ABSTRACT

NORVILLE, KAYLA. Characteristics of Master of Arts in Teaching Preservice Science Teachers’ Pedagogical Content Knowledge during Student Teaching. (Under the direction of Dr. Soonhye Park).

Due to the demand for high-quality teachers in the United States, especially in the areas of science, technology, engineering, and mathematics (STEM), developing pedagogical content knowledge (PCK) in teachers can be critical for their becoming effective in the classroom. Employing a multiple-case study design, this dissertation examines the PCK of two Master of Arts in Teaching (MAT) preservice science teachers (PSTs), who were observed a total of nine days during their student teaching semester, in order to explore the characteristics of their PCK as well as the influence of their cooperating teacher (CT) on their PCK. The pentagon model of PCK for teaching science served as the conceptual framework for this study, capturing the interactions among the components of PCK and other characteristics that each PST exhibited in each observation.

Data from observations, interviews, the researcher’s field notes, edTPA materials, lesson plans, and other artifacts and documents were analyzed using four approaches to explore the characteristics of the MAT PSTs’ PCK: (a) coding with a priori codes, (b) analysis of the PCK Evidence Reporting Table using descriptive statistics, (c) in-depth analysis of explicit PCK and the enumerative approach to create PCK maps, and (d) the constant comparative method.

Analysis revealed three salient features in regard to the MAT PSTs’ PCK during student teaching: (a) the quality of PCK was weak and unstable throughout the student teaching semester; (b) the MAT PSTs’ PCK made minimal changes between class periods; and (c) the MAT PSTs’ orientations to teaching science (OTS) were not greatly reflected in
their lessons. In order to capture the impact of the CTs on their MAT PST’s PCK development, the constant comparative method was used. Three salient features also emerged in regard to the influence of the CT on their MAT PST’s PCK: (a) regardless of the instructional types (i.e., co-teaching or PST lead teaching) the CTs did not significantly impact PSTs’ PCK; (b) the influence of the CT on PCK usually happened during the planning and reflection stage of instruction; and (c) avoiding “offending” the CT was a priority in the PSTs’ instructional decision making that hindered the development of PCK.

Discussion centers on how these features are related to current science education research and implications for future research, teacher education programs, and cooperating teachers.
Characteristics of Master of Arts in Teaching Preservice Science Teachers’ Pedagogical Content Knowledge during Student Teaching

by
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A dissertation submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Learning and Teaching in STEM

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BIOGRAPHY

Kayla Norville was born and raised in Rockingham, NC and attended public schools for the entirety of her education in Richmond County. She always knew that she wanted to be a teacher and always loved learning. Both she and her sister would “play school” around the clock, and because she was older, Tina was always the teacher. After her little sister Jessie was born, Kayla was able to take over as the teacher. Her passion for education grew throughout her childhood and teenage years. She imagined trying out other careers such as being a pharmacist, a veterinarian, or a psychiatrist, knowing that they all earned more money, but once she began her 11th grade year, she made the decision that money was not everything, and she would rather be happy doing what she loved. From there, she entered her high school teacher cadet program and applied for the Teaching Fellow scholarship.

As it was all meant to be, she received the Teaching Fellow scholarship, and in 2007, she began her undergraduate degree in Middle Grades Education at the University of North Carolina (UNC) at Pembroke. Her passion for education continued to grow at UNC Pembroke while participating in professional development sessions that the Teaching Fellows provided, interacting with other future educators, and gaining more knowledge in her coursework. After graduating in 2011 with her B.S. in Middle Grades Education, she began teaching in Pitt County, close to where she and her husband lived.

After a semester of teaching, she desired to continue her education and began the M.Ed. program in Science Education at NC State University. While teaching 7th-grade math and science in Pitt County Schools, she obtained her master’s degree in the Spring of 2014. This opened the door for amazing opportunities such as being a Kenan Fellow and
participating in the Educators of Excellence program, where she was able to travel to Belize and apply her newfound knowledge to the classroom.

After the 15-16 school year, she made the very difficult decision to leave the classroom and pursue her Ph.D. full-time. She is now thirty-years-old and is about to have two boys under the age of two. After this incredible journey, she is looking forward to seeing what God has in store and what new knowledge is still left to obtain.
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I would also like to individually thank my other committee members who have been wonderful mentors throughout my journey as well. I want to thank Dr. Margaret Blanchard, who has practically been one of my unofficial advisors since beginning my M.Ed. at NC State. Dr. Blanchard has, no matter what, always been there to give me advice, whether academic or personal, even when she did not have to. As a professor, she provided engaging and rigorous content that helped me grow as a scholar. I always felt like I could go to Dr. Blanchard whenever I had a question, and she would respectfully and kindly help me at all times.

