, modeling software, and virtual learning (Krajcik & Mun, 2014). Science teachers may need PD to plan informal science learning experiences outside of school and to foster relationships with local zoos, museums, and other science centers (Rennie, 2014). In general, PD assists science teachers to "teach science as an integrated body of knowledge and practice – to teach for scientific proficiency" (NRC, 2007, p. 7).

Nature of Science Professional Development

Recent science education debates have centered on "content standards, complex ideas about the nature of science and scientific inquiry … [and] content mastery" (Rudolph, 2019, p. 204). Researchers recommend science teachers participate in PD relating to the nature of science (NOS) which consists of philosophical, historical, and sociocultural accounts about the uniqueness of the discipline of science and the development of scientific knowledge (Duit et al., 2014). In order to shift towards teaching with scientific inquiry, science teachers need to participate in PD experiences with opportunities for teachers to personally experience authentic science investigations. Crawford (2014) recommended science teacher PD relating to scientific inquiry should, "include connecting with teachers' needs, their science discipline, opportunities for reflection, and substantial time to teachers to travel on their journey of learning how to teach science as inquiry" (p. 535).

NOS can be applied to learning about the history, philosophy, and development of knowledge in specific scientific disciplines such as biology, chemistry, and physics, although philosophers of science do not agree on a common description of NOS for school science (Lederman et al., 2013; Osborne, 2014). Lazarowitz (2014) recommended biology teachers receive PD in biology PCK including the nature of biology ethics and decision making in relation to biology topics such as cloning, human genetics, and evolution. Chemistry teachers need PD focused on chemistry specific PCK topics that relate to the unique nature of chemistry teaching such as macro and microprocesses, use of models, and understanding chemical bonding (Jong & Taber, 2014). Physics teachers need PD focused on constructivist methods for teaching physics and physics-specific PCK topics such as the NOS of physics, inquiry-based physics, and teaching specific topics such as circuits, mechanics, and atomic theory (Duit et al., 2014). Earth System Science (ESS) teachers need PD focused on best practices for teaching from a systems approach and how to integrate ethics, decision making, and technology with ESS instruction (Orion & Libarkin, 2014). Lederman et al. (2013) recommended science teacher PD relating to NOS should focus on how teachers can foster the development of students' NOS knowledge.

Secondary science teachers have unique PD needs due to the NOS education and they require continuous opportunities for PD experiences with emerging scientific and technological innovations to prepare students for the 21st Century (Luft & Hewson, 2014). One way for science teachers to practice continual refinement and improvement in their teaching craft is to participate in PD experiences that foster the development of their TPACK. TPACK may be understood with more specific descriptions of technology applications such as geospatial technologies (Hammond et al., 2018). Because scientists use a variety of technical tools to visualize scientific phenomenon, there is a need to design PD experiences so teachers can help students use

authentic scientific technology in school science (Charles & Kolvoord, 2004). As science teachers attempt to replicate "doing science" in their classrooms, teachers require PD experiences to learn the tools scientists use such as geospatial technologies (Whitworth et al., 2022). Science teachers may incorporate authentic technological tools into their instruction with the use of digital models and interactive simulations to assist with understanding topics like climate change and nuclear energy (Delgado, 2015; Higgins & Spitulnik, 2008). PD may assist teachers in understanding the strengths and weaknesses of using models with science instruction (Delgado, 2015).

Although teachers may need educational opportunities to use innovative technologies and to incorporate emerging digital technologies into their content and pedagogy; research has shown that teachers who participate in technology PD may not continue using the technologies with their students in the long term (Collins & Mitchell, 2019; Niess et al., 2010). Hammond et al. (2018) suggested PD focused on curriculum and instruction reforms may be more successful if teachers participate in the design of the curricular materials and experience PD to foster their understanding of TPACK. Examining how science teachers acquire and implement knowledge and skills can inform science teacher educators how to design PD and learning to improve TPACK for teachers and increase the use of authentic scientific skills and technologies in K-12 science education (Higgins & Spitulnik, 2008).

Evaluating Professional Development

Effective Professional Development

Effective PD should improve science teacher PCK and result in improved student achievement in science. Garet et al. (2001) outlined characteristics for effective PD which included specific subject matter content, active learning for teachers, coherence in the content of

the PD, sustained time and duration of the PD experience(s), and collective participation in PD by teachers. Assuming effective PD characteristics are met, PD has the potential to change teachers' knowledge, beliefs, and instructional practices (Borko, 2004; Hochberg & Desimone, 2010). Documenting the effectiveness of PD is difficult for several reasons: 1) researchers may survey a large population of teachers with varying PD experiences, 2) measuring changes in teachers' classrooms after PD is challenging, 3) PD providers may not offer a full explanation of the PD intervention, and 4) outcomes for successful PD may not be clearly defined (Penuel et al., 2007). After a PD experience, teachers must go back to their classrooms and implement ideas, lessons, and strategies from PD. Adopting and adapting curriculum and instruction materials after a PD experience may be easier and take less time than creating innovative lessons and experiences for students (Charles & Kolvoord, 2004). More research is needed to assess how teachers implement what they learn from PD into their classrooms and how PD leads to improved student outcomes (Gale et al., 2022; Whitworth et al., 2022).

Barriers for Professional Development

Thomas et al. (2019) recommended "supporting teachers professionally makes them more content with their job and gives them more intrinsic motivation to teach" (p. 175). Research suggested PD designers consider teacher needs when creating PD experience, however there is scant research on the PD preferences of science teachers (Zhang et al., 2015). PD providers should be aware of potential barriers that may impact teachers making changes as a result of PD. These barriers may be a result of internal tensions such as a teacher's prior experiences or from external tensions with campus cultures and attitudes toward change and innovation, and/or campus and district-level resource constraints (Penuel et al., 2007).

Although teacher PD is recommended as the mechanism for school change to improve student achievement, there are a variety of reasons science teachers do not transform their practices. Teachers' attitudes and beliefs about curriculum and instruction changes may dictate the success or failure of the impact of PD interventions have on student learning outcomes (Gale et al., 2022). Time is often cited as an obstacle to providing teachers with the PD needed to adopt new science education curriculum and improve teacher PCK (Gunckel et al., 2018; Hammond et al., 2018; Penuel et al., 2007). The amount of time spent in formal PD experiences could explain why some teachers adopt new technologies and curriculum more successfully than others, and there may be interactions between the delivery of the PD experiences and duration of time spent in PD (Bodzin et al., 2014; Penuel et al., 2007). Waves of reform in science education over the last sixty years continue to place teachers with the ownership of change in the system (van Driel et al., 2014). Luft and Hewson (2014) called particular attention to the impact government and school policies have on the process of science teacher PD.

A number of other challenges impact the effectiveness of PD on science teacher practices including campus, state, and federal educational expectations, educational climates opposed to change, innovation, and creativity, and the politics of school accountability measures (Crawford, 2014). For example, science teachers may be hesitant to participate in PD experiences related to innovative curriculum and instructional practices because of pressures to prepare students to do well on high stakes assessments that are heavy in science content (Charles & Kolvoord, 2004). Using PD to impact teachers' knowledge and behaviors is complex and may require sustained investments in material, financial, and/or human resources to support teachers after the formal PD experience ends (Gale et al., 2022; Jones & Leagon, 2014). Material resource support could include access to laboratory materials or kits, assistance using classroom equipment and tools, or

access to reliable technology, software, and applications (Penuel et al., 2007). Financial resources might include providing teachers with more time for planning instruction after PD with the use of stipends for summer work or substitutes during the school year.

Science educators, policymakers, administrators, parents, and other stakeholders hold science teachers responsible for producing a scientifically literate citizenry (Luft & Hewson, 2014). Eraut (1995) suggested the different priorities of these stakeholders can lead teachers to question who they should listen to in terms of their PD plans. In *Enhancing Professional Development for Teachers* (NRC, 2007), a paragraph advocating for teacher PD to change includes the following quote from a teacher, "If you involve the teachers, you are going to get the buy-in, and you are going to get what you need for professional development, whether it's online or face-to-face. Please involve the teachers" (p. 33).

Professional Development Needs Over Time

Science teacher educators seek to understand how science teachers develop knowledge and teaching expertise over the course of their career (Schneider & Plasman, 2011). Science teachers participate in PD throughout their careers to improve their science teaching and improve student learning in science (Luft et al., 2019). Science teachers build a repertoire of skills and knowledges as they enter the teaching profession and community of science teachers (Lave & Wegner, 1991). Luft et al. (2019) explained science education research on PD has few examples of sequenced PD opportunities for science teachers. Nixon et al. (2017) proposed teachers should be science learners during PD, and Treagust et al. (2015) suggested science teachers view learning to teach as a lifelong professional aspiration. The PD needs and preferences of science teachers are likely to change over their careers as teachers transition from novices to experts in

the community of the teaching profession (Higgins & Spitulnik, 2008; Lave & Wegner, 1991; Schneider & Plasman, 2011).

Novice Science Teacher PD

Early career science teachers rarely receive science-specific PD and there is need for research into how the PD needs of science teachers may change as they progress through different roles or through time in their career (Luft & Hewson; 2014; Luft & Zhang; 2014). Beginning science teachers struggle for a variety of reasons, even after completing a university-based teacher education program (Ingersoll & Strong, 2011). PD provides an avenue to support newly hired science teachers as they begin their careers and as they transition through the careers in science education (Luft et al., 2019). Research from PD with science teachers demonstrates teachers must start with CK and add to their PCK as they learn from their experiences with teaching and learning. During the first year of teaching, educators refine their CK and experiment with their instructional strategies (Davis et al., 2006; Dubois & Luft, 2014; Luft & Zhang, 2014). New teachers may not seek help or support because they feel they don't have the time or because they are too embarrassed to reveal weaknesses (Jones et al., 2016; Kearney, 2015; McIntyre & Hobson, 2016). New science teachers may have weak CK which is needed both to understand science concepts and to explain science concepts to students.

Experienced Science Teacher PD Needs

When new science teachers become part of the science teaching community, they assimilate into the profession and are more likely to persist with teaching (Lave & Wegner, 1991; Luft et al., 2019). Despite some research on new and early career science teachers, there is little research on the PD needs of more experienced science teachers. Inservice science teachers need to learn a variety of new content, concepts, and skills to stay current in the field of science

teaching, and any learning opportunities for teachers should be interesting, meaningful, and relevant (Eun & Lim, 2009). Secondary science teachers may be assigned to teach more than one science content course during a school year, making planning and designing lab experiences more difficult (Davis et al., 2003; Dubois & Luft, 2014). They may be more likely to teach different courses as they progress through their early years of teaching, resulting in additional curriculum and lesson planning challenges (Nixon et al., 2017). For these reasons, Luft et al. (2019) proposed each science teacher may grow at different rates and in different ways during their career. Science teachers may experience changes in professional vision, identity, and leadership roles during careers in science education. Understanding how science teacher attitudes, beliefs, identity, and self-efficacy change over a teacher's career could lead to more effective models of professional learning and a deeper understanding of science teaching and learning (Jones & Leagon, 2014).

Conclusions

Ultimately, "all children deserve to have science teachers who possess a robust understanding of the content they are teaching, the nature of science, how students learn, and research-based science pedagogy that promotes agreed upon goals for science education" (Olson et al., 2015, p. 22). Notably absent from the research reviewed on U.S. science education are any studies which assess what science teachers want to learn in PD, how science teachers prefer to participate in PD, or why science teachers choose to participate in professional learning opportunities. Crawford (2014) stated, "It would be helpful to reexamine the issues science teachers themselves identify as being problematic" (p. 536) in regard to the daily issues classroom teachers experience that impact their teaching practice. Reviews of the literature regarding science teacher education paint a picture of PD as the prescription to cure all

educational ailments. Understanding how science teachers experience PD may lead to more effective models of professional learning and a deeper understanding of science teaching and learning (Jones & Leagon, 2014). Whether a teacher struggles with PCK, needs to revise instructional methods, feels inadequate to support all students in learning science, or lacks an understanding of the NOS within in their discipline, PD is almost always the answer for teacher change and improvement.

Chapter 3: Methodology

The purpose of this research was to explore high school science teacher experiences with PD and ways teachers describe their priorities for teaching and learning in relation to their PD needs. A qualitative study using grounded theory and narrative research methods was the optimal research design to deeply explore how high school science teachers relate to PD. Because research questions using grounded theory and narrative research remain tentative, my research question was malleable during data collection and analysis (Madison, 2020). My initial research question was how do teachers from the same high school science department describe their experiences and perspectives on PD? The stories, experiences, and perspectives compiled from the teachers were used to explore high school science teachers' perspectives on PD and how teacher priorities for teaching and learning may influence their PD needs.

Theoretical Framework

Educational research paradigms investigate the complex human processes that occur within the institution of schooling and can lend themselves to a variety of research methods (Mertens, 2020). The primary focus of this research was to explore how individuals remember, describe, and explain their experiences with PD as high school science teachers. The methodology for this research study was based upon a constructivist worldview placing science teachers as social actors and qualitative research methods were used to examine a group of high school science teachers' experiences with PD.

Constructivism

In the constructivist research paradigm, researchers assume teachers create meaning and knowledge both individually and socially as they experience and interact with language, phenomenon, and ideas (Narayan et al., 2013; Rannikmae et al., 2020; Walshe, 2020). The

constructivist epistemology posits that knowledge is created within the individual, and radical constructivism specifies that each individual makes meanings because of unique life experiences (von Glasersfeld, 2001). Thus, the constructivist ontology recognizes multiple realities exist because each individual creates a unique reality (Lee, 2012; Narayan et al., 2013). When combined with sociocultural theory, a constructivist axiology focuses on the broader collaborative and reciprocal experience of teaching and learning (Cobb, 1994).

While the constructivist epistemology assumes learning creates knowledge within an individual, Packer and Goicoechea (2000) argued there is a "social transformation – in short, ontological change" that occurs as a result of learning (p. 235). A sociocultural ontology considers these transformations that take place *in* an individual and *on* the society because of the learning (Packer & Goicoechea, 2000). Using a constructivist framework in educational research allows the researcher to ask questions, collaborate with others, make connections to personal experiences, and apply the information to future problems they encounter in research. Leavy (2017) described a constructivist research paradigm as one which "examines how people engage in processes of constructing and reconstructing meanings through daily interactions" (p. 129). Each teacher develops thoughts, ideas, and memories as a result of a PD experience; therefore, this qualitative research study attempts to interpret individual teacher understandings from PD.

Qualitative Research

Qualitative research methods such as interviews, focus groups, and field observations of teachers interacting in the school setting provided data about the research phenomena, namely the science teachers' rich histories and experiences with PD (Leavy, 2017). Documenting stories, events, and experiences from the perspectives of science teachers offered insights into occurrences which "transforms everyday life practices into more elevated ritual and magical

acts" (Rosaldo, 1993, p. 51). Furthermore, experienced educators may develop individual forms of social, economic, and cultural capital that do not easily transfer to novice teachers when considering PD experiences (Bourdieu, 1986). Teacher PD experiences contain specific rituals and customs that intertwine with other social actors, events, and activities in both the personal and work life of the individual (Erickson, 1984; Geertz, 1973; Madison, 2020). Acting as a participant-observer gave me the opportunity to observe the content, delivery, timing, and intended outcomes of some beginning of the year PD, while noticing teacher interactions and participation with peers and the expectations placed on teachers at different durations of their careers (Desimone & Le Floch, 2004).

Methodological Approach

Narrative Research

This research focuses on understanding the "intersection of multiple coexisting social processes" present in the complex and complicated lives of human beings (Rosaldo, 1993, p. 11). I was interested in how individuals experience PD as science teachers and how these experiences shape their lived experiences and understandings as educators. The reasoning for using narrative research with a small group of high school science teachers was to "elucidate the everyday of schooling, the nested and knotted systems and cultures in schools" (Wozolek, 2015, p. 49). Focusing on individual teachers at a micro-level in the system of science education provided insights into the web of tensions between other components in the system including other teachers, administrators, accountability measures, and instructional methods (Brandt et al., 2010; Erickson, 1984).

Narrative research was used to understand the various discourses present when teachers begin the school year and participate in both district and campus-level PD. Conducting research

with a small group of science teachers with different career histories at a single site afforded the opportunity to observe parallels and divergence among the narratives of science teachers (Rahm, 2012). Multiple narratives generated possibilities for triangulation and uncovering hidden meanings, missing pieces, and silent voices (Traianou, 2007). The voices, stories, interpretations, and explanations of the science teachers was the most important because, "no analysis of human action is complete unless it attends to people's own notions of what they are doing" (Rosaldo, 1993, p. 103).

Grounded Theory

Glaser and Strauss (1967) proposed grounded theory for sociology and other social research focused on understanding and explaining human behavior. Using grounded theory in this educational setting provided "flexibility and legitimacy" as a qualitative researcher "with varied theoretical and substantive interests" (Charmaz, 2006, p. 9). Grounded theory methods gave me as the researcher permission to avoid predetermined rules when collecting and analyzing observations and instead allowed the data to determine the direction of the research (Charmaz, 2006; Mertens, 2020). This research method situated and immersed me as the researcher within the research context while I simultaneously collected data, considered observations, and proposed hypotheses as they appeared during the research process (Mertens, 2020).

Research Design: Context

Gaining Access

Narrative research methods situated in grounded theory provided the opportunity to build relationships with science teachers and interact with them as they moved through their daily school activities at the beginning of a new school year. As a researcher, it was important for me

to consider my personal biases and subjectivity in voice, tone, purpose, methods, interpretations, and retellings of the teachers' narratives. As a former science teacher, instructional coach, campus and district administrator, and now doctoral student in science education, I was cognizant of my personal beliefs and biases. I was critical of actions and events that educators may take for granted (Erickson, 1984). The intersection of these roles in my personal career history was my motivation to explore how science teachers navigate their roles within the educational system as it relates to PD.

"Gaining access" to science teachers required a connection to high schools, school districts, and the teaching profession (Madison, 2020). I selected a suburban school district, referred to as Poleville Independent School District (PISD) and Poleville High School (PHS) pseudonyms, in North Texas where I worked for nine years as a teacher and administrator. After being away from PISD for another nine years, some of the innerworkings and politics in the district were different, even if the buildings and classrooms themselves remain virtually unchanged. Since I left the PISD, campus and district administrators changed positions and locations, a new 9th grade center divided the high school campus into two, and the high school science department moved its biology teachers to the 9th grade building. My former principal is now the superintendent, my former assistant principal is now the principal of the high school, and the district science curriculum director retired. I have effectively been out of the classroom for fourteen years and I was aware that science teachers might not initially trust me as an educator or as a researcher. In addition to gaining access to the high school and building relationships with the science teachers, gatekeepers such as the building principal, science director, or science department head were needed to support my research with teachers (Leavy, 2017).

My relationships with the district superintendent and high school principal provided me access to the head of the science department to introduce my research plans. As a former campus administrator, I understood the importance of following the "chain of command" and communicating with the campus principal before discussing any ideas with central office administration or classroom teachers. I emailed the campus principal to briefly explain my research plans and to seek initial support before contacting the district superintendent and science curriculum director. After I received IRB approval from my university, I submitted formal approval to conduct research in the school district. An initial meeting with the campus principal and the science department head were necessary to establish supportive relationships and a communication bridge between the campus administration and the science teachers. Without support from these school leaders, introductions to potential science teacher participants and formal approvals for school district research would have been difficult.

A face-to-face meeting with the department head prior to meeting the teachers and collecting data facilitated a positive introduction to the science department and began a rapport with the campus (Madison, 2020). When I met with the science department head, I asked about their background in education, their experiences within the district and school campus, and about the current state of the science department. Listening to the previous lived experiences the department head shared at this initial introduction was important as I shared my background in science teaching and education. While the focus was not on my identity as a science educator, explaining my connection to the campus, science teaching, and research helped to build a personal connection with the department head. Because the department head was both a teacher leader and communicator of ideas from the campus administration to the science department, it was essential for the department head to understand the research plans and be able to answer

questions from the science teachers about the research. We discussed how the science teachers experience PD in PLCs, district-led workshops, online training sessions, full-day district "science academies" and other PD opportunities outside of the school district. We discussed strategies for collecting teachers' stories in quick and simple ways to minimize the stress placed on teachers during the beginning of the school year. A conversation about the science teachers' daily campus logistics including back-to-school concerns, teaching schedules, and personal commitments outside of school provided some initial insight before recruiting teacher participants. I addressed concerns about personal, student, and school privacy and confidentiality, and other matters relating to research protocols and consent. Finally, I shared the timeline for research including dissertation requirements, university approvals for human subjects' research, and ways to communicate with the teachers during their summer break.

When I met with the campus principal, I provided a brief overview of my meeting and discussions with the department head. The campus principal provided a broad plan for the back-to-school PD including school-level initiatives for PD and professional learning. I explained my research focused on larger narratives about science teachers' experiences with PD, rather than any individual reports or analyses of PD events or evaluations of the teachers' classroom implementations of PD. We discussed the next steps required in the dissertation research process, and the school district process for conducting research with teachers. Without the campus principal's approval and support, no research could occur with the high school science teachers.

Participant Identification

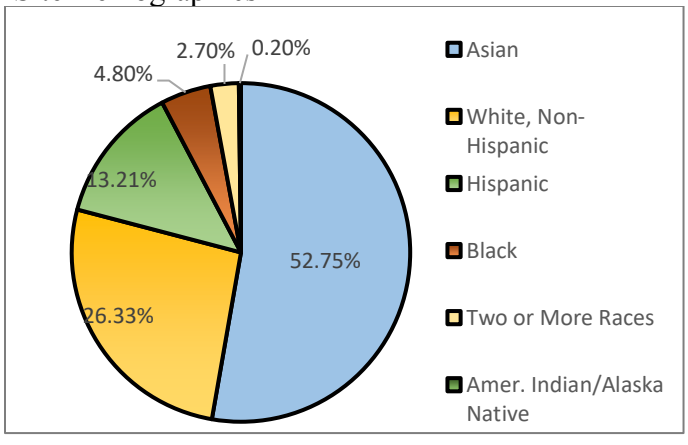
Because elementary and middle-school teachers may not exclusively teach science full time and they may have different PD needs, this research focused only on high school science teachers. Furthermore, private and charter school teachers may have different teaching

certification requirements, different teaching subject areas, and may not exclusively teach science courses full time, therefore the participants were all public high school teachers who teach a full-time load of science courses. This eliminated other specialized teaching areas such as special education, gifted and talented, and science coaching positions from the participant group. Concentrating the research on high school in-service science teachers from a single school district ensured the teachers have shared in some of the same PD experiences and allowed the teachers to explain nuances in their perceptions of the same PD events.

Research Site

PISD is located in North Texas and is classified as a large suburban district by the National Center for Education Statistics with a student enrollment of about 13,000 in the 2021-2022 school year (NCES, 2023). The comprehensive high school with grades 9-12 had a student enrollment of about 3800 students during this same period. Figure 2 below illustrates the high school student demographics for the campus: 1) Asian = 52.7%; 2) White, non-Hispanic = 26.3%; Hispanic = 13.2%; Black, non-Hispanic = 4.8%; Two or more races = 2.7%; and American Indian/Alaska Native = 0.2%. The student to teacher ratio for the campus was 15.5 for the 2021-2022 school year. During the 2022-2023 school year, the high school campus had grades 10-12 and 18 science teachers.

Figure 2: High School Site Demographics



School District Research

Working with a group of teachers from the same science department at a single high school streamlined some of the permissions needed to access public high school science teachers. Because the district is relatively small with only one 9th grade campus, one small choice high school, and one 10th-12th comprehensive high school, the process to conduct university research in the district is less complicated than larger urban districts in the same metropolitan area. I emailed the district superintendent and the executive director of instructional leadership to coordinate district-level approvals to conduct research with the high school science teachers. The application to conduct research in the district included copies of university IRB documents, CITI human subjects training certificate, a background check as a non-district applicant, a personal resume, copies of consent forms for participants, and copies of interview and focus group questions. PISD required the district and its teachers are not personally identifiable in the final research documents and that the district receives "interim and final reports" of the research.

Research Participants

After I received university and school district approvals for conducting research, a recruitment email was sent to all full-time teachers in the PHS science department. I explained my research which would include interviews with audio and video recordings, PD observations, and a focus group. If teachers had any additional questions about my research, I answered them via email and provided copies of the university IRB documents if requested. There were 18 teachers in the science department, and I wanted to secure a minimum of six science teachers to participate in the research. After I reviewed the list of the interested science teachers with the department head, I created an email list from the PHS website and recruited teachers in mid-July. From these emails I had six teachers volunteer to participate, and a seventh teacher asked to

participate in the research on the first day of the back-to-school PD week. A total of seven teachers from the science department completed pre- and post-interviews, were observed during back-to-school PD week, and participated in a focus group at the end of back-to-school PD week. The career histories of the seven science teacher participants are described in Table 2 below. For this group of participants, the years of teaching experience range from 7 to 37 years, and years of experience teaching at PHS range from 0 to 21 years. All of the participants hold current Texas science teaching certifications and one teacher is certified in Mathematics and Physical Education. All of the participants have bachelor's degrees, and four of the seven participants have a master's degree.

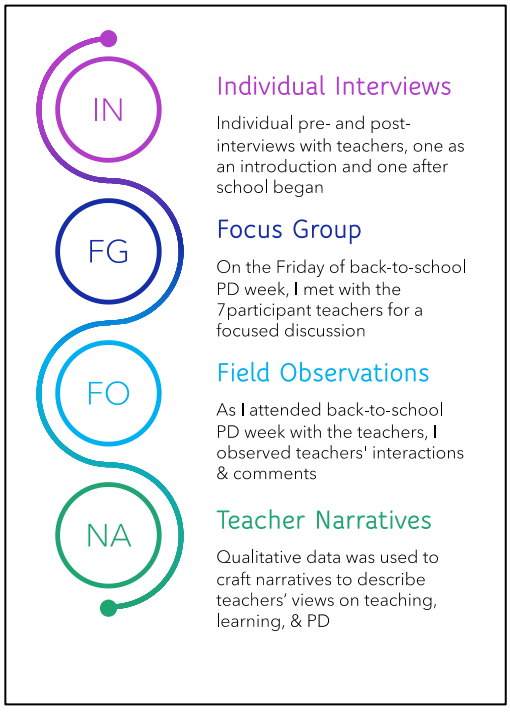
Table 2: Science Teacher Participants' Career Histories

PSEUDONYM	YEARS OF TEACHING EXPERIENCE	CERTIFICATION(S)	YEARS EXP. AT PHS	MASTER'S DEGREE
Paula	25	Biology 6-12	21	
Connie	37	Science 6-12	6	Natural Resource Education
Crystal	12	Science 8-12	5	
Eddie	11	Science 8-12	1	Physics
Abby	7	Science 7-12	0	
Rachel	21	Science 6-12	7	Chemistry
Melanie	17	Mathematics 6-12 Physical Education 6-12 Physical Science 6-12 Physics 6-12	11	Health & Kinesiology Education
	18.6 average years of experience		8.3 average years at PHS	

Data Collection

To explore how teachers from the same high school science department described their experiences and perspectives on PD, a variety of qualitative data were collected in August 2023 during the week prior to the beginning of the school year, sometimes referred to as "back-to-school or in-service PD week" and in September 2023 after school started (Figure 3). Choosing to study teachers experiences with PD at the beginning of a new school year defined the research in both time and space (Rahm, 2012; Rosaldo, 1993). Qualitative data collected for this narrative research study included two individual interviews with teachers, one focus group discussion, and field observations of the science teachers as they moved through PD and other activities at the beginning of a new school year. Open-ended questions during interviews and focus groups provided teachers with multiple opportunities to describe their experiences and perceptions about PD. This qualitative information lends itself to a wide range of possible narratives, stories, and understandings about PD. Qualitative research methods captured nuances about teachers' thoughts and concerns relating to PD that otherwise would have remain hidden if quantitative survey data was used instead.

Figure 3: Data Collection



Interviews

Teacher interviews served to "probe teacher understandings, establish why they had these understandings, and also why they practiced as they did" in regard to PD (Kapofu, 2019, p. 3). During the initial interview, science teachers described their careers in education and were asked to consider three open-ended questions to prompt their thinking about their PD experiences:

1) What is the worst experience you've ever had with PD?

2) What is the best experience you've ever had with PD?

3) What would be your ideal PD experience?

These initial interview questions focused on general PD experiences, without a time frame relating to their first year of teaching or back-to-school sessions. This gave teachers space to describe a variety of PD experiences that occur at different times of the school year, over different places in the teachers' careers, or even a singular significant event that impacted their perspective or outlook on teaching. Meeting teachers virtually on the Zoom platform for interviews provided videos, audio files, and transcripts of the interviews with the individual teachers. The introductory interviews occurred prior to the back-to-school PD week before school began in mid-August. The second round of interviews occurred after school started in September. Teachers were able to select interview time slots that did not interfere with their teaching schedules or personal commitments either during the school week or over the weekend. The purpose of these interviews was to probe teacher thoughts about teaching and PD after the back-to-school PD week in August. Specific questions for these interviews were crafted after experiencing the August in-service PD week alongside the teachers. The questions were tailored to explore comments, stories, or interactions documented in my field observations (Appendix B). These interviews were conducted on the Zoom platform in order to record video and audio files and transcripts for later analysis.

Focus Group

At the end of the back-to-school PD week, a focus group was conducted during lunch on Friday. Specific prompts were drafted from the introductory individual interviews conducted earlier in the week. To begin the focus group, teachers shared what is most important to them when they think about PD. The focus group were conducted in-person with the Zoom platform to record video and audio files and transcripts for later analysis. The focus group generated some teacher reflections about how the PD week prepared them for the upcoming school year and illuminated differences between how teachers report their experiences from the week's PD activities (Glaser & Strauss, 1967).

Field Observations

In addition to individual interviews with teachers and the focus group, field notes taken from observing teachers during the back-to-school PD week provided understanding and depth for teachers' stories about PD and science teaching (Martin, 2019; Traianou, 2007). Working alongside the teachers in a collaborative research process could assist with developing a common understanding about what activities qualify as "professional development" or professional learning. For example, teachers might not consider casual conversations in the teacher's lounge about a difficult student or venting to their assigned mentor teachers as a possible informal PD experiences (Desimone, 2011). Attending PD sessions with the science teachers granted me access to the "teachers' talk about scientific phenomena and teaching [which] reflects the knowledge they use to engage in scientific and teaching practices" (Gunckel et al., 2018, p. 1341). Teachers attended some mandatory sessions for administrative updates and were able to choose some PD sessions relevant to their teaching experiences. While attending PD sessions and other meetings with the teachers during back-to-school PD week, I sought to notice nuances

not formally expressed by the teachers during interviews or the focus group. Field notes documented what I saw and heard from the teacher participants in addition to the location, time, and environment of the interactions (Charmaz, 2006). Being present as both an *active participant* and a *privileged observer* at the school during this week provided a deeper understanding of not only PD experiences, but other complexities present for science teachers as they prepare for a new school year (Wolcott, 1998). When I joined the back-to-school PD week events alongside the teachers, I hoped to gain the trust of the teachers so that I was allowed to make observations of their interactions and interpretations from the week (Glaser & Strauss, 1967).

Data Analysis

Exploring science teacher perceptions about PD lends itself to triangulating a variety of qualitative data from multiple sources that may illuminate how teachers understand PD as part of their roles as science teachers (Desimone & Le Floch, 2004; Gale et al., 2022). A large amount of qualitative data was collected before, during, and after the back-to-school PD week including individual interviews, a focus group, and field observations (Figure 3). Carlone and Johnson (2012) explained "these individual actions must reveal something about a group's shared meanings. Behavior must be patterned, either in ways that align with local cultural meanings or contest them" (p.157). First, I processed each teacher's pre-interview and post-interview transcripts into individual Word documents. Next, I processed the focus group transcript by color-coding each teacher's comments and then added each teacher's focus group comments into their individual Word document. Finally, I processed my field notes with observations and reflections by sorting them chronologically into a single Word document.

Coding

Coding, processing, and organizing the narratives occur simultaneously using a grounded theory framework that was appropriate for the topics, trends, and themes that developed (Charmaz, 2006; Madison, 2020). For the initial phase of coding, I combined the qualitative data from interview transcripts, focus groups, and field notes for each participant into Microsoft Word documents for each participant. Each individual Word document for the teacher participants and my field observations was uploaded into the MaxQDA software program for qualitative data analysis. Because I used grounded theory methods, I did not use a list of *a priori* codes from other research or my predictions about what teachers might share about PD.

After reviewing the data, I created initial codes that emerged from the words, events, and ideas of the participants (Charmaz, 2006). The codes were added to the Word documents in MaxQDA and showed up in the margins of the documents beside the highlighted section of the corresponding text. Charmaz (2006) suggested looking for participants actions and using the participants' words as a means to avoid conceptualizing data too soon in the coding process. *Incident by incident* coding was used to review qualitative data from individual participants along with my field observations (Charmaz, 2006). This method allowed me to go beyond the sequence of events described by teachers and instead focus on nuances, tensions, and isolated episodes which might be significant without the teachers realizing it. At the conclusion of the initial coding phase, I had *in vivo* codes that reflected the teachers' words and terms understood within the campus and school district that situated the research in a specific time and place (Charmaz, 2006).

For the second phase of coding, I compared the initial codes across the participants to search for themes, trends, or commonalities between the participants. This focused coding helped

to organize larger themes that went beyond specific events or descriptions of experiences (Charmaz, 2006). I reviewed my *in vivo* codes and created a higher level of codes after further synthesis and analysis of the qualitative data. For example, I reviewed the data to compare descriptions from teachers' individual interviews with the field notes' observations of the teachers' comments and interactions during PD events. Comparing what teachers said they do versus what they actually did provided justification for unspoken meanings (Charmaz, 2006).

Processing

After the coding phases were complete, grounded theory searches for meaning and illuminates larger discourses present in the narratives (Charmaz, 2006). It was important to consider language and the meaning of words throughout the research process. Charmaz (2006) cautioned "about applying a language of intention, motivation, or strategies *unless the data support your assertions*. You cannot assume what is in someone's mind – particularly if he or she does not tell you" (p. 68). My goal for this research was to create narratives about the lived experiences of science teachers so that those in science education research can better understand how some teachers view teaching, learning, and PD. Glaser and Strauss (1967) wanted researchers to remain connected to people and their everyday lives rather than focusing too much on abstract concepts and formal theories. Therefore, the language and ideas used in the research must cross over between teachers, administrators, and academics or I risk either not fully representing the participants or not establishing meaning beyond the group of participants. One specific example would be the use of the term "pedagogy" in academic research referring to "the theory or science of teaching" (Robinson, 2017, p. 60). The science teacher participants did not use the term pedagogy, but did discuss their instructional strategies, tools, and ideas that are

considered pedagogical concepts. Whenever possible, the words and phrases used by the teachers were used in the codes in order to reflect the teachers' voices.

Before crafting narratives to retell the stories and experiences of individual teachers, I drafted "teacher profiles" to connect the science teachers to themes and larger ideas that began to emerge from the qualitative data (Charmaz, 2006; Glaser & Strauss, 1967). These profiles served to highlight key quotes from teachers illustrating specific ideas or concepts. Revising the profiles at this stage revealed which incidents from individuals were worthy to consider as part of a teacher's grand narrative and which events may fade into the background. Additionally, some codes from initial reviews became less important to consider while other initial codes stood out and required further investigation. For example, I removed information about the teacher's career histories and teaching certifications because this information did not seem necessary to highlight in the teacher profile. Glaser & Strauss (1967) suggested remaining open-minded during this process since no researcher:

> … can possibly erase from his mind all the theory he knows before he begins his research. Indeed, the trick is to line up what one takes as theoretically possibly or probable with what one is finding in the field. Such existing sources of insights are to be cultivated, though not at the expense of insights generated by the qualitative research, which are still closer to the data. (p. 253)

Sharing the profiles with the teachers before moving forward served as a member check as I negotiated with the teachers over the emerging themes, selected quotes, and highlighted incidents at this point in the research process (Clandinin, 2013). Any questions, concerns, or disagreements about my interpretations were addressed and resolved as the teacher profiles were

developed. None of the seven teacher participants asked for any information in the profiles to be changed or edited at this point in the research process.

Crafting Narratives

How the teachers explain and negotiate their lives was the starting point for crafting their profiles (Wozolek, 2015). Further analysis of the qualitative data included a "detailed investigation of how they interpret the situations they face and how they deal with them" (Traianou, 2007, p. 211). The qualitative data were synthesized into narratives about teaching, learning, and PD with the teachers' voices through direct quotes and my field observations. The ways in which I situated the teachers and their experiences with the retellings of the teachers' narratives impacted the final research product and opens spaces for dialogue about science teacher PD in the field of science education (Wozolek, 2015). As a researcher, I did not insert my personal experiences alongside the teachers' narratives, but I sought to understand the possible ways in which institutions, social interactions, and culture are present in each of the teacher's narratives I crafted (Clandinin, 2013). The information I selected for the narratives was subjective, and yet selected quotes, events, and stories provided reliability for the research because they supported larger themes that emerged during the research (Glaser & Strauss, 1967). Finally, each teacher's narrative is unique in its flow, content, and organization, reflecting the individual personalities and dispositions of the individuals who participated in the research process.

Emerging Themes

Narrative research blended well with a grounded theory framework because the narrative research methods were fluid and the steps were not predetermined prior to the research study (Clandinin, 2013). After drafting the teachers' narratives, I reviewed the codes a third time to

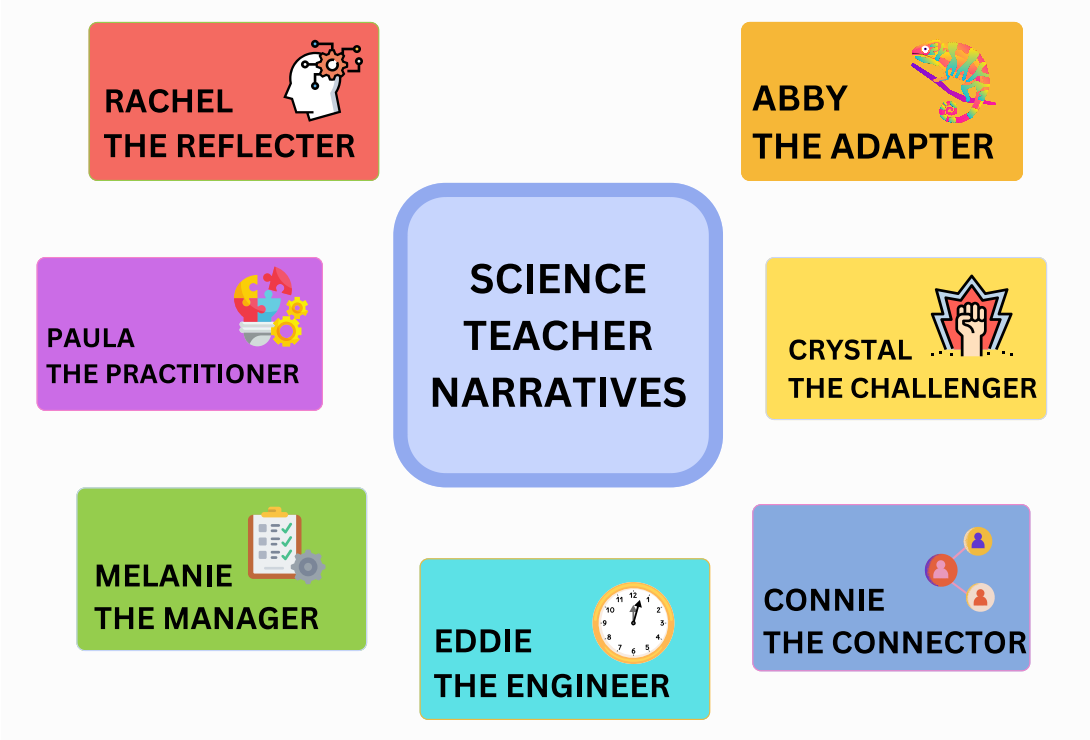
look for major themes that appeared across all of the participants' qualitative data. Analysis of data in these areas revealed two major themes: the teachers' perspectives on the teaching profession and their thoughts about PD.

Chapter 4: Science Teacher Narratives

The following narratives reflect how the participants view themselves as science teachers at PHS and as members of the teaching profession. Each teacher received a draft version of their narrative to review whether it accurately represented their thoughts and ideas from their interviews, conversations, and interactions with me. As a researcher, I wanted to understand how the teachers describe themselves in relation to PD and use these narratives to better understand how science teachers might approach PD from varying perspectives. As expected, each of the seven teacher participants had unique career and life experiences that impacted their views on teaching, learning, and PD.

The individual variances among the teachers resulted in different perspectives on teaching, learning, and PD. For example, one teacher took ownership for their professional learning and completed an online course over the summer in science content related to their teaching assignment, while another teacher wanted PD that will help them save time on mundane tasks like grading and other teaching responsibilities. There was no clear consensus on how the teachers would prefer to experience PD, what types of PD they need, or what content they would like to learn in PD. Each participant was assigned a pseudonym, and each teacher's narrative describes their role within the PHS science department and their ideas about teaching, learning, and PD (Figure 5).

Figure 5: Science Teacher Narratives



Paula the Practitioner

Even the best schools may only have a couple of teachers with more than twenty-five years of experience on the campus who have seen administrators, teachers, and students come and go. These teachers know that there will be good times and bad times in the life of a school, so they avoid student and teacher drama, will be honest about what is working and what needs to change, and are good role models for new teachers. When administrators want to know what their staff are truly thinking, these teachers are usually a good gauge of how the rest of the teachers are feeling.

Paula exemplifies this type of seasoned and experienced educator who has seen it all in 25 years of teaching in the PISD. She spent most of her career teaching Anatomy and Physiology (A & P) at the high school level, while she did leave for a few years to teach middle school science. I knew from working in PISD years ago that Paula was one of the first Apple

Distinguished Educators in the district, and students in her classes were instrumental in co-creating some of Apple's first online interactive biology textbooks. She was still in the same science lab at the farthest end of the school that she has been in for most of her career. In addition to her course being overwhelmingly popular each year as a science elective, she sponsors the environmental club and its garden project. In the environmental club, Paula said, "We have 200 kids, but I would say 50 are consistently showing up and that I can depend on" (pre-interview, August 1, 2023).

While these accolades are admirable on Paula's resume, she did not specifically share any of these accomplishments while being interviewed about her experiences in science education. She is humble when it comes to personal achievements and talents and prefers to talk about students and the bigger picture of education outside of her classroom. Paula wants her classroom to reflect the real world, saying "I love all of the service projects that we do. Any kind of thing that I can connect content with doing good in society. I just think that's so fun" (post-interview, September 14, 2023). She chooses to stay up to date with technology so students can see the relevance, not because it could make her teaching and planning easier. Her favorite activity with classes each year is a project-based learning unit in which students work in small groups to identify environmental and humanitarian problems that could be solved or improved with science. She said:

> It's just so fun seeing them do something cool or be proud of themselves … We're doing a project right now where they have to come up with a way to improve society's health and wellness, and they're presenting their ideas tomorrow … Some of them are just so genuinely excited about what they're going to present. I just - I love it. It's just so fun to see them kind of be proud. (post-interview, September 14, 2023)

Some projects have been as simple as collecting school food waste in the cafeteria and composting the remains to use in the school garden, while other projects helped find ways to increase clean water supplies in Sudan.

More than anything, Paula appreciates the challenge of learning something new to use in the classroom with students, but because she has so much experience in the subject area, she very rarely gets to learn anything new. There was a tone of disappointment when Paula talked about the ways science PD might be improved because she recognized that teaching science is both difficult because the field of medicine is constantly changing. She said:

> A bone is a bone, but it's new technologies and new things. It obviously looks different than when I worked in a hospital, right? … everything is so different. I would like to have time to go in and see - what does it look like now when you're a medical intern, or if you're a Med tech or whatever, just to kind of job shadow. Something like that would be really cool to see where the kids are going so that I could figure out more about how to help them be more prepared. (post-interview, September 14, 2023)

A & P has biology and medical terminology content and can be classified as a career technology course because it is in the STEM pathway for graduation. While most science teachers at PHS have multiple courses to prepare, Paula has the luxury of only teaching A & P. The downside to teaching a specialized course is that some teachers could become complacent and content to teach the same material with the same activities year after year. Teachers in these types of positions may feel isolated because they do not have a team of teachers who are all teaching the same subdiscipline with whom to brainstorm.

Paula combats the redundancy of teaching a solo course by seeking out opportunities for professional learning and creates innovative ways for students to connect with science outside

the classroom. This past summer, Paula paid for and completed an online professional learning course from Harvard. She said, “The Impacts of Climate Change on Human Health that was super interesting and gave me lots of topics of things that I want to incorporate into my curriculum now. So, I'm always looking for stuff like that” (pre-interview, August 1, 2023). She emphasized more than once that PD would be better if teachers could simply have some choices in the PD they attend. She suggested, “They should do for us what we're asked to do for students, you know, just differentiate, and provide options for different pathways depending on what the needs are (post-interview, September 14, 2023). One recommendation from Paula was:

> I think if they could split us into three groups, life science, physical, and chemical, then at least if I were in a group of life science teachers, that's going to be interesting to me, even if we're talking about cells or genetics or anything like that. It's still going to be interesting because it still applies to my subject. (pre-interview, August 1, 2023)

Because Paula only teaches in the life science discipline, it makes sense that she would feel more comfortable learning within this group of teachers. Even if their content is not the same and others might be teaching freshman on-level biology or Advanced Placement (AP) Environmental Science, they have some similar topics that are taught in all three courses.

When it came to technology PD, Paula compared working with Apple’s PD providers with district and campus PD experiences. When working with Apple:

> The other thing that I really like with professional development is all the stuff that I do with Apple and not because of the technology side of it, but because of the people. It's like everybody that's there is super into it and excited about it and you don't have those people in the room that are just like, you know in the back working on something else,

you know, like you have the whole room is engaged. So, it's more fun. (pre-interview, August 1, 2023)

For PD experiences with technology, Paula mentioned that everyone in the science department recently attended the same PD for a technology application. One example from the back-to-school PD week was a district-sponsored session on an online digital portfolio platform. During the session, there were no applications for science teachers, even though the only teachers in the room were middle and high school science teachers, and ironically, the presenter was a former middle school science teacher in the district. Paula said, “I sat in a session where my example was the example they used. If you're using it, why am I sitting here” (focus group, August 11, 2023). In the focus group she stated that she would like to hear the perspective of someone who has used the technology application in a secondary science setting. What the teachers discussed during the focus group was a desire to share ideas with their science peers rather than listening to a presenter share examples that are not applicable to their age level, coursework, or teaching style. Paula said, “I feel that would be way more relevant and interesting than to hear our DLCs [Digital Learning Coaches] who don't ever use it in the classroom and probably have never used it in the classroom” (focus group, August 11, 2023). She wants to see and hear examples of the technology being used in high school science classes with similar students.

As an experienced educator, Paula knows how difficult it is to change school traditions and systems that have been in place for years. Paula summed up her thoughts on PHS’s back-to-school PD saying, “I can say that I honestly haven’t learned anything this week. I don't have anything new (focus group, August 11, 2023). As simple as the response was, Paula implied she isn’t expecting change in a positive direction for science teachers anytime soon. She understands how hard it is to provide individualized PD for all the different subdisciplines of science. She

recognized the importance of the “nuts and bolts” compliance items that the district and campus have to cover in the back-to-school PD week, but she suspected there could be better ways to deliver and follow through with PD. Paula described a session from last year:

> We never talked about it again and now I can't even remember what it was called, but it was literally eight hours, and everyone was so beat down. I can't even tell you how angry I was, like the worst back-to-school, ever. I don't know who was in charge of it. (pre-interview, August 1, 2023)

Paula shared her thoughts and ideas openly but did not come off as a complainer or discourager when she spoke to science teacher peer (field notes, August 2023). Even during the focus group, she said, “I feel bad - I don't want to complain. I don't want to say anything bad about our school or make us look bad at all, but nobody asked me what I needed before we got here” (August 11, 2023). She will likely continue to have a positive attitude when she’s in the classroom interacting with students, and their experiences will be the main focus during the school year. Paula deserves to have opportunities to learn new information, continue to grow and improve in science teaching, and be able to generate new ideas for the classroom.

Constance the Connector

Few teachers advance from the classroom to campus administration, teach in rural, urban, and suburban settings, and work in both elementaries and high schools. Teachers with vast experiences like these can become negative, jaded, or at best nostalgic when reflecting on the changes in education over the years. Some may even count down their retirement to the exact day and use every last personal and sick day, so they leave nothing behind when they walk away from their career. Others view ta long career in education as fulfilling their life’s purpose and

will go back to the classroom trenches if they still feel that there are students who need saving. Constance is a rare saint in the latter category.

Constance was beginning her 37th year in education and had a wealth of knowledge about teaching science, building relationships, and leading schools. She had a calm and positive tone when she spoke (field notes, August 2023), and she enjoyed sharing experiences from her early career in a neighboring state:

> I started out teaching middle school, high school chemistry, biology two, and physics. Then I went back to high school and taught physics and biology two, which was considered like an outdoor classroom type. I worked during that time with the Water Conservation District in Western Oklahoma, and we opened up an outdoor classroom - a 100-acre outdoor classroom. (pre-interview, August 3, 2023)

When asked about her best PD experience, Constance said one of them was "kind of pie in the sky" (pre-interview, August 8, 2023). She described how she applied for a National Science Foundation Teacher Fellowship:

> They were trying to target rural schools and get kids in rural schools to be more open to the idea of getting degrees or getting training using electronics and computers. I was the first person in my school district to have a computer even before my Superintendent … It was with Oklahoma University, their meteorology department, the state climatologist, who also was a professor at OU, and some other professors, and some other school teachers. (pre-interview, August 8, 2023)

The grant set up weather stations all over the state and sent data to the National Weather Service and the University of Oklahoma. Constance went on to explain why the grant and its PD made such an impact:

> It was three years long, and you had to be hand selected. I know it was kind of a shot in the dark, but it happened. That's probably one of the best ones that I went to because they asked for input. What would you have done differently when we taught this? How are you going to take this back to the classroom? (pre-interview, August 3, 2023)

The other lasting outcome of the grant for Constance was "one of my students went to school and got a degree in meteorology and wound up being on The Weather Channel" (pre-interview, August 8, 2023). This student-first lens Constance uses helps prioritize where she spends time preparing for the upcoming school year. Rather than discuss science content or instruction, Constance was concerned about giving students choice in the assignments and understanding their individualized learning plans. For the chemistry courses she said, "Honestly, on-level is my love. I love those kids. I love to watch them have that a-ha after all of that struggle" (pre-interview, August 3, 2023). As an on-level chemistry teacher, Constance said:

> I have the majority of 504, SPED, and ELL kids in my chemistry class … when that bell rings, we hit the ground running. We're taking care of each kid where they are. We're trying to figure out where they are, or do we still remember what we did the day before when we left? Or do we need to go back and have a little refresher? Do I need to sit down and have a small group of one-on-one? Every day is dynamically different, and I love that challenge. (August 3, 2023)

For Constance, science content is a secondary priority after she ensures that each student's needs are being met in the classroom.

Even as a young teacher, Constance wanted to do what was best for students, and this theme continued throughout her career. She frequently gave examples from both a teacher's and

an administrator's perspective, and she considered how other teachers would feel in different situations. During the focus group, she said:

> I want to share from the administrative point of view about that, not just a teacher point of view. Sometimes you have to use what you got, and as someone who is creating the environment for learning, whether it's compliance learning or whether it's skill learning, or whether it's sharing data learning, and what you're going to do to move forward. The person that's presenting it has to think far out enough. (August 8, 2023)

As she reflected, Constance provided some recommendations for PD presenters such as giving relevant classroom examples for the subject areas represented in the room. She prefers to have interactive PD sessions rather than have someone read slides from a PowerPoint. She had clear ideas about the types of PD delivery that are ineffective including complicated directions, little interaction with participants, and information that is not easily integrated into her classroom. She explained:

> Don't read it to me. Don't put a slide up there and read the slide. I have an advanced degree … If you're going to gather us, make it pertinent. I believe in KISS - Keep It Simple Silly. That's how I teach it … when you're presenting, present things simplistically that we can immediately take back into the classroom or into our professional position … if you're training us on something, give us a dummy program and train us. Don't say these are the steps and put them on the slide. (pre-interview, August 3, 2023)

Constance spoke about a desire to have PD "that can help you with your level of students" (pre-interview, August 3, 2023). She recognized that the same PD content may be implemented differently depending on whether or not students are "self-engaged and you don't have to

motivate them" or have students that say, "I don't like chemistry" (pre-interview, August 3, 2023).

Even though science had been the content focus for her entire career, she spoke much less about teaching science and much more about how she had tried to help students in life. In almost every story she told, Constance forged relationships with others in order to improve the lives of students. I was reminded of Malcolm Gladwell's (2002) types of people in social networks from his *Tipping Point* book. Constance fit the "connector" personality type because she called on teaching peers, administrators, and even local law enforcement when she needed help as a teacher. Gladwell (2002) explained that connector people are the force that brings together other people who otherwise would not have met. Connectors bring disconnected people together because they are able to identify how different people with unique qualities can join to solve problems or advance ideas. Connectors recognize that they cannot solve all the problems they encounter, so they rely on other acquaintances when they need to fill a specific role in their situation.

Constance told a story about a young high school student she helped years ago and had kept in touch with until the last few years. The girl had a baby at 14 and lived in a rundown mobile home with an abusive boyfriend and his grandmother. The girl confided in another teacher who came to Constance and said, "If anybody knew what to do, we knew that you would probably have the answer" (post-interview, September 13, 2023). Constance and her teacher friend took an afternoon from school to help the girl move out of the mobile home with a baby and move into a battered women's shelter. She called in some favors to friends saying, "I got a girl that's just turned 15. She has a baby and the boyfriend's abusing her, and I need to get her into a shelter" (post-interview, September 13, 2023). Only Constance could leave school in the

middle of the day, take a student off campus in a personal vehicle, call a relative who knew the county judge, convince the judge to find a shelter to take in an underage minor and a baby, and avoid being arrest for kidnapping a minor and helping them disappear. Constance used knowledge of the school system, a small rural community, and powerful people to help a young girl who had no one else.

How does Constance's passion for helping students impact preferences for PD? She filters PD needs and wants through the lens of how it will help students:

> In the end, my kids are the ones that are gonna reap the benefit, not me. We're not here for me. I've already had my education. I've got my degrees, and we're here for you as a child or as a student. What do I need to do here? To make it better for that kid and if I have to learn something, then I will learn it. (pre-interview August 3, 2023)

Constance has participated in some amazing long-term PD experiences during her career, and she has led PD sessions for teachers as a campus administrator. Truthfully, Constance does not need much more PD at this point in her career, but she's not coasting through responsibilities or preparing to retire. Rather, Constance has the perspective of someone who has impacted hundreds of students as both a teacher and administrator, and she has seen tons of educational fads come and go. When asked about her worst PD experience, Constance said, "I'm really having a blank on that one because out of everything that I went through for professional development, I've always gotten something out of it" (pre-interview, August 3, 2023). As a former administrator, she knows how much advanced planning is required for effective back-to-school PD. Constance understands that coordinating and planning campus and district PD is complicated, and she reminded other science teachers to be patient when they vented their frustrations about the back-to-school PD week.

Even though Constance is the most experienced teacher in the science department, she leads with a quiet wisdom and offers helpful suggestions only when she observes other ideas might be needed (field notes, August 2023). The on-level chemistry teachers did not have everyone scheduled to meet regularly as a PLC because their teaching schedules are not aligned. Constance volunteered to meet individually with each teacher so they could review their common assessments and plan their instruction together. This selfless attitude was evident when Constance shared what she wished would change in education. She said:

> The one thing that I really wish I could change that I know I can't, is that you should be able to pass some kind of heart test that you're in it not for the paycheck. You're not in it just to use your degree as a stepping stone to get to something else. You're in it because you really want to help people. You want to see people grow you. You want to bring out the best in people, even though sometimes those people bring not their best every day. That's the one thing I wish I could change, and the only way I know to change that is to just show people I work hard. (post-interview, September 13, 2023)

Constance does not become flustered if the PD week schedule changes at the last minute or she does not have planning time with the other chemistry teachers. Constance only cares about what will help or harm students, and she likely has the personal connections to solve any problem she encounters.

We need more teachers like Constance who can weather the storms in their careers and continue sailing their ship because there are more students who need their wisdom. Constance freely shares past experiences with the other science teachers and is respected as a voice of reason when others are upset. She gives sound advice and provides another perspective others may not have thought of on their own. Constance has figured out how to enjoy being a science

teacher despite all the external issues that make teaching challenging and frustrating. During the focus group she told suggested how PD could be improved for all teachers saying:

> I think if you're going to offer development for your teachers, you need to have a buffet. You need to not have - here's your ham and cheese sandwich on white bread or that everybody has to eat a ham and cheese sandwich, right? Here's a buffet, and you can pick what you want, what you're gonna use, what you want. Not everybody's gonna get this exact same thing, right? (August 11, 2023)

Perhaps Constance's experiences as both an administrator and a teacher give her some unique insight regarding science teacher PD. Could providing teachers with more choice in their PD improve teacher satisfaction with PD?

Eddie the Engineer

Eddie was beginning his second year at PHS, after almost 30 years as an engineer and nine years of physics teaching. As a former engineer, Eddie has a unique outlook on science teaching, how schools operate, and PD. He described himself as "an introvert, engineer-type person" who initially struggled with classroom management, while "the classroom content has never been an issue for me" (post-interview, September 18, 2023). When Eddie was asked for feedback and input about how PHS operates or how the district designs PD, he was open and honest about recommendations to improve efficiencies. He said, "I guess that's one thing I picked up on from being an engineer, I want everything to be applicable. Don't waste time teaching things that have no relevance" (post-interview, September 18, 2023). Eddie's previous career experiences made him an outlier in this sample group of teachers, and he had his own ideas about teaching and PD.

As a physics teacher, Eddie was confident in his ability to know and understand the science content for an AP Physics course, even though the district was not able to send him to the AP Summer Institute workshop for the course. He said, “Content I know because what we teach in physics doesn't really change year after year. It's pretty static other than the minor tweak changes that they make every year” (post-interview, September 18, 2023). Eddie was more focused on *how* he taught the course, rather than *what* he taught in the course. Eddies looks for strategies to make labs more experiential for students and less prescribed, and he tries to find ways to make class fun for the students. Eddie said he would like to have some “ways to make my job easier” (post-interview, September 18, 2023), although he did not elaborate specifically what he wants to be easier. Perhaps it’s the engineering background, but Eddie wants to simplify the time it takes to complete PD assignments and not waste time doing activities that take away from classroom instruction. Because Eddie takes teaching responsibilities seriously, he does whatever he is told to do for PD activities. Some PD assignments are cumbersome for Eddie if they require technology modules because he admits that technology is frustrating for him at times. He wants PD experiences to be immediately applicable to the current teaching assignment. He described a technology PD assignment saying:

> Talking about the [technology] training we need to be doing … I'm not going to be using that. That's a high barrier to usefulness. Yes, I can see it might be kind of useful, but I'm not seeing the payback. I want ROI. I want return on investment. (pre-interview, August 9, 2023)

Several other teachers disliked the technology PD modules assigned during the back-to-school PD week, but Eddie’s reasoning for dismissing the training was articulated in a distinctive way.

Eddie is willing to complete PD assignments, but he prefers that they are worth the time and energy.

Eddie was the only teacher from the group who spent the majority of his life outside of the education profession. Eddie shared that he had been an engineer for almost 30 years. His role was in production engineering, helping to take ideas for electronics and put them into production. When he explained engineering professional learning, he said there were some annual compliance-type trainings, but "there weren't any new tools training unless you specifically asked for it" (post-interview, September 18, 2023). When he began his engineering career, many of the training sessions were held in person because online training was not yet an option. He said required training included topics such as sexual harassment, handling money, and in some cases not taking financial bribes at work. When asked how engineering "professional development" compared to teacher PD, Eddie was quick to share that all of the engineering training had an immediate application or use on the job, he said, "there wasn't much fluff" (post-interview, September 18, 2023).

To clarify, "fluff" in education for Eddie was all of the training he sat through for back-to-school, and while some sessions were needed, in Eddie's opinion, most of the PD time was not used wisely. In engineering, for example, a company would never make everyone sit through a meeting or a training session unless every single person in the room needed that information for their job. He recalled "new teacher PD week" from the year before when he was new to PHS. He said the new hire PD was all a waste of time because none of it prepared him for what he would need to know to work at PHS. He described the introduction to the campus as a new employee:

> The training didn't have anything to do with learning the systems [at PHS]. When you're starting it in a new place it'd be nice to actually spend a lot of time just going over the new systems that are there. Instead, they went through the system so quickly that you never had actually time to sit down there and actually start getting some things done. (post-interview, September 18, 2023)

The campus had policies, procedures, rules, and nuances that Eddie felt were more important to understand, and all of the information was all thrown at him in a very rushed and confusing manner.

When asked what Eddie would like to do for PD this year if he could choose a PD experience, he smiled and said, “That's a darn good question. One thing that I've been wanting to do is actually have more fun activities” (post-interview, September 18, 2023). Eddie said, “I want to have fun, and I know that if I'm having fun, the kids will be having fun too” (post-interview, September 18, 2023). Eddie wants PD to help him improve the experience students have in the classroom. He explained:

> If I could see something I can actually use in my classroom, then yes, I'm much more excited about it … life is far too short to be bored all the time. I want to have fun doing things. Even when I'm learning, I want to have fun doing things. (pre-interview, August 9, 2023)

Eddie also wanted to learn things that will save him time. He wants to be more efficient at grading because “I just spent 7-8 hours rating the free response to our first test” (post-interview, September 18, 2023).

Eddie sees teaching high school physics as an engineering design problem that needs to be understood, streamlined, and constantly improved. He is not looking for a quick fix or a

shortcut that might not provide the best learning experience for students, but he is looking for the best and most efficient ways to teach content. He wishes he could "see something I can actually use in my classroom. Then yes, I'm much more excited about it" (post-interview, September 18, 2023). He looks for new ideas on the American Modeling Association's Instagram page and wants to attend the Texas science teachers' conference for more teaching strategies. While other teachers mentioned the word "time" as something they wish they had more of, or they wish they could balance their time between work and home, Eddie saw time as an area for personal improvement. As a former engineer, Eddie has a simple and efficient approach to teaching and learning that really cuts through some of the "fluff" distractions in education.

Crystal the Challenger

Crystal admitted she has behavior and attitude problems as a teacher in the first statement she gave in the introduction pre-interview. She said, "OK, so going to college, I knew that I wasn't going to get a job doing anything financially because I can't spell dyslexic. I have behavior and attitude problems, and I don't think everyone's always right" (pre-interview, August 9, 2023). She was open and honest about her feelings towards teaching peers and administrators, both past and present, as she described teaching experiences across several different school districts and campuses. When she was encouraged to be honest during the pre-interview, she quickly responded, "I will tell them. That's why I like this. Yes, I don't mind my name on any of it" (August 9, 2023). An outsider might see Crystal as a tough personality who confronts authority and might be difficult to get along with in a work environment, but Crystal has a huge heart for working with students who are similar to herself as a teen (field notes, August 2023). Her motivation for teaching stems from personal memories of school when "school was not fun

for me … I was in trouble all the time … or I couldn't keep up with what was going on because it was so boring" (post-interview, September 13, 2023).

Crystal frequently reminds whomever she is talking with that she can be difficult to work with, although no one else in the science department appears to notice the self-denigration (field notes, August 2023). For someone who claimed to be hard to get along with, Crystal freely shared time and knowledge with peers. The day before school began, Crystal said, "I came on campus because there's so many new people, so I came up to be available, to help out. I don't know that anyone took advantage of that … I kind of stayed here in case anybody needed something" (post-interview, September 13, 2023). When she offered to help other on-level physics teachers, they came to her classroom and received help with generating assessment questions in an online learning management system question bank (field notes, August 2023). She helped new teachers navigate the district's technology PD modules that was assigned as a completion activity during PD week. Her advice for new teachers was, "I'm like you, don't worry about this … this is the last thing on your list … you can just feel it … my God, one more thing. How am I even going to figure that one out?" (focus group, August 11, 2023).

Crystal said she shares a passion for helping students with the PHS principal. For Crystal, feeling supported by the principal makes all the difference in how she is able to teach in the classroom. She is grateful to work in PISD because she has had other teaching experiences that were less than ideal. As Crystal said:

> I've taught low income, high income, country, city. I've taught in all those situations. I really like the low-performing because I'm low-performing, right, so you can't have an excuse. I have everything covered. There's nothing that you can say as to why you can't

because I have everything that I would have used. I was best at making up these excuses. I really like it. I enjoy my job. I call it my hobby. (pre-interview, August 9, 2023)

Unlike some other teachers at PHS, Crystal prefers to work with students who struggle with science and even mathematics content, and she enjoys the challenge of getting students to be successful in a physics course. She understands most students may not major in science, but she wants them to know how science is relevant in their everyday lives. During an informal meeting with the other on-level physics teachers, the group discussed whether or not students needed to master scientific notation in order to be successful in their course and meet the state standards for physics. Crystal was adamant that this mathematics skill should not prevent students from understanding the physics content and asked the other teachers to consider how often scientific notation is used by the general public. While she passionately defended a stance against teaching scientific notation, Crystal listened to opposing views and considered how other teachers approached teaching mathematics concepts within the physics curriculum (field notes, August 2023).

Teaching on-level courses at PHS puts teachers into a different group as compared to the International Baccalaureate (IB) and AP teachers. PHS is known for its vast AP course offerings and high AP scores. In the previous school year, the campus administered over 1500 AP exams and 80% of the students scored a three or higher on the exams (field notes, August 2023). Crystal expressed concern that most teachers do not want to teach on-level students and even on-level teachers often complain about how unmotivated students are towards school. She explained, "Nobody wants to teach my kids. I have a new person to teach with every year because everyone wants to go honors and AP. Nobody wants on-level, even in the other departments, they're cruel" (pre-interview, August 9, 2023). Crystal was frustrated when teachers talked negatively about

students or looked down on students rather than being kind and building relationships with low-achieving students. Crystal was concerned about "the social emotional piece … [teachers who] care about the kids … like to teach the high needs kids" (pre-interview, August 9, 2023).

For PD preferences, Crystal had a mild disposition about past "mediocre" (pre-interview, August 9, 2023) PD experiences and decided what she disliked the most was repetition. She participated in the same technology trainings over and over, and said, "I have three or four copies of the same book because I keep going to the same trainings … it's not a bad experience, it's just kind of redundant" (pre-interview, August 9, 2023). Paying attention during PD sessions can be a struggle for Crystal, and she acknowledges that sometimes she can tune out a presenter, doodle on some paper, and have no idea what is actually happening in the session or even what she is supposed to learn as a result of the experience. She explained, "Because of my ADD [attention deficit disorder], if I don't have value for the thing at the moment, I may remember something that was cool, but the overall whole of it, it's not going to sink in" (pre-interview, August 9, 2023). Crystal said she can learn anything if she has a reason to learn it and it's interesting, and she wants to streamline the PD experience to the essential parts she really needs to know. She gave the following example:

> I don't need to know all the steps. I need to know this step, right? I don't need you to explain every detail of the nuance. Just tell me what I need to know and tell me fast. I probably won't watch the whole video. I will fast forward. I don't have to hear you. I can see you did your math. And from then on, I can perform it. I don't need to hear everything you think. I don't want to know about your life. I don't want to know anything more than the steps to achieve what I'm supposed to do. (focus group, August 11, 2023)

Crystal does not need or want to have a relationship with a PD presenter; she just wants the information and to move on to the next item on the list of things to complete. At the beginning of the school year, Crystal said everyone is at "maximum cognitive load, your brain can only hold so much" (pre-interview, August 9, 2023) so it's not a good time to learn new information, new strategies, or new content. She suggested the school should "try to flip that timeline of 'let's push everything out with the firehose' you know, five days before school starts" (pre-interview, August 9, 2023). A recommendation was for spring PD sessions to slowly introduce content that teachers will use the following school year and experiment with new ideas and strategies in May after state and AP testing is complete.

The best PD experiences were in a previous district when she was asked to lead PD in an area that others had noticed she excelled. For Crystal, it seemed that the compliment of being asked to present made it a positive experience (field notes, August 2023), and she said, "I felt more responsible for that and I enjoyed it … it was a win-win" (pre-interview, August 9, 2023). She enjoyed providing PD, and it was not repetitive information because she chose the presentation material and format. Like many other teachers, she exceeds the required minimum amount of PD hours each year. She told the principal that she is okay with *choosing* to complete extra PD hours, but she would be upset if more hours were *required*. In her words, "My participation is because I want to participate … as soon as you offer me a cookie, I am not wanting to participate anymore" (pre-interview, August 9, 2023). Crystal dislikes technology applications that are time-intensive to master and have a steep learning curve before being able to use them with students during class. If the technology is too complicated, takes too much time to create, or isn't useful with students, then the PD related to the technology is a waste of time. According to Crystal, "I will learn one new thing of technology a year, so you can throw all this

at me, and I may know it already, or I may not. It doesn't matter. I will choose one, that's it" (pre-interview, August 9, 2023).

Crystal's current professional learning focus is on growth mindsets and how your mindset can influence your interactions with your family and your education and career (field notes, August 2023). The Texas science teacher conference had a session that "was not anything to do with teaching, it was literally just brain conversations" (pre-interview, August 9, 2023). She said the information helped her better understand herself, rather than thinking of how she could change student mindsets. She admitted to learning about growth mindsets because she enjoys thinking about how it might "play out in your classroom" (pre-interview, August 9, 2023). Crystal almost apologized for seeking information for personal learning because it did not directly relate to classroom science teaching. After school began, Crystal said learning more about "ESL [English as a Second Language] might be helpful if I had a choice choosing" (post-interview, September 13, 2023). She went on to say she would prefer:

> "Not to do the same thing I've done for years … I got it down and I am not learning anything new. I'm answering questions in the meeting and helping them figure out how to do things because some of the people who run it have never used it. (post-interview, September 13, 2023)

Crystal portrays herself as a teacher who can frustrate administrators and is easily bored in redundant PD sessions, but she is a champion for students who struggle in school. Although Crystal said she does not need external motivation or validation, she likely has students who will remember a teacher who did not give up on them when they were not interested in physics (field notes, August 2023). During the back-to-school PD week, her door was always open for any teacher who had a question or needed help (field notes, August 2023). Crystal has dedicated

more than 12 years to the teaching profession, and she simply wants to be respected and left alone to teach students real world applications of physics.

Abby the Adapter

Abby was beginning her 7th year of teaching and was the least experienced teacher in the group of participants. She was the last participant to join the group because she was not on the summer email distribution list. Abby was moving from one of the middle schools in the district to a life science position at the high school. She was excited about teaching two new subjects and spending time creating new materials and labs for students. Abby was ready for a change and was prepared to adapt teaching, planning, instruction, and assessment for a new high school setting (field notes, August 2023). She learned about the research project from another participant, and she found me on Monday of the back-to-school PD week. Abby said, "You don't know me, but I heard about your project, and I want to help. I have lots of things to say about PD" (personal communication, August 7, 2023).

Abby appeared comfortable to be starting a new teaching position at a new school, in part because she knew many of the other teachers in the science department and had worked for the PHS principal years before. She shared her thoughts and ideas openly during the focus group with the other research participants at the end of the back-to-school PD week (August 11, 2023). Her teaching partner, Paula, was another research participant in the present study who would be serving as Abby's mentor for the school year. The two were teaching A & P, and Abby had a couple of sections of AP Biology. As a former 7th grade science teacher, Abby had taught much of the basic life science content that was a precursor for learning more advanced topics in human anatomy, cell biology, and plant physiology. Even though Abby's undergraduate degree was in secondary education and biological sciences, she was mindful that there were different

expectations for teaching and learning science at the high school level with high-achieving students (pre-interview, August 8, 2023). She said she would have loved to spend time with "a veteran teacher on how to interact with juniors and seniors, or some classroom management, or creative things because the way that juniors and seniors do things is going to be a lot different than I would lead 7th graders" (pre-interview, August 8, 2023).

Teaching at a new campus in the same district meant Abby would likely have some students in her class now as high school juniors or seniors that she knew from the middle school. When Abby was asked about how she might be remembered as an educator, she immediately thought of students and which activities had been the most engaging and memorable for them in class. Rather than remembering specific science content, Abby said former students usually said what they remembered was having fun and not what they learned in her 7th grade science class. She said:

> They all told me how excited they were when they saw even just my name on the roster because they remembered me as nice, fun, kind. Did they forget all about cell survivor - this amazing project that I thought no one would ever forget about? Yeah, they did … it's just kind of like a lesson in that they will forget the content, but they will never forget how teachers made them feel. (post-interview, September 14, 2023)

As Abby discussed teaching experiences, she referred to relationships with students on several occasions. Her passion for teaching was evident when she described her initial motivation for choosing teaching over a career in nursing. She explained:

> I became a science teacher because … I did not have good teachers. I didn't really have a teacher to lean on that helped me much, and I felt like they didn't really care about me as a person … the main thing was to provide a safe environment and never make a kid feel

> dumb for asking questions and loving science … that's kind of my why. (post-interview, September 14, 2023)

Abby simply wants to help students feel safe to ask questions and love science because she did not always have that same experience in science classes growing up.

Compared to the other teacher participants in the group, Abby is a novice when compared to others with over 20 years in the profession. She said, “I feel like I'm even though this is my eighth year, I still feel sometimes like I'm a such a baby in the educational community” (pre-interview, August 8, 2023). Despite her youth, Abby was cognizant of the shortcomings of being an educator, even after a relatively short tenure in science teaching (field notes, August 2023). She candidly shared concerns about the unrealistic expectations put on teachers in PISD. She lamented:

> I wish parents in the community realized that we're teachers. We're not supposed to be parents. We're not supposed to be counselors. We're not supposed to be nurses. We're not supposed to be … all these things that they're wanting and expecting us to do - we physically can't. But because of the kind hearts that teachers have, we often bear those burdens. And that's why so many people are leaving the profession because of these crazy expectations. (post-interview, September 14, 2023)

In order to meet these teacher expectations, Abby admitted she often works more than she knows she should. Like other research participants in this study, Abby shared a struggle to maintain a work-life balance despite the demands of teaching, planning, and grading:

> I'm single. I don't have kids … I don't have to rush home to a family. I'll stay here and I'll do XYZ, and I kind of make that excuse, and then all of a sudden, I wonder why I'm super burnt out, you know? There are some years, and sometimes that are worse than

> others. Like this year, I don't have work life balance because I'm learning two new subjects and then turning around and teaching them. (post-interview, September 14, 2023)

Abby described her struggle during the teaching day when there are so many items that require attention outside of actual classroom instruction as a "balancing act" (post-interview, September 19, 2023).

After discussing the demands and expectations of teaching, Abby was quick to express dissatisfaction with the PD experiences she has had during the last seven years in PISD. When asked about what her choice for PD would be for the school year, she said:

> If someone had asked me what is something that I would like to learn this week, it would probably be to get with a veteran teacher on how to interact with juniors and seniors, or some classroom management, or creative things because the way that juniors and seniors do things is going to be a lot different than I would lead 7th graders. (focus group, August 11, 2023)

She was frustrated that teachers have little support and valuable PD provided PISD:

> It just kind of baffles me that we don't have better options, especially when we know how much teachers are struggling. But we're not being helped, and that would be a way to help us … let us have planning time … We just deserve more. If we're expected to plan out all this cool stuff for our students, why can't … the district work and plan out good things for us? (post-interview, September 14, 2023)

Because Abby was not able to attend the AP College Board Summer Institute prior to teaching AP Biology this year, she was concerned about setting up the required AP labs. Abby wanted PD focused on teaching upper level and AP science courses, saying "How do I keep up the rigor in

my classroom and challenge the kids" (post-interview, September 19, 2023). Because PHS is known for its AP program and has a long-standing history of students being successful in a wide variety of AP exams, Abby may have felt pressured to be an effective AP Biology teacher even though she was not able to attend an AP Summer Institute PD session (field notes, September 2023).

In all the comments, Abby used "us" and "we" when she discussed what she and fellow science teachers experience in PISD. Her team mentality was evident, even as she was starting a new role at a new campus with science teachers she had only known for a day. Abby is relationship-driven and was an honest commentator on what it is like to be a science teacher in 2023. Despite criticisms about the realities of being a secondary science teacher, Abby remained optimistic as an encourager for students and wanted to students to "enjoy learning and finding new interests" (post-interview, September 14, 2023) rather than feeling pressured to pick a career path and worry about getting into a top college. Abby's care and concern for students was the underlying reason she was willing to move schools, change teaching assignments, and ultimately challenge herself as a science teacher.

Rachel the Reflector

Rachel is a wise and experienced chemistry teacher who works with some of the most talented and gifted science students in PISD. She cares deeply about designing challenging experiences in her classes so students will be successful in rigorous college coursework (field notes, August 2023). In addition to a master's degree in chemistry, Rachel has spent years refining the school's IB diploma program and the science coursework required for the program. Students in IB Chemistry take two courses with Rachel in order to master both the advanced chemistry content and the laboratory research component for IB sciences.

Rachel likely knows more chemistry than anyone else in PISD, though Rachel would never acknowledge she is an expert. She spent numerous hours over the summer revising the honors and IB Chemistry curriculum for the district and provided a mini-workshop for the PLC group, showing them where to access the new curriculum documents with driving questions and options for "phenomena-based" lab experiences (field notes, August 2023). Because Rachel has expert-level knowledge in the chemistry content and is responsible for the curriculum, there are no advanced chemistry content or pedagogy resources for her in PISD. Rachel yearns for PD experiences that provide chemistry-specific examples:

> Give me real examples of how I could use this in my classroom because I'm busy enough that if I have to create those examples, if I have to brainstorm how I'm going to use it in my classroom, it's not going to happen … I don't have the time. Send me out with some things that I can use right then and there so I can try it out and decide whether I like it. (post-interview, September 11, 2023)

Like many popular science teachers, Rachel has too many students to place in the six periods she is able to teach each semester, so she has to prepare for three courses and has extra students squeezing into the IB Chemistry sections. She reflected, "They offered me to come in and start teaching one of the IB Chem sections. They told me I needed to give up forensic science because three preps was too many for anybody. I have three preps now" (focus group, August 11, 2023). When Rachel discussed what she would change in the teaching profession, she brought up the subject of preparing for three different courses again. Like other research participants in this study, having enough time to manage teaching responsibilities with family and life commitments is difficult for Rachel. She said:

> I wish that we didn't feel so forced into choosing to do so much work at home. Because there is always that whenever you do complain, whenever you do say to admin., I need more time, blah blah blah. Too many times what you get back is, well, I know it's a sacrifice, but it's for the kids. You're not a good teacher if you're not willing to do everything that the kids need, and I want to do everything that the kids need. (post-interview, September 11, 2023)

Rachel admitted that she often grades assignments at home while her family watches movies "together" and she always completes the required paperwork and documentation for students. Rather than complaining, shirking responsibilities, or cutting corners, Rachel sacrifices personal time and wellbeing in order to be a "good teacher."

Rachel's inner turmoil regarding balancing time surfaced when she described PD experiences as a science teacher. Rachel explained her worst PD experience by focusing on the content:

> The TEKS [Texas Essential Knowledge and Skills] that were chosen, they said that they were physics, but they were more appropriate for elementary pre-physics. So right off the bat, it was kind of like this isn't really relevant to us. Kind of lost your trust that they were preparing something that was at your level, and it wasn't even something that would be useful for our physics teachers. (pre-interview, July 31, 2023)

As a chemistry teacher, Rachel was aware that even the physics teachers would be disappointed with the science content examples in the PD session. Rachel described another PD session focused on teaching to small groups did not give ways to teach advanced chemistry content with IB students, and she had questions about how to use "data-driven decision-making". She explained:

> It feels like a lot of times when they say data-driven, we'll just go back and look at your data and talk about it. But the analytical part of me would like a little bit more than that. Should we be looking at least a little bit more guidance so that I know that I'm doing it right? Are we just looking at some of it? Are we looking at overall averages? Are we disaggregating it, you know, give us some direction instead of just saying go look at your data. (post-interview, September 11, 2023)

She described how it could be useful to pull students into small groups to address their mathematical misconceptions:

> I've got some kids that are in Algebra 2 that had no problem with doing a system of equations for average atomic mass. Then I still have kids on the other end of the spectrum that are struggling to use their calculator to do 39 minus 20. That that's a big gamut. How do you how to use small group learning in a more impactful manner when you have kids that are on such very different starting levels? (post-interview, September 11, 2023)

Because she is analytical and reflective, Rachel is conscious of the deeper pedagogical implications from PD, and she wants PD experiences to be meaningful and impactful to teaching.

As for PD preferences, Rachel volunteered she wants choice in the types of technologies she incorporates into instruction, rather than feeling forced to use an application that may not be the best fit for the content and/or curriculum. She admitted, “obviously I don’t know all the technological options out there” (post-interview, September 11, 2023), so she is open to learning about different programs and applications. However, the time it takes to learn and implement a new technology application is a barrier for Rachel. She wants technology applications to be easy with some immediate examples that show how she can take it and use it in advanced chemistry courses because “it’s not helpful to be told … here is an app and everyone’s using and you have

to use it" (post-interview, September 11, 2023). Without examples that apply to the advanced chemistry classroom, Rachel is not likely to ever use the technology application with students. She explained, "I don't use PowerPoints or Google Slides. What they are representing the technology to me would have meant that I had to completely change my teaching style" (focus group, August 11, 2023). How much time do teachers like Rachel spend in PD sessions listening to new information that they never intend to use in their classrooms?

As the lead for honors-level Chemistry courses, Rachel reflected on how the chemistry teaching team could benefit from PD experiences. Most of the teachers who teach AP or IB chemistry meet together as a PLC a couple of times each week. Like many PLC groups that meet during the school day, the meetings can become more about paperwork and compliance rather than professional learning and improving instructional practices. Rachel was aware that the chemistry PLC group could be more transformative if everyone had more training in PLCs and how to use them to discuss data and improve student outcomes. She said:

> I know in my heart of course, that PLC's need to be about us talking about our data, about our students ... but what it ends up being is us talking about deadlines and vetting test questions and those are all important, but I feel like that's not the meat of a PLC. A PLC is us learning and growing together as professionals, as teachers, and we're not getting to that. (post-interview, September 11, 2023)

Rachel's PLC group met together during PD week and specifically addressed how their time would be spent during the school year. They wanted to manage their time wisely, so meetings are not a gripe session or discussions over unimportant issues (field notes, August 2023). Rachel shared PHS "did away with PLC leaders" (post-interview, September 11, 2023), so no one is in charge of the discussions. Even without being the official PLC leader, Rachel considered the

possibilities of a true learning community, and she wanted training on how to facilitate a PLC group and make it better.

Rachel said she is motivated by the "light bulb moments" when students are able to problem-solve for themselves and they realize how one piece of information fits in with another piece of information (post-interview, September 11, 2023). She hopes students will learn some lifelong skills in her chemistry courses that will be useful later in life (post-interview, September 11, 2023). In other words, Rachel understands the importance of scientific literacy and how the chemistry content can help students beyond the classroom. She went on to say, "So much of science isn't facts. So much of science is a methodology. It's a way of thinking. It's the problem solving, and that is not something you can write down in a step-by-step procedure and memorize" (post-interview, September 11, 2023). Despite a passion for chemistry, Rachel ultimately wants to be remembered not for the content, but as a teacher who loved and helped students feel more confident in science:

> Also knowing that when they walk out the door for me in May, even if they're never going to be a chemist, even if they're never going to take this class again in any way, shape, form, or fashion, maybe I put some logical problem solving in there that's going to help them through the rest of their lives. (post-interview, September 11, 2023)

She regularly reflects on teaching and is able to identify specific ways PD could improve teaching practices. Furthermore, few teachers voluntarily spend their summer rewriting curriculum and pacing guides to share with the rest of the department. Rachel is a team-player who raises the level of expectations for teaching and learning in the science department, and she has high expectations for professional learning.

Melanie the Manager

Melanie is an ideal science department head who is an experienced science teacher, great listener, and patient leader. As a department head, Melanie seemed like a coach who was there to manage and coordinate the science teachers so they could perform at their highest ability. She asked the science teachers to share their "happies and crappies" from the summer at the first department meeting during back-to-school PD week (field notes, August 2023). Despite more than 20 years of teaching both mathematics and physics, Melanie was humble when she described her teaching and classroom instruction. None of the other participants had a single complaint about how Melanie represented their department to campus administration, and yet no one else seemed to realize how hard Melanie worked to support the science team and protect them from "administrivia".

Not everyone aspires to be a high school science department head. With the title often comes additional responsibilities and time commitments such as attending department head meetings, approving department budget expenditures, and communicating administrative expectations to the department. Although Melanie has been in the department head role the past few years, she seemed to enjoy being the liaison between the science department at the school's principal and leadership team (field notes, August 2023). The back-to-school PD week was especially stressful however, because Melanie had to balance personal teaching preparations with those of the science department. She explained:

> I'm in a little bit of a different boat from everybody else because I'm department chair, so I have additional responsibilities … during the week of PD because I'm also putting out this fire because I've got 4 new teachers or I'm planning the department meeting for the next day … I even learned last year that I had to get my compliance training done before

> in-service even started because I was trying to do that like I was a regular classroom teacher. (post-interview, September 11, 2023)

As the department head, Melanie was required to attend additional meetings, support four newly hired science teachers who were transitioning to a new campus, and lead ad-hoc science department meetings when she could squeeze them into the schedule. Preparing her classroom and activities for the first week of school was low on Melanie's priority list for the week. Referring to the last teacher workday before school began, she said:

> That was the first day that I actually felt like I had concentrated time in my room and could get some stuff together, get myself organized, get all of the stuff out on the tables, and copy and laminate and do all the all of the things. I still didn't feel like I got it all done before school started. (post-interview, September 11, 2023)

Melanie was annoyed the back-to-school schedule did not provide specific meeting times for departments to meet, or for the science PLC groups to coordinate before school began. As the department head, Melanie reported the teachers wanted time to work in their classrooms independently, so she felt guilty if she asked the teachers to meet as a department or subject-area team during "free time" before school began:

> That was what I the feedback I got from every teacher I talked to during that week - was it's all fine and good that we're doing all these meetings, but I really just need to be in my room. That's what's stressing me out, is that I'm not ready for day one when there are kids here. (post-interview, September 11, 2023)

Melanie takes the department head role seriously and serves as the communication channel between the campus administrators and the science teachers. She said, "It would have been nicer if I ruled the world … that they said … this afternoon is going to be your department meeting"

(post-interview, September 11, 2023). During department meetings, PD sessions, and informal conversations, Melanie was often listening to others' feedback about the back-to-school PD week events so she could share concerns with administrators later.

Like some of the other experienced science teachers at PHS, Melanie expressed frustration during the focus group meeting saying "I don't think I've learned anything" during back-to-school PD week (August 11, 2023). Melanie prefers to learn from other classroom teachers who are "in the trenches" (focus group, August 11, 2023) either at the Texas science teacher conference or at AP Physics grader sessions. She described conference sessions that were useful because they provided teaching strategies and ideas teachers are currently using in their classrooms. The AP grading sessions have a "PD night" when AP teachers bring trifold boards with QR codes and share AP lesson ideas from their AP Physics courses. She said she "came back with a lot of good ideas for this year" after participating in the AP grading session (pre-interview, August 1, 2023). Melanie enjoys learning from other AP Physics teachers in this format because she gets ideas about teaching specific content for her course. In both of these examples, Melanie went outside of PISD to find meaningful opportunities for personal professional growth.

The only new thing Melanie said she learned during the back-to-school PD week was during an informal conversation with a non-science teaching peer during one of the district-led technology PD sessions. Melanie shared with the department that she only learned something new because she asked how another teacher used the technology application in their class. She said to another teacher:

> Hey, you mentioned how you lead the kids through pre- and post- and using it for reflection. Like actually getting into the nitty gritty of how she does it. One, it doesn't

> involve technology, she just has them post things online as the reflection. I wanted the - what do you actually do? How do you get them to visually see, and how do you get them to synthesize data from the test that they just took? Then using that for themselves personally to improve their learning. That is what I want to use, but that was a 5-minute conversation with the teacher in the trenches. (focus group, August 11, 2023)

As an experienced science teacher and department head, Melanie often seeks out PD experiences that are useful, or at least to make the most of the PD sessions she is required to attend.

Melanie is a proud member of the teaching profession, and she was happy to share that she always knew she wanted to be a teacher. From a young age, Melanie wanted to be a teacher and her mother was also a teacher:

> I always knew I was going to be a teacher. I say always, third grade is the earliest I remember making a decision about what do you want to be when you grow up? I used to play school all the time. My mom was a teacher, and I loved school, and mostly I wanted to be a teacher so that I could be the boss. That kind of morphed and changed as I grew up, because I feel like that's a very immature way of looking at education. (post-interview, September 11, 2023)

Now, Melanie and her sister both teach in PISD. She began her career as both a mathematics teacher and a coach, and eventually switched over to teaching physics and dropped the coaching responsibilities. As she begins to think about retirement, Melanie said some professional learning about investing and retirement from education would have been really useful early in her career. Melanie suggested:

> I personally think that part of my training to be a teacher in college should have included a class on personal finance. Including budgeting, investing, how to buy a house, how to

> get a loan, how not to get a loan, all of those things. I feel like and I know I'm in a little bit of a, a different boat from some people because I'm single. I have to figure all that out on my own and I have to make all those decisions myself. It really would have been nice to be investing from the age of 20 … TRS [Texas Retirement System] isn't going to cut it when it comes time to retire. (post-interview, September 11, 2023)

Personal finance and retirement courses for teachers may not be directly related to teaching, learning, or assessment, yet these types of informational sessions could provide professional growth for teachers.

As Melanie reflected back on a career in education, she was honest about the experiences with PD. The most memorable PD experience was with the American Modeling Teachers Association at Arizona State. Not only was the trip to PD sponsored by the school, but the instructional strategies she learned changed every part of how she taught physics from that point forward (field notes, August 2023). The common theme in Melanie's career with PD was that she took personal initiative to learn and grow. If Melanie had only attended district-provided and/or required PD sessions, then she would have missed opportunities to learn from other teachers from across Texas, find lesson ideas from other AP teachers, and discover unique instructional strategies for physics. She said PISD has funds if teachers want to attend outside PD saying, "It's definitely available, and one of those things that we'll figure out if you want to go, but there's a lot that don't take the opportunity" (pre-interview, August 1, 2023). If teachers view PD as a professional requirement or mandate and they passively attend sessions, then perhaps they have different experiences than teachers who look for opportunities to learn and grow for themselves.

Chapter 5: Themes

The seven teacher narratives, pre- and post-interviews, focus group conversations, and field notes were analyzed, and two major themes emerged from the data: the teachers' perspectives on the teaching profession and their thoughts about PD. Information on the teaching profession was divided into three categories: teaching science, student impact, and support systems. Information relating to PD was separated into five categories: content and pedagogy, technology, environment, personal learning, and required learning. "Teachers" in this chapter refers to the seven teacher participants in this research study and not as broad reference or generalization for all science teachers.

The Teaching Profession

Teaching Science

The seven science teachers shared their thoughts about what makes science teaching unique as compared to other subject areas during their post-interviews after school began. For five of the seven teachers, science teaching is the only profession they know. Melanie was a coach and taught mathematics early in her career, and Eddie worked as an engineer for almost thirty years before moving into science teaching. They are each passionate about science and knowledgeable in their specific content area. They recognized science instruction is unique from subjects like mathematics or English. For example, Paula wants to stay current on new developments in the medical field so she can design rigorous and relevant experiences for students (pre-interview, August 1, 2023). Crystal said, "I enjoy teaching stuff that most people don't" (pre-interview, August 9, 2023), and "I feel like science takes from every other content to develop what it is" (post-interview, September 13, 2023). Rachel explained why science is important:

> Science helps you even if you never become a scientist. Scientific reasoning and problem solving will fix that problem for you every time because you start to think rationally. You start to look for patterns. You start problem solving instead of just overwhelmed by what you see in front of you. (post-interview, September 11, 2023)

Rachel wants to help train students and other teachers in the scientific method because she believes science teaches problem-solving and critical thinking skills (post-interview, September 11, 2023). Abby loves science because it is hands-on and tactile, and she wants to provide a safe environment and never make a student feel dumb for asking questions (post-interview, September 2023). Melanie appreciates that her course is "more interesting when you're not doing the same thing every day" (post-interview, September 11, 2023). Rachel, Melanie, Connie, and Crystal all spoke about the connections between science and using mathematics (post-interviews, September 2023). Crystal said science is a challenging subject to teach because it incorporates content from other subjects like mathematics and English saying, "I do math everyday" (post-interview, September 13, 2023). Connie explained teaching and learning in a chemistry course:

> There's a lot of mental capacity that goes into science teaching and science learning. It's almost like juggling with one hand sometimes ... They're learning new equipment all the time ... it's like investigating on the fly ... I'm teaching you to be a thinker ... If you learn some chemistry, that's wonderful, but I want you to think. (post-interview, September 13, 2023)

Student Impact

When asked about why they became a teacher or how they hope they will be remembered as a teacher, most of the science teachers mentioned helping students. Several teachers are motivated by a desire to help students succeed and make a difference in their lives. They see

students as individuals in their classes who they hope will be scientifically literate adults after graduation. Abby enjoys working with struggling students and "finally that light bulb goes off because of something I said or a lab we did" (post-interview, September 14, 2023). Crystal said, "it's the kindness piece" that is important, not just to "give then a pass and they move on" (pre-interview, August 8, 2023). She said, "it's fun to watch the very beginning of you know, creating change in perspective of life" for students (post-interview, September 13, 2023). Connie values kindness and emotional support in teaching, as well as academic success. She explained:

> Not every person goes through school and it's a nice, wonderful rosy experience. Sometimes it's just really hard and you got to be a champion for those people and you have to let them know learning is hard. But we do it together and we make it better. (post-interview, September 13, 2023)

Melanie became teary when she discussed all of the students she has taught over the years and how she hopes students remember her for how she made them feel (post-interview, August 1, 2023). Rachel wants to be remembered as student-focused and supportive, with a goal of helping students learn and become good human beings (post-interview, September 11, 2023). Finally, Abby and Paula focused on student outcomes from their science courses. Abby wants students "feeling good and feeling confident and making them feel loved and heard in more than a score" (post-interview, September 14, 2023), and Paula has a goal of not only teaching content but helping students learn "how to take care of yourself and not be an idiot in the world" (post-interview, September 14, 2023).

These science teachers value understanding and connecting with individual students to find the best way to teach their content. Eddie wants to make his content fun and applicable so students enjoy learning physics (post-interview, September 18, 2023). He dislikes lecturing and

prefers to set up situations where students can learn through exploration in his AP Physics classes. Eddies prefers using a modeling method because it allows for hands-on learning and student-led experimentation. He said, “I don’t like lecturing because kids typically don’t learn by lecturing ... I love setting up situations where the kids learn” (pre-interview, August 9, 2023). Connie gives students the option to demonstrate mastery of chemical stoichiometry with a lab experiment, rather than a multiple choice or short answer exam (pre-interview, August 3, 2023). Rachel wants to improve her use of small group instruction to better differentiate learning for students. She focuses on making learning applicable and memorable for students, rather than just memorizing facts. She said, “I want them [students] to remember the fun stuff, and that even if learning was hard, I try to make it fun” (post-interview, September 14, 2023). None of the teachers focused on students retaining their science content long term, but rather want students to be successful on their own accord.

Teaching high school science also involves preparing students for their next steps after graduation, whether they plan to attend college or pursue a career. Thus, real-world applications, technologies used in careers, and connections to students' interests are important in high school science courses. Helping students transition from high school to college was a concern for some of the teachers. Paula said, “What can we do better in high school to make our kids, you know, better prepared … what are they lacking in college when they get there” (pre-interview, August 1, 2023). Paula includes service projects in her curriculum “where they have to come up with a way to improve society’s health and wellness” (post-interview, September 14, 2023). Rachel values scientific reasoning and problem-solving skills that will be used throughout the students’ lives (post-interview, September 11, 2023), while Abby worries that pressure on PHS students to attend college can be detrimental (post-interview, September 19, 2023). Connie wants to “answer

the question that the kids ask … I really like lab, but I don't understand why I'm doing this. I don't know what the connection is to my real life" (post-interview, September 13, 2023). Several of the science teachers said they feel successful when students realize the relevance of what they are learning, and seeing students comprehend and connect with the content is rewarding for teachers. The honors chemistry PLC teachers discussed student technology use, cheating and plagiarism, and ways to model better technology habits for students (field notes, August 2023). Helping students transition from high school to college was a concern for some of the teachers. Paula said, "What can we do better in high school to make our kids, you know, better prepared … what are they lacking in college when they get there" (pre-interview, August 1, 2023).

Support Systems

Teachers discussed the importance of sharing ideas and learning from each other, rather than relying solely on PD sessions (field notes, August 2023). The science department as a whole was welcoming to the new science teachers joining the campus and each discipline helped each other by making suggestions and sharing resources (field notes, August 2023). Crystal and the other on-level physics teachers met as a department to discuss teaching strategies and curriculum changes for the upcoming year (field notes, August 2023). The group welcomed a new science teacher and introduced him to previous successes and changes for the year. While they were meeting, Crystal tried have the group review the required PD module over creating questions on the LMS assessment bank but had issues demonstrating how to use the tool for others. Rachel spent the summer revising the chemistry curriculum for the district, and she shared her process with the other honors chemistry teachers and encouraged them to continue to come up with activities and lesson ideas. The two new chemistry teachers were able to ask questions and learn about the common assessments the group creates as a PLC (field notes, August 2023).

During the back-to-school PD week, there was almost no acknowledgement of how challenging managing various non-teaching responsibilities can be, especially for those who are new to the profession. Even experienced teachers like Connie, Paula, Rachel, and Abby discussed difficulties balancing required paperwork and documentation for students with special education or 504 plans (post-interviews, September 2023). Abby lamented, "the amount of paperwork and documentation that we have to do ... with all this data analysis that is being shoved down our throats ... it killed me last year in the middle school level" (post-interview, September 14, 2023). Paula wished she could change the amount of paperwork for student accommodations because "I'm going to take care of every kid regardless. I don't like having to prove it" (post-interview, September 14, 2023). Eddie said his classroom management has improved over time with experience, but the time he spends grading could still be more efficient (post-interview, September 18, 2023).

Professional Development

Content and Pedagogy

During the one session that all of the secondary science teachers were gathered together during back-to-school PD week, the district science curriculum director introduced new teachers and department chairs for each campus and showed everyone where to access curriculum guides and new documents in the district LMS (field notes, August 2023). The district science director explained the district is transitioning to STEM scopes as the primary K-8 resource, and teachers were advised not to spend the first few weeks of school covering all science and engineering practices and recurring themes and concepts (field notes, August 2023). This presentation on new state curriculum standards revisions and the use of phenomenon in science instruction was the only session during the week that was content-specific for science teachers. Abby declared

that this type of curriculum update was not PD (focus group, August 11, 2023). This was an example of high school teachers receiving a curriculum update that was not aligned to their teaching assignment for grades 10-12.

None of the teachers were able to cite recent science-specific PD that was sponsored by the district, and there were few examples of science-specific PD that the teachers have experienced in their careers. Melanie said in her teaching career most of her PD used non-science examples. She said, "Can I have a math or science example of this please? But that requires more thought, more organization, and more expertise" (focus group, August 11, 2023). Abby said, "this is starting my 8th year in science, and I have almost no science-specific PD" (focus group, August 11, 2023). Abby and Eddie are teaching AP courses this school year for the first time and have not attended the AP Summer Institute (APSI) for their course (pre-interview, August 8, 2023; post-interview, September 18, 2023). These APSIs typically provide intense instruction in the science content and pedagogy for the AP science curriculum.

Most of the teachers were confident with their content knowledge in the subject they teach but did want PD in instructional strategies to use in their science courses such as phenomena-based activities to connect science to real life and improve student understanding. Although teachers did not use the term "pedagogy", they do want PD in instructional strategies that are specific for teaching science and the scientific sub-discipline they teach (anatomy, biology, chemistry, physics, etc.). Paula and Crystal both complained that the district has repeatedly required PD training on using Socratic seminars as an instructional strategy that works well in humanities courses, but not in science classes (pre-interviews, August 2023). Paula said she wants PD that is specific to science so she will know if "what I'm actually teaching the kids – is it beneficial to their future" (post-interview, September 14, 2023).

Teachers reported most PD gave general application examples, was not relevant for science classrooms, and did not address both on-level and advanced levels of students. Teachers want PD and support for adopting the following strategies in their science courses: differentiation, classroom management, formative assessments, and small group instruction. Rachel said, “I would also love some more [PD] with small group instruction, but specifically, what does that look like in a science classroom” (post-interview, September 11, 2023). Eddie said attending the modeling PD training “was probably one of the best courses I’ve ever taken. It was useful ... it was a totally new way of designing instruction” (pre-interview, August 9, 2023). Abby said, “The worst professional developments I've been involved in are ones where I'm forced to do something that I feel does not work within a science classroom” (pre-interview, August 8, 2023). Melanie admitted that when she first changed from teaching mathematics to physics, “I treated it more like an applied mathematics course because you got a mathematician teaching physics, and I’ve since learned and been trained on better ways to teach science” (post-interview, September 11, 2023). Melanie expressed a desire for more advanced physics training and instruction, implementing small group instruction in science, and more PD examples geared toward science (post-interview, September 11, 2023). The science teachers want PD to relate to the curriculum, include discussions among science teachers and experts in the field, and provide examples geared towards science.

Technology

Teachers need to be knowledgeable about instructional technology tools in order to effectively teach students and be familiar with science-specific technologies in STEM careers. Technology PD was a hot-topic during the back-to-school week. District-sponsored technology PD was disliked by almost all teachers, but the reasons for disliking the PD varied. During the

back-to-school PD week, all PHS teachers were assigned asynchronous online PD assignments over the Peardeck application and a learning management system (LMS) assessment bank, and district-led technology PD was provided on digital portfolios using the Bulb application. Some teachers struggled with accessing and using the Bulb application, while others found it not useful for their teaching needs (field notes, August 2023). Paula wants instructional technologies that are easy to use and don't require a special training session (post-interview, September 14, 2023). If there is a training session, then teachers want hands-on training with real student data or creating authentic products, rather than watching someone else go through show-to steps on a slideshow. Paula said she dislikes sitting through training on technology topics and applications because “it’s either user friendly or it doesn’t work, so I don’t need that stuff explained to me” (post-interview, September 14, 2023). They want PD to be differentiated for teachers with different levels of proficiency and needs, and they want to work with other science teachers during or after a technology PD session to find ways to integrate the technology into their science courses.

Melanie, Crystal, and Abby suggested real examples of how to use technology in the classroom should be provided during PD to make it easier for them to implement new tools (focus group, August 11, 2023). Melanie wanted more time “getting into the nitty gritty” of how teachers really use the application with students (focus group, August 11, 2023). Rachel explained how forcing all teachers to use one specific technology application like Gizmos can result in “over-saturation” of certain technology tools, making them less effective and engaging for students (pre-interview, July 31, 2023). Some teachers felt forced to learn and use technology tools that do not align with their teaching style or needs. Rachel wants the freedom to choose what is appropriate for her classroom. She said, “Let me pick and choose what my kids need and

what's appropriate for what I'm teaching in my classroom ... give me buffet but don't force me to eat a particular thing" (post-interview, September 11, 2023). Eddie, Abby, and Paula also expressed frustration with repetitive technology training (pre-interviews, August 2023).

Teachers expressed the need for relevant and engaging technology training that is differentiated based on individual needs and proficiency levels. Providing choice in technology PD was especially important for teachers since their levels of expertise and use of instructional technologies vary widely, for example Melanie said, "I always say I'm not tech savvy" (post-interview, September 11, 2023). Abby explained her level of technology proficiency:

> I don't mean to like toot my own horn, but I'm very good with technology. Technology is my jam. I'm a younger, you know, teacher, if you will. I pick up on that stuff ... I feel like we're forced to do the very, very, very basic parts of technology which I'm well versed in and so it's very hard for me to sit through that when I know a lot of stuff. I know that some people know nothing ... but that's a big struggle for me when I'm I feel like I'm just repeating all this stuff that I'm good at. (pre-interview, August 8, 2023)

Other teachers dislike being forced to learn basic technology skills they already know and with receiving information in a way that is not how they teach, i.e. direct instruction with lecture. The science teachers were generally frustrated that the district sponsored certain technology applications over others and required them to be trained year after year on Peardeck, for example (Abby, post-interview, September 14, 2023). Paula said, "A lot of the stuff that is offered at the high school on our PD time, it's stuff I already know" (pre-interview, August 1, 2023). Technology-savvy teachers like Paula want PD content that focuses on "new technologies" and innovative ideas rather than basic skills (Paula, post-interview, September 14, 2023). Although technology is ubiquitous in today's educational system, this group of teachers was disappointed

in the ways they learn about instructional technologies and how technology supports their instruction.

Environment

The PD environment included teachers' detailed descriptions about how PD is delivered and who should provide PD for science teachers. *How* PD occurs includes the modes of delivery such as listening to a presenter or completing an online assignment and *who* provides PD includes teachers with current classroom experience or district personnel in instructional support roles. Melanie said *when* PD occurs before school "stinks" and said February PD might be a better time to introduce new instructional tools and strategies (pre-interview, August 1, 2023). In some cases, these were minimum expectations for the PD environment such as providing a comfortable learning environment with adult-sized chairs and not asking teachers to sit on kid-sized cafeteria stools (Melanie, focus group, August 11, 2023). In most instances, the seven teacher participants spoke about their personal preferences for PD and did not consider how other teachers in the department might want to experience PD. In general, this group of teachers wanted PD experiences that require active learning and are delivered by a current classroom teacher.

The science teachers were adamant that they did not want to sit in a classroom and have information read to them from a screen. Several teachers referenced a PD session during the previous year's back-to-school PD week in which the teachers were all "trained" on a software platform that managed student data. Rachel, Paula, Abby, and Crystal all expressed frustration with being trained and never using the system later in the school year. The PD was delivered in a lecture-style direct instruction format with no hands-on experiences for the teachers to look up their incoming student data (Melanie, pre-interview, August 1, 2023). Several teachers reported

the student data was related to state-mandated student exams that may not have been relevant if teachers are not in a tested grade level or subject area. A couple of the teachers expressed concerns the student testing data could negatively impact how a teacher views a student before ever meeting the student in person.

This group of science teachers had strong opinions about the qualifications of PD providers. They clearly prefer to learn from other classroom teachers rather than receiving PD from a campus or district administrator or outside PD expert. Paula described attending PD sessions with the district science curriculum director saying, “I don’t usually dread going to the ones that he's hosting because I know at least he’s engaging and he’s funny and he respects our time” (pre-interview, August 1, 2023). Connie supports the PD provided by the district science curriculum coordinator saying, “[He] does a real good job … presenting material that everyone of us can take back in some, shape, or form” (pre-interview, August 3, 2023). Teachers gave examples of ideal PD presenters from state science teaching conferences, AP grading sessions, peer-to-peer PD sharing sessions in a previous school district and attending corporate education technology sessions. Melanie appreciates learning from veteran teachers and sharing best practices with colleagues (pre-interview, August 1, 2023). She wants PD presenters who are passionate and knowledgeable about their subject and most prefer to learn from other teachers who have first-hand classroom experience using the tools and strategies presented in their classrooms. Abby and Paula also mentioned wanting PD presenters to be passionate about their topics (pre-interviews, August 2023). Teacher-presenters with recent classroom experience can provide real-world examples make for more relevant and useful PD experiences. Melanie and Crystal said they prefer to have PD sessions lead by other classroom teachers (focus group, August 11, 2023). Crystal said some PD presenters “haven’t done the ins and outs of it, so you

can't answer the questions and you … can't do it yourself in this live moment" (pre-interview, August 8, 2023). She emphasized her preference for peer-to-peer PD sessions saying, "teachers with experience definitely have a better ability to explain, answer, and process" (focus group, August 11, 2023). Paula said, "I just want you to tell me what you're doing and why it's working for you, why you like it" (pre-interview, August 1, 2023).

If current classroom science teachers present PD, then they can share relevant and useful ways to take the PD content and use it in new and engaging ways with students in science courses. Rachel gave an example of a PD session that encouraged student-led inquiry in science and was not appropriate for her advanced level science students. She was concerned about lab safety in honors chemistry courses, as students may be working with dangerous materials (post-interview, September 11, 2023). Teachers want classroom teachers to present PD because they understand current student needs and can give examples from their classrooms during PD sessions. Teacher participants want to be able to ask application questions about their content area and receive feedback and ideas from the presenter that demonstrate an expert-level of understanding about the PD and their content. For this group of high school science teachers, classroom experience at the high school level is a requirement for PD presenters, and some want experience teaching either unengaged or highly motivated students.

Personal Learning

All of these science teachers have a personal desire to learn more about teaching and learning. None of the teachers said that they do not need PD or that PD is a waste of their time. Crystal explained, "If it's something that's in my field of wanting to know and it's in my interest, that's what I spend my time learning" (pre-interview, August 9, 2023). She explained that she "spent the summer reading and learning … and I wrote some curriculum" (post-interview,

September 13, 2023). Teachers in on-level courses want to learn how to help at-risk students and those who struggle in school. For example, Abby was moving from middle school up to high school, and she wanted PD to learn how to interact with older students and how to manage a high school classroom effectively (focus group, August 11, 2023). Paula is frustrated with boring and irrelevant PD and prefers to learn from a passionate community of educators like those in the Apple EDU space (pre-interview, August 1, 2023). Connie described herself as a team player and she seeks out opportunities for learning. She is intrinsically motivated to learn about topics that interest her and prefers to focus on areas where she needs improvement. She explained, "I'm hungry to learn because I will research something to the last page on the Internet. I want to know everything about it" (pre-interview, August 3, 2023). Eddie enjoys finding new activities and instructional strategies to make learning fun and engaging. When asked what PD he would like this year, Eddie said, "One thing I've been wanting to do is actually have more fun activities because I want to have fun, and I know if I'm having fun, the kids will be having fun too" (post-interview, September 18, 2023). Crystal said "choice has to be involved to determine what someone feels is valuable" regarding teacher PD sessions (focus group, August 11, 2023). Abby values the ability to choose what she wants to learn in PD, saying "Any PD that I've done that involved choice is my favorite" (pre-interview, August 8, 2023). For this group of science teachers, a desire to continually learn and improve in their profession was an underlying assumption, but there was obvious dissatisfaction with the ways in which they were given opportunities for professional learning as science teachers at PHS.

Rachel expressed a desire for more time to collaborate and discuss teaching strategies after a PD session or throughout the year during PLC meeting time (post-interview, August 11, 2023). Despite the name "professional learning community", PLCs are often used as a meeting

and planning time for a group of teachers. Some of the PLC groups, like Rachel's chemistry PLC, focus on making their meetings productive and efficient. Rachel wants more time for collaboration and discussion of PD content during these PLC meetings (post-interview, September 11, 2023). Due to scheduling constraints, there are some teachers who are not scheduled to meet regularly with their PLC during the school year. Rachel suggested PLCs could be used for reflecting and processing information learned from PD sessions and for science teachers to generate ways to incorporate PD content into their classroom instruction (post-interview, September 11, 2023). On the first day of the back-to-school PD week, the campus principal identified the priorities for campus PLC meetings. Teachers are expected to collaborate in their PLCs to identify learning standards, create common assessments, design learning experiences, build relationships, evaluate with data, and close the gap for struggling students (field notes, August 7, 2023). Rachel explained PLCs are often used to discuss common assessments or managerial issues like student discipline, and time for learning together often does not occur. She said:

> I feel like we're missing something there that, you know, if we have these PLC communities where we're going to talk to each other, that professional development should come over into those communities. But we don't have time to work that in necessarily to just the Everyday PLC meeting. (Rachel, pre-interview, July 31, 2023)

Required Training

During the back-to-school PD week, teachers participated in a variety of meetings and sessions, including compliance courses like ethics and handbook training, special education updates, and facilities maintenance information. The bulk of the content from this back-to-school week fell into the category of compliance and required training and would not be classified as

professional learning or traditionally defined PD. The back-to-school PD week was spent on activities that could be classified as *professional preparedness*. The compliance courses were mandatory for all instructional staff, and the science teachers saw them as repetitive and boring. Eddie said, "The compliance training is mind numbingly boring … I understand we have to do it, but since the training is based on hours and not content, it means they stretch it out to fit the time" (pre-interview, August 9, 2023).

Compliance training can be frustrating when teachers want to learn innovative instructional strategies or improve their teaching during required PD sessions. For example, all teachers were given an online ethics training module to complete independently, but then the same content was covered during an in-person session which required all teachers to sign in to verify their attendance (field notes, August 2023). The teachers were frustrated with the duplicate training and reported that the compliance training requirements can be confusing. Eddie explained his frustration with the online training modules saying, "I'm typically screaming at my computer … the system is not set up to make it easy. There's a lot of clicking here, clicking there" (pre-interview, August 9, 2023). While none of the teachers said the compliance information unnecessary, they did want ways to complete it online or in a more efficient way before the school year begins.

The teachers rotated together as a science department during back-to-school PD week to attend sessions hosted by the assistant principals. Connie shared during the focus group that campus administrators do carefully plan the timing and scheduling of PD (August 11, 2023). These sessions reviewed campus policies and procedures over topics including special education, facilities and maintenance, textbooks and technology, and school safety. Teachers were instructed on their responsibilities when handling money and reporting child abuse or neglect.

All teachers attended these sessions, whether it was their first year on the campus or their 21st year at PHS (field notes, August 2023). These sessions were important for teachers to understand any district and/or campus policy changes and to better support students. Crystal explained when she chooses to do her professional learning saying, "I do that on my own time … my hobby … I'm reading, I'm listening to those things. I'm development on my own time" (pre-interview, August 9, 2023).

In the pre-interviews when teachers were asked to share their worst PD experience, most of them referred to a session from the previous year over a new student database program (field notes, August 2023). The PD was required by the school district for all teachers, so there was no individual choice or input about attending the session. The PD session lasted one full day during the previous year's back-to-school PD week, and the teachers all reported that there was no follow through later in the school year to inquire about whether or not the teachers were using the software or if the software was effective. Paula described the session saying, "I don't even remember what it was called because it was the only time we ever discussed it. It was never brought back up to us" (pre-interview, August 1, 2023). Abby said, "Our presenter read from a script. We logged on to this program, but if there were any troubleshooting issues, they didn't know how to fix it because they weren't experts in it (pre-interview, August 8, 2023). Melanie described discussing the PD with the principal and being reassured that the data was there to support students and getting to know them (post-interview, September 11, 2023). Teachers did not participate in hands-on and interactive activities, provide input or feedback before or after the session, choose from a variety of sessions related to their teaching assignment, or manipulate student data in the software program. This group of teachers viewed this PD experience as an insult to their professional roles as teachers (field notes, August 2023).

The science teachers want PD to meet their needs and preferences without overloading them with unnecessary tasks immediately prior to the beginning of the school year. The teachers agreed that they needed to know the "nuts and bolts" (field notes, August 2023) information about campus procedures, including facilities, maintenance, discipline referrals, and substitute teachers, but that this information should not be considered "professional development" because it was all compliance training. Paula explained:

> I feel like that could be maybe spread out better or done in a different way because it is useful information … but learning it in 7 minutes and then rotating to the next session - It's like, wait, what just happened? … I can't even imagine as a new teacher trying to process all that information. (post-interview, September 14, 2023)

Crystal was concerned about new teachers who "have to figure out how to do the job and now all these things … that's a panic for new people" during back-to-school PD week (pre-interview, August 8, 2023). Eddie mentioned it would be helpful if the administrators would make a checklist for this week with required PD sessions such as counseling and ethics updates, setting up courses in the district LMS, AP audit paperwork, facilities, and maintenance requests, etc. (field notes, August 2023). The teachers agreed that these types of mandatory PD before school begins are poorly timed because there is too much to learn and then immediately implement in their courses.

During the interviews, focus group, and conversations with the science teachers there were no negative comments about the campus principal or the leadership in the building. The principal spoke several times to the PHS teachers and staff in the auditorium during the back-to-school PD week and it was evident that building relationships with students and teachers is a priority (field notes, August 2023). Connie described the support she receives from the campus

principal by saying, “When she got there … she didn’t have to say a lot of preachy words … when somebody’s got your back, she’ll get you what you need” (pre-interview, August 3, 2023). Despite the feelings of being supported by the campus administration, the teachers still had some concerns about the district-level administrators (focus group, August 7, 2023). The science teachers expressed frustration with district-level planning of PD and the focus of PD sessions each school year. Melanie said PISD provides opportunities to attend PD and state science teaching conferences, “but there’s a lot [of teachers] that don’t take the opportunity (pre-interview, August 1, 2023). As a former administrator in other school districts, Connie said “there is a large amount of professional development that is available” in PISD (pre-interview, August 3, 2023). Teachers want more valuable and beneficial PD opportunities, and more support from the district.

During the focus group, the science teachers questioned the time spent each year during the district’s convocation event. During this year’s convocation, all teachers, administrators, and school staff including cafeteria workers, maintenance staff, and district support personnel met for approximately three hours in the PHS’s large gymnasium. Each campus sat together and was recognized at the beginning like a pep rally and the campus teachers of the year were recognized in a slideshow on the jumbotron (field notes, August 2023). The district teacher of the year was from PHS and gave an inspiring talk, and the district superintendent gave a motivational speech for the district employees. During his speech, the superintendent read from his journal from his first year of teaching, which happened to be in PISD more than twenty years earlier. A particularly interesting entry was his reflection from his first convocation experience and how he would change convocation in PISD if he was ever in charge. During the focus group, Paula cited this moment as proof that the school district never changes saying:

> I found it interesting that the superintendent, at the end of reading of his journal, made a comment about how he wrote if he were ever in charge, he would do it differently, but he hasn't. No one has - it's not any different than it ever has been. It's always been - we do all these things, we check it off the list, and we get nothing out of it. (August 11, 2023)

Could the back-to-school PD week be reimagined and repurposed so that compliance training is accomplished AND teachers participate in meaningful individualized professional learning?

Chapter 6: Discussion

Interpretation of Themes

The teachers were concerned about the content of PD and how PD fits in their current schema of teaching and learning. Their recommendations for PD were based on both positive and negative PD experiences the teachers had during their careers. This group of teachers associated poor PD experiences with a lack of interest, relevance, and/or usefulness, and a lack of coordination and expertise for those responsible for organizing PD. Some recommendations were specific to science teaching like considering lab safety standards or providing examples from upper-level science courses. Other suggestions were specific to the ways PD is delivered like providing teachers with online modules for compliance training and using classroom teachers for PD providers.

The science teacher participants were passionate about their positions as classroom teachers and hoped this research would spur some changes at PHS. Because *professional development* is a unique requirement positioned within the *teaching profession*, the boundaries between the two themes are murky at best. Teaching science requires a different skill set than other subjects because the content often requires hands-on experimentation in laboratory exercises, uses mathematics to calculate science phenomena, and integrates technical reading and writing of science content. The PD needs of these science teachers are not the same as rest of the PHS faculty, and yet there was less than three hours of scheduled time for the secondary science teachers to meet during the back-to-school PD week. Beyond being science teachers, the participants had their own individual preferences for what they wanted to learn and how they would like to learn. The overwhelming feeling among the seven science teachers was that they are not respected as educated professionals to make choices about what they need to learn to do

their job effectively. If teachers feel like no one understands the demands of their job and they are constantly given more tasks to complete without any compensation, then completing PD items can become another duty or chore.

Choice and Differentiation

The science teachers expect PD to model best teaching practices, individualized instruction, and adult pedagogical methods. Melanie said, "What makes professional development the worst or ineffective is when it's done in a way that is not how we teach" (pre-interview, August 1, 2023). Abby compared one-size-fits all PD to differentiation for students:

> We're told all the time we have to differentiate ... but we're often not given the same courtesy when it comes to professional development ... It seems like they're serving one teacher and we're different too ... We learn in different ways. We learn at different speeds. Some are experts, some are not ... I kind of wish professional development catered more to that. (pre-interview, August 8, 2023)

PD could be more effective if teachers are given choice in what they learn. These teachers want to have a variety of PD options and be able to choose which PD sessions are best suited for them, including more tailored and relevant PD. Ideally, PD experiences will directly relate to the teachers' grade level and content area and provide new strategies that teachers can immediately use with their existing curriculum. Teacher-led PD sessions could be an effective way for science teachers to share their expertise with their peers as part of the PD experience. Other teachers had their own professional interests and wanted to seek out opportunities for their own PD. For teachers who want PD with advanced level science content, this may require bringing in outside experts or finding PD experiences outside of the school district such as online PD courses offered by universities.

Defined Outcomes

This group of science teachers is willing to participate in a variety of PD experiences, but they want to understand the intended outcomes of the PD. For PD to be effective, teachers want to know what will be expected of them after the PD session is over. Teachers want to balance classroom accountability with a meaningful implementation of PD, meaning they need time to plan, process, and implement new methods in their classrooms. In general, these science teachers are willing to implement items from a PD session if they have clear and tangible items that must be completed. Teachers expressed a desire for practical strategies and immediate implementation as a PD outcome. Most teachers dislike participating in PD training on a new tool during PD if campus or district administrators never bring up the tool again. In order for teachers to try something new with students, they need time for hands-on practice and reflection with teaching peers during and after the PD experience. One suggestion from Rachel for improving PD outcomes and implementation:

> A lot of times PD ... happens and then we're never asked about it again ... it'd be nice if there was some follow up. If it was like, hey, you remember that PL [professional learning] ... how are you using that in your class? Instead of just ok, in-service is over, you can put that handout in your filing cabinet and not think about it again. (pre-interview, July 31, 2023)

The science teachers associate poor follow through of PD with poor planning by the campus and district leadership.

Implications

Researchers in science education should encourage a holistic understanding of problems facing our field and teacher narratives fill a void in the literature that other methods simply

cannot. Wolcott (1988) noted that education research tended to simplify complexity in order to explain rather than drawing attention to the complex social structures present in schooling. PD is one of these complex structures within schooling that deserves to be unpacked and deconstructed, but not oversimplified into prescriptive lists and recommendations for best practices. Wolcott (1988) suggested the dichotomy between simplicity and complexity may explain the difficulty in making education research useful for practitioners in education. If scholarly research on PD is never translated into documents that are useful for school leaders, then the research has no lasting impact.

The seven teachers in this research study implicitly described a top-down control of professional development planning and decision-making shown in Figure 6.

Figure 6: Top – Down Control of Professional Development

The schedule for the back-to-school PD week was given to the teachers the morning they arrived at work (field notes, August 2023). After teachers renew their contract in the spring for the following school year, they have no control over the school calendar, the number of hours of PD that are required, the content of the PD sessions provided during the back-to-school PD week, or PD sessions provided during the school district. Teachers want to have more ownership in the PD process and more input in the planning of PD experiences. They want to be treated and

respected as professionals in their field. The term “trust” came up in more than one conversation with the science teachers, often referring to teachers being trusted and respected to have more autonomy and choice in their PD. Paula values teacher-led decision-making and wants classroom teachers to give more input:

> The people that are in charge of making the decisions have been out of school for too long or have never been a teacher… There's a lot of decisions being made about things that make no sense … Even at the district level, there's decisions coming from the administration office … When's the last time you were in a classroom … do you really know… what would that look like? I just wish that teachers had more say in the day-to-day things that are happening here. (post-interview, September 14, 2023)

Treating teachers as individuals and providing opportunities for choice and differentiation is an issue of respect for their roles as professionals. They deserve more than listening to lectures and reading from slideshows (Figure 7) both of which ignore their prior knowledge and experiences.

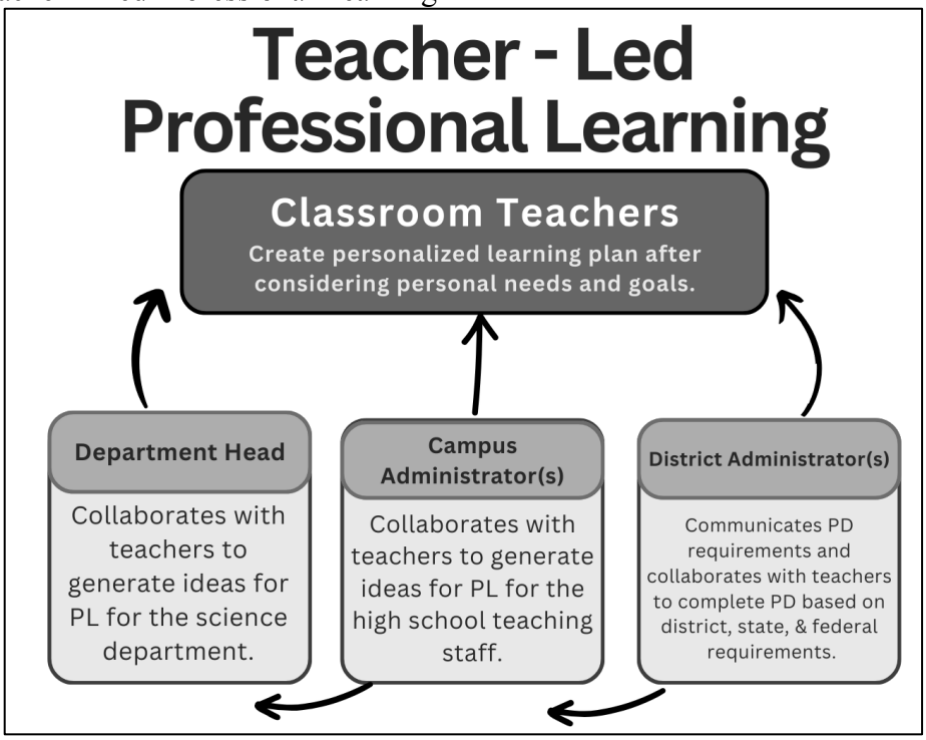
Figure 7: PHS Professional Development

If PD is reimagined with teacher input and choice in professional learning, how might the control be redistributed among the school decision makers? This research illustrates each of the

seven science teachers have unique perspectives on PD and unfortunately there is no list of recommendations for PD that would satisfy all of them. There are however requests the science teachers made that do make sense and should be honored.

After years of teaching science, these seven teachers have developed individual forms of social, economic, and cultural capital (Bourdieu, 1998) that are not easily defined, captured, or transferred to novice teachers. Unfortunately, this "science teacher capital" does not translate into an ability to negotiate for their own personalized professional learning that is meaningful and relevant. Andeotti (2017) suggests teachers should renegotiate their trip down the river by "letting go of the investments and desires for failure-proof, predetermined scripts … open up more responsive and exciting possibilities in education" (p. 320). The current hierarchy in school districts often handcuffs individuals who swim against the stream or deviate from the PD that is provided. Is science teacher PD one of these "predetermined scripts" that schools could consider changing how teachers learn and grow in their profession? Teachers will not be able to "renegotiate" for "exciting possibilities" in PD without the full support of campus principals, district administrators, and even the school board because the current system assumes these leaders have top-down management of all facets of PD. Teachers should be able to choose what they need for their *professional learning*, a purposeful distinction from *professional development*. "Professional development" carries a connotation of mandates and requirements including annual updates, compliance training, and required PD sessions. Professional learning implies that teachers might truly learn something that would assist them in their profession as a teacher. Figure 8 illustrates one possible scenario for reimagining how science teachers experience PD *and* professional learning.

Figure 8: Teacher – Led Professional Learning



In this model, teachers receive input from the science department head and campus administrators, and the district communicates expectations for the district and other state and federal requirements for PD. There may be required PD sessions that are outside of the realm of professional learning, but the campus and district administrators should collaborate on the most efficient way for teachers to complete these requirements. Ultimately, the science teachers design their professional learning plan (PLP) after receiving input from the campus and district, and determining their own strengths, weaknesses, and needs for professional learning. Teachers set their own goals for professional learning, identify and request resources and supplies needed for their PLP, outline what evidence they will use to document that they completed their PLP, and identify the intended impact of their PLP. If teachers design their own professional learning and feel supported in reaching their own goals, then there is a potential for teachers to also feel respected as professionals.

Considerations

The lack of scholarship on science teachers' perspectives on PD prevents researchers in the field from comprehending the full range of variables interacting within the boundaries of science education. The use of narrative research with grounded theory in a single school with a group of teachers is time-consuming and complex when compared to using quantitative data to understand a problem across multiple classrooms, schools, or even school districts. Conducting qualitative research with science teachers with varying teaching experiences affords differing perspectives about the teaching profession and PD experiences. Teachers are defined by more than a profession; they possess other identities based on gender, age, ethnicity, social class, religion, marital status, and so on (Bordia et al., 2020; Rosaldo, 1993). When schools are viewed as a micro community, then understanding their complexity requires more than statistical figures about student and teacher demographics, formal test scores, six weeks grades, and attendance or bullying reports (Erickson, 1984).

What if there is no truth to be discovered, no universal recommendation to find for science teacher PD? Should science education scholars stop searching for answers if they are likely to be complex, murky, and obscure? Or are these the spaces where we should spend time exploring, discussing, and questioning so that there is some illumination even if we can't fully understand or grasp the wholeness of the issue? Paula described the complexity of planning science teacher PD by saying:

> I think because science is so broad of a topic, it's hard … try to plan a PD for all of science. I don't know where I would start .... Who do you target? Who are you trying to help and who needs the most help? Or you know which subject is lagging behind the

most? I don't know. This is what your project is trying to do, right? Fix it. Zero advice. (post-interview, August 1, 2024)

Any definition of professional development for teachers is ultimately useless if it does not take into account what teachers actually do as part of their PD for a new school year. While the state board of education does not consider presenting PD towards an individual's required PD hours for the renewal of teaching certificates, teachers most certainly develop and grow as professional educators when they teach their peers. This group of teachers wants PD to be relevant and useful, rather than just a requirement to fulfill hours. No one received a PD certificate for the two hours spent in the district's convocation ceremony, and yet spending time together as an educational community inspires, motivates, and provides teachers with a sense of renewal and purpose for the upcoming year. None of the science teacher participants counted how many hours they spent learning content, preparing technology, sharing instructional strategies, or completing "nuts and bolts" sessions. Rather, these science teachers were focused on doing what they do best – preparing to welcome students and sharing their love of science.

Future Research

This research has the potential to go beyond analyzing science teacher PD and could promote positive change by improving PD at the school for the teachers. There is an opportunity to encourage administrators and teacher educators to value science teachers' needs, preferences, and prior experiences when designing PD. This group of science teachers appreciates choice and differentiation in PD activities and wants PD to provide practical strategies that align with their teaching styles. In order for a district and/or campus to provide differentiated PD options for teachers, PD designers need to plan with teacher input and feedback in mind. Several teachers said they were not asked what they wanted or needed to learn this year during the back-to-school

PD week. However, during back-to-school PD week, science teachers are not reflecting on PD they want or need. They are focused on the more pressing and important issues that are facing them before a new school year begins. Can I see my student rosters yet? How do we access the curriculum planning guides for the first nine weeks of school? Where do we find the department student learning objective to place into our annual goal planning form for HR? Perhaps the most important question asked is, "When will maintenance repair the AC [air conditioning] in my room (Abby, field notes, August 2023). These questions do not diminish the importance and value of PD for science teachers but acknowledges what science teachers ultimately prioritize in their race to prepare for the first day of school. When back-to-school preparation for teachers appears to "push everything out with the firehose … five days before school starts" (Crystal, pre-interview, August 8, 2023), then school districts need to reconsider their annual plans for teacher PD.

Learning about the identities and lived experiences of science teachers as they interact with PD may allow others in science education to open spaces (Barton, 2001) for conversations about the profession of teaching and how PD is defined within the profession. Science teachers deserve to have opportunities to reflect on their own professional learning needs and should be encouraged to advocate for choice and differentiation in PD. Future research could investigate survey instruments to gather input from science teacher about their preferences and needs for PD. Science educators could provide workshops for classroom science teachers to explore their professional strengths, weaknesses, and learning needs. Facilitating partnerships between science education researchers and school district administrators could increase the flow of information between research scholars and school practitioners. Dismantling the top-down power control of PD will require a collaboration between science education scholars, school leaders, and

classroom teachers who are all treated with equal power and authority. If science teachers are truly education *professionals*, then perhaps the phrase *professional development* is an outdated concept in need of revision to meet the needs of today's science teachers.

Appendix A: Recruitment Email

Dear [redacted] High School Science Teachers:

My name is Kristen Brown, and I am a doctoral student working with Dr. Molly Weinburgh at Texas Christian University (TCU). I previously worked in [redacted] ISD as a science teacher, assistant principal, curriculum coach, and curriculum director from 2005 – 2014.

I am conducting a research study on six high school science teachers' experiences with professional development. Participation will include a 1-hour pre-professional development, a 1hour post- professional development interview, and a 1-hour focus group for a total of 3 hours of participation time. An additional 30 minutes of your time will be needed to email and schedule interviews. Your total participation time will be no more than 3 hours and 30 minutes. I will also observe during [redacted] ISD's professional development the week August 7th – 11, 2023.

Participation is completely voluntary, any data collected for the research will keep your identity confidential, and data will be securely stored on TCU's server. Your decision to participate or not to participate will not affect your job status, employment record, employee evaluations, or advancement opportunities.

If you are interested in participating in the research study, please respond back to this email. I will contact you with additional information and will schedule an initial 1-hour pre-professional development interview prior to August 7, 2023.

While there is no financial incentive for participating in this research, there is the potential to help others better understand what science teachers want and need from professional development. The study has been designed to minimize the amount of time and effort required for you to participate. There are minimal risks involved in this research such as the possibility of discomfort when discussing previous job experiences as a teacher. [redacted] and [redacted] are also aware that this study will be taking place at CHS.

If you have any questions, please do not hesitate to contact Kristen Brown at [redacted]@tcu.edu or [redacted]

Thank you for your time.

Kristen A. Brown
Doctoral Candidate in Science Education
College of Education
Texas Christian University

Appendix B: Interview and Focus Group Protocols

Pre-Interview
Question Protocol
(Recorded with Zoom July and August 2023)

Title of Research: Science Teacher Narratives on Professional Development
Principal Investigator: Dr. Molly Weinburgh
Co-investigator: Kristen A. Brown

Please state your first and last name.

Thank you. Now I will review the informed consent for this research.

This study is being conducted at [redacted] and is supported by TCU. The purpose of this study is to explore high school science teacher experiences with professional development. During the week of August 7-11, 2023, science teachers will be observed as they participate in professional development. Additional data will be collected in an online 1-hour pre-professional development interview on Zoom, a 1-hour in-person focus group during professional development week, and a 1-hour online post- professional development interview recorded via Zoom after school begins for a total of 3 hours. Your participation is voluntary. You do not have to participate and may stop your participation in the study before August 12, 2023. If you decide to leave the study after August 12, 2023, your data will still remain as part of the study. Participation in the post-interview is also voluntary. If you decide to leave the study after the post interview, you have two weeks after your post-professional development interview to stop your participation and withdraw your post- professional development interview data from the study.

Do you verbally agree to participate in this research study? Thank you. Please send me a PDF copy of your signed consent form by tomorrow to my email. Do I have your permission to record this interview? Thank you.

Can you please introduce yourself and tell me about your career in science teaching?

I now have three open-ended questions about professional development.

1. What is the worst experience you've ever had with PD?
    a. Can you give me some reasons why the experience stands out to you?
2. What is the best experience you've ever had with PD?
    a. Can you give me some reasons why the experience stands out to you?
3. What would be your ideal PD experience?
    a. What are some of the barriers that prevent ideal PD experiences?

In-Person Focus Group
Question Protocol
(Recorded with Zoom on August 7, 2023)

Title of Research: Science Teacher Narratives on Professional Development
Principal Investigator: Dr. Molly Weinburgh
Co-investigator: Kristen A. Brown

Please state your first and last name.

Thank you. Now I will review the informed consent for this research.

This study is being conducted at [redacted] and is supported by TCU. The purpose of this study is to explore high school science teacher experiences with professional development. During the week of August 7-11, 2023, science teachers will be observed as they participate in professional development. Additional data will be collected in a 1-hour online post-professional development interview recorded via Zoom after school begins for a total of 3 hours. Your participation is voluntary. You do not have to participate and may stop your participation in the study before August 12, 2023. If you decide to leave the study after August 12, 2023, your data will still remain as part of the study. Participation in the post-interview is also voluntary. If you decide to leave the study after the post interview, you have two weeks after your post-professional development interview to stop your participation and withdraw your post- professional development interview data from the study.

Do you verbally agree to participate in this research study? Thank you. Do I have your permission to record this interview? Thank you.

During your pre-post development interviews, you each responded to three open-ended questions about professional development: 1) What is the worst experience you've ever had with PD? 2) What is the best experience you've ever had with PD? 3) What would be your ideal PD experience?

How have your professional development activities this week helped to prepare you for the upcoming school year? Can you give any examples of something new you learned this week?

Can you identify professional development activities this week that addressed the following: Science content, science pedagogy and/or instruction, other areas such as classroom management, student engagement, technology, or supporting students with learning differences (i.e. special education, language learners, and/or gifted and talented)

Post-Interview
Question Protocol
(Recorded with Zoom in September 2023)

Title of Research: Science Teacher Narratives on Professional Development
Principal Investigator: Dr. Molly Weinburgh
Co-investigator: Kristen A. Brown

I now will review the informed consent for this research.

This study is being conducted at [redacted] and is supported by TCU. The purpose of this study is to explore high school science teacher experiences with PD. During the week of August 7-11, 2023, I observed science teachers as they participated in PD. Data was also collected in an online 1-hour pre-PD interview on Zoom, a 1-hour in-person focus group during PD week, and with this 1-hour online post-PD interview recorded via Zoom for a total of 3 hours. Your participation is voluntary. Participation in this post-interview is also voluntary. If you decide to leave the study after the post interview, you have two weeks after today to stop your participation and withdraw your post-PD interview data from the study.

Do you verbally agree to participate in this research study? Thank you. Do I have your permission to record this interview? Thank you. Please state your first and last name.

1. What did you do with your time on Monday, August 14th for the "teacher workday"?
2. What would you like to learn this year if you could truly request your own personalized professional learning?
3. Do you need any PD in the following areas? Content knowledge, instruction/teaching/pedagogy strategies, technology, other areas such as student needs, personal or professional growth, district/campus policies or procedures, attend a conference or take a course.
4. Have you had another profession outside of education? If yes, can you tell me about the profession or job. Did the profession have any continuing education or professional training requirements? How did these experiences compare with your experiences with professional development in education?
5. Talk to me about why you became a science teacher.
6. What is the most rewarding part of being a teacher?
7. How do you think science teaching is different from other subjects?
8. What is one of your favorite memories from your teaching career?
9. What do you wish you could change about the teaching profession?
10. What has been the most challenging part of being a teacher?
11. When you leave the teaching profession or retire, how do you hope others describe you as a teacher?
12. Is there anything else you want to share with me as I wrap up my data collection on your experiences with PD?

References

Abd-El-Khalick, F., BouJaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., Niaz, M., Treagust, D., & Tuan, H. (2004). Inquiry in science education: International perspectives. *Science Education, 88*(3), 397-419. https://doi.org/10.1002/sce.10118

Abell, S. K. (2008). Twenty years later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education, 30*(10), 1405-1416. https://doi.org/10.1080/09500690802187041

Abell, S. K., Rogers, M. A. P., Hanuscin, D. L., Lee, M. H., & 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*(1), 77-93. https://doi.org/10.1007/s10972-008-9115-6

Abrams, E., Yore, L. D., Bang, M., Brayboy, B. M. J., Casagno, A., Kidman, J., Lee, H., Villanueva, M. G., Wang, M. H., Webb, P., & Yen, C. (2014). Culturally relevant schooling in science for indigenous learners worldwide. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 671-696). Routledge. https://doi.org/10.4324/9780203097267

Akin, J. M., & Black, P. (2007). The history of science curriculum reform in the United States and the United Kingdom. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education* (1st ed.), (pp. 573-592). Routledge. https://doi.org/10.4324/9780203824696

Alonzo, A. C., & Kim, J. (2016). Declarative and dynamic pedagogical content knowledge as elicited through two video-based interview methods. *Journal of Research in Science Teaching, 53*(8), 1259-1286. https://doi.org/10.1002/tea.21271

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* Oxford University Press.

Amin, T. G., Smith, C. S., & Wiser, M. (2014). Student conceptions and conceptual change: Three overlapping phases of research. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 57-81). Routledge. https://doi.org/10.4324/9780203097267

Andeotti, V. (2017). Renegotiating epistemic privilege and enchantments with modernity: The gain in the loss of the entitlement to control and define everything. In J. Paraskeva & S. Steinberg (Eds.), *The Curriculum: Decanonizing the field,* (pp. 311-328). Peter Lang.

Barton, A. C. (2001). Science education in urban settings: Seeking new ways of praxis through critical ethnography. *Journal of Research in Science Teaching, 38*(8), 899-917. https://doi.org/10.1002/tea.1038

Barton, A. C., Tan, E., & O'Neill, T. (2014). Science education in urban contexts: New conceptual tools and stories of possibilities. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 246-265). Routledge. https://doi.org/10.4324/9780203097267

Bodzin, A. M., Fu, Q., Kulo, V., & Peffer, T. (2014). Examining the effect of enactment of a geospatial curriculum on students' geospatial thinking and reasoning. *Journal of Science Education and Technology, 23*(4), 562-574. https://doi.org/10.1007/s10956-014-9488-6

Bordia, P., Read, S., & Bordia, S. (2020). Retiring: Role identity processes in retirement transition. *Journal of Organizational Behavior, 41*(5), 445-460. https://doi.org/10.1002/job.2438

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3-15. https://doi.org/10.3102/0013189X033008003

Bos, B. (2011). Professional development for elementary teachers using TPACK. *Contemporary Issues in Technology and Teacher Education*, *11*(2), 167-183.

Bourdieu, P. (1986). The forms of capital. In J. G. Richardson (Ed.), *Handbook of theory and research for the sociology of education* (pp. 241-258). Greenwood Press.

Brandt, C. B., Shumar, W., Hammond, L., Carlone, H., Kimmel, S., & Tschida, C. (2010). Habitus, social fields, and circuits in rural science education. *Cultural Studies of Science Education, 5*(2), 477-493. https://doi.org/10.1007/s11422-009-9229-y

Buxton, C. A., & Lee, O. (2014). English learners in science education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 204-222). Routledge. https://doi.org/10.4324/9780203097267

Bybee, R. W. (2002). We should teach about biological evolution. *Bioscience, 52*(7), 616-618. https://doi.org/10.1641/0006-3568(2002)052[0616:WSTABE]2.0.CO;2

Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of Science Teacher Education*, *25*(2), 211-221. https://doi.org/10.1007/s10972-014-9381-4

Carlone, H., & Johnson, A. (2012). Unpacking 'culture' in cultural studies of science education: Cultural difference versus cultural production. *Ethnography and Education, 7*(2), 151-173. https://doi.org/10.1080/17457823.2012.693691

Chai, C. S. (2019). Teacher professional development for science, technology, engineering, and mathematics (STEM) education: A review from the perspectives of technological pedagogical content (TPACK). *The Asia-Pacific Education Researcher*, *28*(1), 5-13. https://doi.org/10.1007/s40299-018-0400-7

Chaipidech, P., Kajonmanee, T., Chaipah, K., Panjaburee, P., & Srisawasdi, N. (2021). Implementation of an andragogical teacher professional development training program for boosting TPACK in STEM education: The essential role of a personalized learning system. *Educational Technology & Society, 24*(4), 220-239. https://doi.org/10.30191/ETS.202110_24(4).0017

Charles, M. T., & Kolvoord, R. A. (2004). *Using visualization tools for inquiry-based science: A longitudinal study of teacher's stage of development* [Paper presentation]. National Educational Computing Conference, New Orleans, LA, United States. http://education.ed.pacificu.edu/charlesm/presentations/necc2004vism.pdf

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis.* SAGE.

Clandinin, D. J. (2013). *Engaging in narrative inquiry*. Left Coast Press, Inc.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*(7), 13-20.

Collins, L., & Mitchell, J. T. (2019). Teacher training in GIS: What is needed for long-term success? *International Research in Geographical and Environmental Education*, *28*(2), 118–35. https://doi.org/10.1080/10382046.2018.1497119

Crawford, B. A. (2014). From inquiry to scientific practices in the science classroom. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 515-541). Routledge. https://doi.org/10.4324/9780203097267

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research*, *76*(4), 607-651. https://doi.org/10.3102/00346543076004607

DeBoer, G. E. (2014). The history of science curriculum reform in the United States. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 559-577). Routledge. https://doi.org/10.4324/9780203097267

Delgado, C. (2015). Navigating tensions between conceptual and metaconceptual goals in the use of models. *Journal of Science Education and Technology, 24*(2/3), 132-147. https://doi.org/10.1007/s10956-014-9495-7

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181-199. https://doi.org/10.3102/0013189X08331140

Desimone, L. M. (2011). A primer on effective professional development. *Phi Delta Kappan, 92*(6), 68-71. https://doi.org/10.1177/003172171109200616

Desimone, L. M., & Le Floch, K. C. (2004). Are we asking the right questions? Using cognitive interviews to improve surveys in education research. *Educational Evaluation and Policy Analysis, 26*(1), 1-22. https://doi.org/10.3102/01623737026001001

Dubois, S. L., & Luft, J. A. (2014). Science teachers without classrooms of their own: A study of the phenomenon of floating. *Journal of Science Teacher Education, 25*(1), 5-23. https://doi.org/10.1007/s10972-013-9364-x

Duit, R., Schecker, H., Hottecke, D., & Niedderer, H. (2014). Teaching physics. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 434-456). Routledge. https://doi.org/10.4324/9780203097267

Eraut, M. (1995). Developing professional knowledge within a client-centered orientation. In T. R. Guskey & M. Huberman (Eds.), *Professional development in education: New paradigms and practices* (pp. 227-252). Teachers College Press.

Erickson, F. (1984). What makes school ethnography 'ethnographic'? *Anthropology & Education Quarterly, 15*(1), 51-66. http://doi.org/10.1525/aeq.1984.15.1.05x1472p

Eun, B., & Lim, H. (2009). A sociocultural view of language learning: The importance of meaning-based instruction. *TESL Canada Journal*, *27*(1), 13-26.

Gale, J., Koval, J., Alemdar, M., Grossman, S., & Usselman, M. (2022). Sustaining shifts in science teaching through a research–practice partnership. *School Science and Mathematics, 122*(6), 298-310. https://doi.org/10.1111/ssm.12545

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*(4), 915-945. https://doi.org/10.3102/00028312038004915

Geertz, C. (1973). *Thick description: Toward an interpretive theory of culture*. Basic Books.

Gladwell, M. (2002). *The tipping point: How little things can make a big difference.* Back Bay Books.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine de Gruyter.

Goldsmith, T. H. (1989). The evolution of biology and adaptation of the curriculum. In W. G. Rosen (Ed.), *High school biology today and tomorrow* (pp. 113-116). National Academy Press.

Gordon, S. P. (2004). *Professional development for school improvement: Empowering learning communities*. Pearson Education.

Gunckel, K. L., Covitt, B. A., & Salinas, I. (2018). Learning progressions as tools for supporting teacher content knowledge and pedagogical content knowledge about water in environmental systems. *Journal of Research in Science Teaching, 55*(9), 1339-1362. https://doi.org/10.1002/tea.21454

Hammond, L., & Brandt, C. (2004). Science and cultural process: Defining an anthropological approach to science education. *Studies in Science Education, 40*(1), 1-47. https://doi.org/10.1080/03057260408560202

Hammond, T. C., Bodzin, A., Anastasio, D., Holland, B., Popejoy, K., Sahagian, D., Rutzmoser, S., Carrigan, J., & Farina, W. (2018). "You know you can do this, right?": Developing geospatial technological pedagogical content knowledge and enhancing teachers' cartographic practices with socio-environmental science investigations. *Cartography and Geographic Information Science, 45*(4), 305-318. https://doi.org/10.1080/15230406.2017.1419440

Higgins, T. E., & Spitulnik, M. W. (2008). Supporting teachers' use of technology in science instruction through professional development: A literature review. *Journal of Science Education and Technology, 17*(5), 511-521. https://doi.org/10.1007/s10956-008-9118-2

Hochberg, E. D., & Desimone, L. M. (2010). Professional development in the accountability context: Building capacity to achieve standards. *Educational Psychologist, 45*(2), 89-106. https://doi.org/10.1080/00461521003703052

Ingersoll, R. M., & Strong, M. (2011). The impact of induction and mentoring programs for beginning teachers: A critical review of the research. *Review of Educational Research, 81*(2), 201-233. https://doi.org/10.3102/0034654311403323

Jin, H., Shin, H., Johnson, M. E., Kim, J., & Anderson, C. W. (2015). Developing learning progression-based teacher knowledge measures. *Journal of Research in Science Teaching, 52*(9), 1269-1295. https://doi.org/10.1002/tea.21243

Jones, G., Dana, T., LaFramenta, J., Adams, T. L., & Arnold, J. D. (2016). STEM TIPS: Supporting the beginning secondary STEM teacher. *Tech Trends, (60)*, 272-288. https://doi.org/10.1007/s11528-016-0052-5

Jones, M. G., & Leagon, M. (2014). Science teacher attitudes and beliefs: Reforming practice. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 830-847). Routledge. https://doi.org/10.4324/9780203097267

Jong, O. D., & Taber, K. S. (2014). The many faces of high school chemistry. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 457-480). Routledge. https://doi.org/10.4324/9780203097267

Kapofu, L. K. (2019). Teacher culture and emergent context in two desegregated science classrooms in South Africa: A focused ethnography. *South African Journal of Education, 39*(2), 1-8. https://doi.org/10.15700/saje.v39n2a1581

Kearney, S. (2015). Reconceptualizing beginning teacher induction as organizational socialization: A situated learning model. *Cogent Education, 2(*1) https://doi.org/10.1080/2331186X.2015.1028713

Kelly, G. J. (2014). Discourse practices in science learning and teaching. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 321-336). Routledge. https://doi.org/10.4324/9780203097267

Kiesel, J. (2013). Introducing future teachers to science beyond the classroom. *Journal of Science Teacher Education, 24*(1), 67-91. https://doi.org/10.1007/s10972-012-9288-x

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60-70.

Krajcik, J. S., & Mun, K. (2014). Promises and challenges of using learning technologies to promote student learning of science. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 337-360). Routledge. https://doi.org/10.4324/9780203097267

Lave, J., & Wegner, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge University Press.

Lazarowitz, R. (2007). High school biology curricula development: Implementation, teaching, and evaluation from the twentieth to the twenty-first century. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education (Vol. 1)*, (pp. 561-598). Erlbaum. https://doi.org/10.4324/9780203824696

Lazarowitz, R. (2014). High school biology curriculum development: Implementation, teaching, and evaluation from the twentieth to the twenty-first century. In N. G. Lederman & S. K.

Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 412-433). Routledge. https://doi.org/10.4324/9780203097267

Leavy, P. (2017). *Research design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches*. The Guilford Press.

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology, 1*(3), 138-147.

Lee, C. G. (2012). Reconsidering constructivism in qualitative research. *Educational Philosophy and Theory, 44*(4), 403-412.

Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S., & Hewson, P. W. (2003). *Designing professional development for teachers of science and mathematics* (2nd ed.). Corwin Press.

Loughran, J. J. (2014). Developing understandings of practice: Science teacher learning. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 811-829). Routledge. https://doi.org/10.4324/9780203097267

Luft, J. A., Firestone, J. B., Wong, S. S., Ortega, I., Adams, K., & Bang, E. (2011). Beginning secondary science teacher induction: A two-year mixed methods study. *Journal of Research in Science Teaching*, *48*(10), 1199-1224. https://doi.org/10.1002/tea.20444

Luft, J. A., & Hewson, P. W. (2014). Research on teacher professional development programs in science. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 889-909). Routledge. https://doi.org/10.4324/9780203097267

Luft, J. A., Roehrig, G. H., & Patterson, N. C. (2003). Contrasting landscapes: A comparison of the impact of different induction programs on beginning secondary science teachers' practices, beliefs, and experiences. *Journal of Research in Science Teaching, 40*(1), 77-97. https://doi.org/10.1002/tea.10061

Luft, J. A., Whitworth, B. A., Berry, A., Navy, S., & Kind, V. (2019). Science education trajectories: Charting the course for teachers, educators, researchers, and policymakers. *Journal of Science Teacher Education, 30*(1), 63-79. https://doi.org/10.1080/1046560X.2018.1535226

Luft, J. A., & Zhang, C. (2014). The pedagogical content knowledge and beliefs of newly hired secondary science teachers: The first three years. *Educación Química*, *25*(3), 325-331. https://doi.org/10.1016/S0187-893X(14)70548-8

Madison, D. S. (2020). *Critical ethnography: Method, ethics, and performance* (3rd ed.). SAGE.

Magnusson, S. J., Krajcik, J. S., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.). *Examining pedagogical content knowledge* (pp. 95-132). Kluwer Academic.

Martin, J. (2019). Researching primary teachers' professional agency: Employing interactive ethnography to overcome reluctance to teach science. *Research in Science Education, 49*(5), 1279-1299. https://doi.org/10.1007/s11165-017-9654-y

Mayer, W. V. (1970). The biological sciences curriculum study. *The High School Journal, 53*(4), 226-240.

McGinnis, J. R., & Kahn, S. (2014). Special needs and talents in science learning. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 223-245). Routledge. https://doi.org/10.4324/9780203097267

McGuinn, P. (2015). Schooling the state: ESEA and the evolution of the U.S. department of education. *RSF: Russell Sage Foundation Journal of the Social Sciences, 1*(3), 77-94. https://doi.org/10.7758/rsf.2015.1.3.04

McIntyre, J., & Hobson, A. J. (2016) Supporting beginner teacher identity development: External mentors and the third space. *Research Papers in Education, 31*(2), 133-158. https://doi.org/10.1080/02671522.2015.1015438

McKinley, E., & Gan, M. J. S. (2014). Culturally responsive science education for indigenous and ethnic minority students. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 284-300). Routledge. https://doi.org/10.4324/9780203097267

Mertens, D. M. (2020). *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods* (5th ed.). SAGE.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teacher's College Record*, *108*(6), 1017-1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Narayan, R., Rodriguez, C., Araujo, J., Shaqlaih, A., & Moss, G. (2013). Constructivism: Constructivist learning theory. In B. J. Irby, G. Brown, R. Lara-Alecio, & S. Jackson (Eds.). *The handbook of educational theories* (pp. 169-183). Information Age Publishers.

National Center for Education Statistics (NCES). (2023). *Common core of data (CCD) public school data* [2021-2022 school year]. https://nces.ed.gov

National Research Council. (1996). *National science education standards*. National Academies Press. https://doi.org/10.17226/4962

National Research Council. (2007). *Taking science to school: Learning and teaching science in Grades K-8.* National Academies Press. https://doi.org/10.17226/11625

National Research Council. (2008). *Common standards for K-12 education?: Considering the evidence: Summary of a workshop series*. National Academies Press. https://doi.org/10.17226/12462

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

National Research Council. (2013). *Next generation science standards: For states, by states*. National Academies Press. https://doi.org/10.17226/18290

National Research Council. (2015). *Guide to implementing the next generation science standards*. National Academies Press. https://doi.org/10.17226/18802

Niess, M. L., van Zee, E. H., & Gillow-Wiles, H. (2010). Knowledge growth in teaching mathematics/science with spreadsheets: Moving PCS to TPACK through online professional development. *Journal of Digital Learning in Teacher Education*, *27*(20), 42-52. https://doi.org/10.1080/21532974.2010.10784657

Nixon, R. S., Luft, J. A., & Ross, R. J. (2017). Prevalence and predictors of out-of-field teaching in the first five years. *Journal of Research in Science Teaching, 54*(9), 1197-1218. https://doi.org/10.1002/tea.21402

Oliver, J. S., & Hodges, G. W. (2014). Rural science education: New ideas, redirections, and broadened definitions. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on*

science education (Vol. 2), (pp. 266-283). Routledge. https://doi.org/10.4324/9780203097267

Olson, J. K., Tippett, C. D., Milford, T. M., Ohana, C., & Clough, M. P. (2015). Science teacher preparation in a North American context. *Journal of Science Teacher Education, 26*(1), 7-28. https://doi.org/10.1007/s10972-014-9417-9

Orion, N., & Libarkin, J. (2014). Earth system science education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 481-496). Routledge. https://doi.org/10.4324/9780203097267

Osborne, J. (2014). Scientific practices and inquiry in the science classroom. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 579-599). Routledge.

Packer, M. J., & Goicoechea, J. (2000). Sociocultural and constructivist theories of learning: Ontology, not just epistemology. *Educational Psychologist*, *35*(4), 227-241.

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal, 44*(4), 921-958. https://doi.org/10.3102/0002831207308221

Peterson, M., Delgado, C., Tang, K., Bordas, C., & Norville, K. (2021). A taxonomy of cognitive image functions for science curriculum materials: Identifying and creating 'performative' visual displays. *International Journal of Science Education, 43*(2), 314-343. https://doi.org/10.1080/09500693.2020.1868609

Rahm, J. (2012). Collaborative imaginaries and multi-sited ethnography: Space-time dimensions of engagement in an afterschool science programme for girls. *Ethnography and Education, 7*(2), 247-264. https://doi.org/10.1080/17457823.2012.693696

Rannikmae, M., Holbrook, J., & Soobard, R. (2020). Social constructivism – Jerome Bruner. In B. Akpan & T. J. Kennedy (Eds.), *Science education in theory and practice: An introductory guide to learning theory* (pp. 259-275). Springer.

Rennie, L. J. (2014). Learning science outside of school. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 120-144). Routledge. https://doi.org/10.4324/9780203097267

Robinson, W. (2017). Teacher education: A historical overview. In D. J. Clandinin & J. Husu (Eds.), *The SAGE handbook of research on teacher education* (*Vol. 1*), (pp. 49-67). SAGE. https://doi.org/10.4135/9781526402042.n58

Rosaldo, R. (1993). *Culture & truth: The remaking of social analysis (with a new introduction)*. Beacon Press.

Rosenthal, D. B. (1990). What's past is prologue: Lessons from the history of biology education. *The American Biology Teacher, 52*(3), 151-155. https://doi.org/10.2307/4449067

Rubino-Hare, L. A., Whitworth, B. A., Bloom, N. E., Claesgens, J. M., Frederickson, K. M., Henderson-Dahms, C., & Sample, J. C. (2016). Persistent teaching practices after geospatial technology professional development. *Contemporary Issues in Technology and Teacher Education, 16*(3), 208-285.

Rudolph, J. (2002). *Scientists in the classroom: The cold war reconstruction of American science education*. Palgrave.

Rudolph, J. (2019). *How we teach science: What's changed, and why it matters.* Harvard University Press.

Rutherford, F. J., & Ahlgren, A. (1991). *Science for all Americans*. Oxford University Press.

Schneider, R. M., & Plasman, K. (2011). Science teacher learning progressions: A review of science teachers' pedagogical content knowledge development. *Review of Educational Research, 81*(4), 530-565. https://doi.org/10.3102/0034654311423382

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-22. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Sparapani, E. F., Callejo Perez, D., Gould, J., Hillman, S., & Clark, L. (2014). A global curriculum? Understanding teaching and learning in the United States, Taiwan, India, and Mexico. *SAGE Open, 4*(2). https://doi.org/10.1177/2158244014536406

Thomas, L., Tuytens, M., Moolenaar, N., Devos, G., Kelchtermans, G., & Vanderline, R. (2019). Teachers' first year in the profession: The power of high-quality support. *Teachers and Teaching, Theory and Practice*, *25*(2), 160-188. https://doi.org/10.1080/13540602.2018.1562440

Traianou, A. (2007). Ethnography and the perils of the single case: An example from the sociocultural analysis of primary science expertise. *Ethnography and Education, 2*(2), 209-220. https://doi.org/10.1080/17457820701350616

Treagust, D. F., & Tsui, C. (2014). General instructional methods and strategies. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 303-320). Routledge. https://doi.org/10.4324/9780203097267

Treagust, D. F., Won, M., & Duit, R. (2014). Paradigms in science education research. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2)*, (pp. 3-17). Routledge.

Treagust, D. F., Won, M., Petersen, J., & Wynne, G. (2015). Science teacher education in Australia: Initiatives and challenges to improve the quality of teaching. *Journal of Science Teacher Education, 26*(1), 81-98. https://doi.org/10.1007/s10972-014-9410-3

Tytler, R. (2014). Attitudes, identity, and aspirations toward science. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 82-103). Routledge. https://doi.org/10.4324/9780203097267

van den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In B. J. Frasier & K. G. Tobins (Eds.). *The International Handbook of Science Education*, (pp. 421-447). Springer. https://doi.org/10.1007/978-94-011-4940-2_25

van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching, 38*(2), 137-158. https://doi.org/10.1002/1098-2736(200102)38:2<137::AID-TEA1001>3.0.CO;2-U

van Driel, J. H., Berry, A., & Meirink, J. (2014). Research on science teacher knowledge. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 848-870). Routledge. https://doi.org/10.4324/9780203097267

von Glasersfeld, E. (2001). The radical constructivist view of science. *Foundations of Science, 6*(1), 31-43.

Walshe, G. (2020). Radical constructivism – von Glasersfeld. In B. Akpan & T. J. Kennedy (Eds.), *Science education in theory and practice: An introductory guide to learning theory* (pp. 359-371). Springer.

Whitworth, B. A., Rubino-Hare, L., Boateng, F., Hamlin, A., Bloom, N. E., & Nolan, E. (2022). Teacher enactment of the geospatial inquiry cycle in classrooms following scaled up professional learning and development. *International Journal of Science Education, 44*(3), 379-415. https://doi.org/10.1080/09500693.2022.2030073

Wickman, P. (2014). Teaching learning progressions: An international perspective. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 145-163). Routledge. https://doi.org/10.4324/9780203097267

Wolcott, H. F. (1988). Ethnographic research in education. In R. M. Jaeger (Ed.), *Complementary methods for research in education* (pp. 187-206). American Educational Research Association.

Woodruff, S. B., & Kahle, J. B. (2014). Project assessment: Its history, evolution, and current practice. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education (Vol. 2),* (pp. 727-746). Routledge. https://doi.org/10.4324/9780203097267

Wozolek, B. L. (2015). *The presence of absence: The negotiation of space and place for students of color at a predominantly white suburban high school* (Publication No. 3726987) [Doctoral dissertation, Kent State University]. ProQuest.

Yoon, S. A., Goh, S., & Park, M. (2018). Teaching and learning about complex systems in K-12 science education: A review of empirical studies 1995-2015. *Review of Educational Research, 88*(2), 285-325. https://doi.org/10.3102/0034654317746090

Zhang, M., Parker, J., Koehler, M. J., & Eberhardt, J. (2015). Understanding in-service science teachers' needs for professional development. *Journal of Science Teacher Education, 26*(5), 471-496. https://doi.org/10.1007/s10972-015-9433-4

Curriculum Vitae

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Fort Worth, TX 76109

Academic Background

PhD in Science Education, Texas Christian University, *August 2020 – May 11, 2024*
Dissertation Title: *Science Teacher Narratives on Professional Development*
Committee Members: Dr. Molly Weinburgh (chair), Dr. Curby Alexander, Dr. Gabriel Huddleston, and Dr. Cathryn van Kessel

M.Ed. in Educational Administration, Texas Woman's University, 2007 - 2008

M.S. in Environmental Science, Texas Christian University, 2002 – 2004

B.A. in Biology, Texas Christian University, 1999 – 2002

University Teaching & Research Experience

Graduate Research Assistant, Texas Christian University, 2020 - 2024

- National Science Foundation (NSF) Grant # 1949393
    - Socio-Environmental Science Investigations: Exploring Alternative New Directions SESI-ExpAND
    - Four-year collaborative grant with Lehigh University and Washington State Tri-Cities, total award $3,000,000
    - Principal Investigator, Dr. Curby Alexander and Senior Personnel, Dr. Molly Weinburgh
- Serving as a consultant for Dr. Molly Weinburgh (TCU College of Ed.) and Dr. Matt Chumchal (TCU Biology Dept). to submit an NSF proposal for a 3-year exploratory curriculum writing and PD project with the National Park Service (*proposal decision expected by Fall 2024*).
- Co-deliver and plan monthly professional development for a cohort of high school teachers from science, social studies, and STEM teaching areas.
- Collaborate with cohort teachers on lesson planning, delivery, and assessment using geospatial technology and tools.
- Present grant research at state, national, and international science and education conferences including ASTE, ESRI, ICRSME, NARST, SSMA, and SW-ASTE.
- Research interests include teacher professional development, first year science teachers, and in-service teachers' technology integration.

Instructor, College of Education, Texas Christian University, 2017 - 2020

- Courses Taught:
    - EDEC 30013 Creative Thinking for Science
    - EDEC 20013 Science for the Elementary Teacher

- EDUC 30013 Professional Roles & Responsibilities *(Writing Emphasis course)*
- EDUC 30001 Professional Practice Seminar

- Supervised student teachers across school district sites in DFW, observed teachers monthly using T-TESS, and mentored students during their last semester before graduation.
- Research interests included effective practices in the science classroom, preservice teacher preparation, and transitioning into the classroom for beginning educators.

University Field Supervisor, Tarleton State University, 2015 – 2020

- Supervised teachers across school district sites in North Texas in grades K-12 in a variety of subject areas during their first year of full-time teaching or student teaching.
- Observed teachers monthly and provided feedback on classroom management, lesson design and delivery, and interactions with students using the Texas Teacher Evaluation and Support System (T-TESS).
- Corresponded weekly with teachers regarding their concerns about classroom management, lesson planning, issues with teaching peers or administrators, and other reflections they had about their experience as a new educator.

Graduate Teaching Assistant, Texas Christian University: Aug. 2002 – May 2004

- Taught three undergraduate biology labs each week.
- Participated in field data collection and laboratory research under Dr. Ray Drenner with freshwater fishes and mercury contamination.
- Planned lab sessions with lecturing professors, Dr. Ray Drenner and Dr. Molly Weinburgh.

Educator Certifications

Texas Principal Certification, Grades PK-12

Texas Composite Science, Grades 8-12

Publications

Alexander, C., Weinburgh, M., **Brown, K.,** & Stroup, M. (2023). Mapping emotions. *Social Education, 87*(2), 119-123.

Popejoy, K., Hammond, T., Malone, D., Morrison, J., Firestone, J., Bodzin, A. M., Leeson, D., **Brown, K. A.**, Alexander, C., & Weinburgh, M. (2023). Integrating ArcGIS digital technologies for learning: Three case studies from university design partnerships with teachers. In J. Trumble, S. Asim, J. Ellis, & D. Slykhuis (Eds.), *Theoretical and Practical Teaching Strategies for K-12 Science Education in the Digital Age* (pp. 98-115). IGI Global. https://doi.org/10.4018/978-1-6684-5585-2.ch006

Casey, P., Dunlap, K., **Brown, K**., & Davison, M. (2012). Elementary principals' role in science instruction. *Administrative Issues Journal: Education, Practice, and Research, 2*(2), 57-62. https://doi.org/10.5929/2012.2.2.5

Conference Proceedings

Alexander, C., **Brown, K.,** Weinburgh, M. & Valverde, E. (2023). "Whose story is being told?": Local History, Cultural Heritage, and Digital Maps. In E. Langran (Ed.), Proceedings of Society for Information Technology & Teacher Education International Conference (pp. 1501-1508). New Orleans, LA, United States: Association for the Advancement of Computing in Education (AACE). Retrieved April 7, 2023 from https://www.learntechlib.org/primary/p/222023/.

Alexander, C., Weinburgh, M., **Brown, K.,** Hammond, T., Popejoy, K. & Leeson, D. (2022). Strategies for Building Hands-On Data Collection Activities for Students. In E. Langran (Ed.), Proceedings of Society for Information Technology & Teacher Education International Conference (pp. 1396-1399). San Diego, CA, United States: Association for the Advancement of Computing in Education (AACE).

Conference Presentations

Brown, K., & Weinburgh, M. (2023). STEM teacher goes rogue: PD with an innovative implementation of GIS. Presented at the *2023 School Science and Mathematics Association Conference*, Colorado Springs, CO.

Brown, K., Weinburgh, M., & Alexander, C. (2022). Professional development during COVID-19: Using socio-environmental science investigations to promote geospatial thinking. Presented as a roundtable themed paper set at the *2022 Association for Science Teacher Education Conference*, Charleston, SC.

Brown, K. A., Weinburgh, M.H., & Alexander, B (2022). Professional development during COVID-19: Using socio-environmental science investigations to promote geospatial thinking. Paper set presented at the virtual annual meeting of the *Association for Science Teacher Education Conference*, Salt Lake City, UT.

Alexander, C., Hammond, T., Popejoy, K., Valverde, E., Stroup, M., Weinburgh, M., **Brown, K.**, & Leeson, D. (2021). Cultural heritage mapping with GIS in two U.S. Cities. Presented at the *2021 National Council for the Social Studies Conference*. Online.

Brown, K., Weinburgh, M., & Alexander, C. (2021). Zooming through professional development: Learning geospatial thinking and reasoning through ZOOM. *2021 School Science & Mathematics Association Conference*. Online.

Brown, K., Weinburgh, M., & Alexander, C. (2021). Teachers learning with GIS while learning about GIS: 2020-2021 PD. Presented at the *2021 Southwest Association for Science Teacher Education Conference*, The Woodlands, TX.

Weinburgh, M., Alexander, C., & **Brown, K.,** (2021). Synchronous or Asynchronous: Learning geospatial thinking and reasoning through ZOOM. Presented as a roundtable themed paper set at the 2021 *International Consortium for Research in Science and Mathematics Education*, online.

Leeson, D., Malone, D., **Brown, K.,** Hammond, T., & Popejoy, K. (2020). Putting it on the Map: Building Authentic Local Geospatial Inquiries with ArcGIS Online. Presented as a Workshop at the *Innovate Learning 2020 Summit*, online. (slides)

Casey, P. & **Brown, K.** (2009). Principal Support for Elementary Science Programs. *2009 Hawaii International Conference on Education*, Honolulu, Hawaii.

School District Administrator Experience

Special Education Coordinator (Long-Term Administrative Substitute), Keller ISD: November 2018 – March 2019

- Supported administrators and teachers at 1 high school, 4 middle/intermediate schools, and 6 elementary schools.
- Supervised teachers, curriculum, and programs for adult transition students and transition services for students over the age of 18.
- Coordinated students moving campuses due to changes in their program of services.
- Provided administrative support to teachers, diagnosticians, and campus administrators during ARD meetings.
- Conducted goal setting and mid-year performance evaluations for 18 special education staff members including diagnosticians, Licensed Specialists in School Psychology (LSSPs), and Speech Language Pathologists (SLPs) using a T-TESS format.

Director of Enrichment Programs, Coppell ISD: July 2012 – May 2014

- Led curriculum and instruction for grades K-12 in the areas of Career Technology Education (CTE), Advanced Placement (AP), International Baccalaureate (IB), Gifted and Talented (GT), Fine Arts, and Languages Other Than English (LOTE).
- Observed instruction and provided feedback for educators in grade K-12 through walkthroughs and learning rounds.
- Designed and facilitated professional learning for educators and administrators in the areas of CTE, Fine Arts, LOTE, GT, and IB, as well as professional learning for campus and district administrators on district strategic initiatives.
- Served as district liaison for programs including Service Learning, Academic Decathlon, Elementary Academic UIL, CISD Elementary Honor Choir, and the CHS Academies.
- Partnered with local colleges and universities for dual credit initiatives and articulation agreements in CTE, Fine Arts, LOTE, and IB.
- Managed district Federal Perkins grant, budget expenditures, required reports, and related documentation.

Content Instructional Coach, Coppell ISD: 2010 – 2012

- Led district-wide staff development in project-based learning for K-12 educators.
- Collaborated with educators in the research and design of project and problem-based learning in science, math, English Language Arts, social studies, and electives.
- Created project-based rubrics, assessments, and instructional activities for K-12 educators.

Assistant Principal, New Tech High @ Coppell, Coppell ISD: 2008 – 2010
- Observed and appraised 10 members using PDAS.
- Managed schedules, textbooks, maintenance, substitutes, student activity funds, 504 plans, student attendance and discipline.
- Assisted in recruitment, staff development, budget, and student events.

Classroom Teaching Experience

Biology Teacher, New Tech High @ Coppell, Coppell ISD: 2008 – 2009
- Wrote a project-based learning curriculum for 9th grade biology course.
- Collaborated with New Tech teachers to write biology, chemistry, and physics projects.
- Participated in a one-week professional learning conference in project-based learning with the New Tech Network.

Biology & Chemistry Teacher, Coppell High School, Coppell ISD: 2006 – 2008
- Lead teacher for a program for at-risk freshman and sophomores.
- Wrote new cross-curricular lessons for biology to meet the needs of learners.
- Served on the CHS Strategic Planning Committee.

8th Grade Science Teacher, Coppell Middle School East, Coppell ISD: 2005 – 2006
- Taught on-level and honors science.
- Represented school on district service learning committee.
- Wrote middle school GT curriculum for science.

Biology Teacher, Polytechnic High School, Fort Worth ISD: 2004 – 2005
- Taught on-level and honors biology, and science TAKS remediation.
- Served as science representative on vertical team for curriculum alignment.
- Completed 30 hours of gifted and talented professional development.
- Coached girls' soccer and cross-country.

Professional Service

Manuscript Reviewer, Electronic Journal for Research in Science & Mathematics Education
Conference Proposal Reviewer, International Consortium for Research in Science & Mathematics Education (ICRSME)
Graduate Student Ambassador, ICRSME, 2022-2023
Conference Proposal Reviewer, National Association for Research in Science Teaching
Conference Proposal Reviewer, School Science and Mathematics Association
Conference Proposal Reviewer, Association of Science Teacher Educators

Professional Service to the Community

Site Based Decision-Making Committee, McLean Middle School, Fort Worth ISD, 2023-2024
Kappa Kappa Gamma Sorority Alumni, 2003 - present
(UNT Chapter Advisor, 2010 – 2011)
Academy 4 Mentor, Alice Contreras Elementary, Fort Worth ISD, 2021-2023
Family & Community Engagement for PTA, McLean 6th Grade School, Fort Worth ISD, 2021-2022

Site Based Decision-Making Committee, McLean 6th Grade School, Fort Worth ISD, 2021-2022
Science Lab Coordinator, Tanglewood Elementary, Fort Worth ISD, 2019-2020
Site Based Decision-Making Committee, Tanglewood Elementary, Fort Worth ISD, 2018-2020
New School Transition Committee, Tanglewood Elementary, Fort Worth ISD, 2017-2018
Site Based Decision-Making Committee, Valley Ranch Elementary, Coppell ISD, 2013-2014

Professional Memberships

Current

Association of Science Teacher Educators
International Consortium for Research in Science & Mathematics Education
National Association for Research in Science Teaching
School Science and Mathematics Association
Southwest Association of Science Teacher Educators

Previous

Career & Technology Association of Texas (CTAT), 2012 – 2014
Association for Career and Technical Education (ACTE), 2012 – 2014
Career & Technical Educators of North Texas (CTENT), 2012 – 2014
Metroplex Foreign Language Supervisors (MFLS), 2013 – 2014
Texas Association for the Gifted and Talented (TAGT), 2012 – 2014
National Association for Gifted Children (NAGC), 2012 – 2013
Metroplex Advanced Academics Cooperative (MAAC), 2012 – 2013
National Science Teacher Association, 2004 – 2009
Science Teacher Association of Texas, 2004 – 2009
Association for Supervision and Curriculum Development, 2008 – 2010

Awards and Honors

TCU College of Education Dissertation Award, Spring 2024
TCU Andrews Institute for Research in Mathematics and Science Education Tuition Scholarship, 2020-2023
TCU Andrews Institute for Research in Mathematics and Science Education Travel Grants, 2020-2023
TCU Office of Graduate Studies Travel Grant for ICRSME Conference, March 2023
College of Education Representative for TCU Office of Graduate Studies 3 Minute Thesis Competition, April 2023
1st Place – 3 Minute Thesis Competition, SSMA Conference, Colorado Springs, CO, October 2023
2nd Place – 3 Minute Thesis Competition, ICRSME Conference, Panama City, Panama, March 2023
Southwest ASTE Travel Grant to ASTE, 2021-2022
Teacher of the Month Award, Coppell MS East, November 2005
Teacher of the Month Award, Polytechnic High School, October 2004
Environmental Science Graduate Teaching Award at TCU, May 2004