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program and was very willing to do everything he could in order for me to succeed. Dr. Delgado has always pushed me to complete tasks that would help me grow as a scholar and help me prepare for my future career. Dr. Delgado continued to give me helpful advice and guide me through this journey.

I would also like to thank Dr. Jason Painter, who also served on my committee, for everything that he has done to guide me through this journey, as well. I knew Dr. Painter before beginning the program, as a Kenan Fellow, when I completed professional development through The Science House. Through my work as a Kenan Fellow and as a summer assistant for The Science House, Dr. Painter has been there through every step of this journey, and I am thankful he decided to serve as my minor advisor.

Also, to all of my colleagues in this program, thank you for being you. I am so thankful to have had a chance to go through this program with you! I am also grateful to each and every professor that has provided me with new knowledge that I can apply to my future!

Now onto my friends and family; I will never be able to thank you enough. To my wonderful husband, Blake, I am so thankful to have you in my life, and I appreciate you being so supportive of my many goals in life, and I am so happy that you did not even hesitate to provide support when I told you that I wanted to quit my job and pursue my Ph.D. You are an amazing husband and an amazing father, and I could not have done this without you. To Jett and Kade, I love you both so much, and I thank you for being so cooperative as I worked through this journey.

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## TABLE OF CONTENTS

<p>| LIST OF TABLES                                                                 | ............................................................... | x  |
| LIST OF FIGURES                                                               | .......................................................................... | xi |
| CHAPTER ONE  INTRODUCTION                                                    | .......................................................................... | 1  |
| What is Pedagogical Content Knowledge and Why Is It Necessary for High-Quality Teaching? | .......................................................................... | 4  |
| Pedagogical Content Knowledge as Necessary Knowledge for Effective Teaching   | .......................................................................... | 7  |
| Preservice Science Teachers and PCK Development                              | .......................................................................... | 9  |
| What Do We Know About Preservice Teachers’ PCK?                              | .......................................................................... | 9  |
| Importance of the Student Teaching Experience for PCK Development            | .......................................................................... | 12 |
| Cooperating Teachers’ Influence on PSTs’ PCK Development during Student Teaching | .......................................................................... | 14 |
| The Significance of the Study                                                | .......................................................................... | 15 |
| Chapter Summary                                                              | .......................................................................... | 17 |
| CHAPTER TWO  LITERATURE REVIEW                                               | .......................................................................... | 19 |
| Pedagogical Content Knowledge Critical to Teacher Quality                     | .......................................................................... | 20 |
| Conceptualizations of PCK                                                    | .......................................................................... | 20 |
| PCK Research on In-Service Teachers’ PCK                                     | .......................................................................... | 25 |
| Previous Research on the Impact of PCK on Teaching Practices and Student Learning | .......................................................................... | 25 |
| Previous Research on the Interaction of PCK Components                        | .......................................................................... | 28 |
| Preservice Teachers’ Development during Student Teaching                      | .......................................................................... | 29 |
| Preservice Science Teachers’ PCK Development                                 | .......................................................................... | 33 |
| There are Instabilities in PSTs’ PCK Development, and PSTs’ PCK is Not Robust | .......................................................................... | 33 |
| During Student Teaching or another Teaching Experience, PSTs’ Knowledge of Students’ Understanding Showed an Increase | .......................................................................... | 34 |
| PSTs’ Lack of Knowledge of Curriculum and Subject Matter Knowledge (SMK) Impact PSTs’ PCK Development | .......................................................................... | 35 |
| PSTs’ Orientations to Teaching Science are Both Informed and Naïve but Can Shift | .......................................................................... | 36 |
| Interventions Can Assist in PSTs’ PCK Development, Especially the KISR Component | .......................................................................... | 37 |
| Cooperating Teachers’ Impact on PST Development                              | .......................................................................... | 39 |
| CTs’ Influence on PSTs’ PCK Development                                       | .......................................................................... | 41 |
| Chapter Summary                                                              | .......................................................................... | 43 |</p>
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three</td>
<td>METHODS</td>
</tr>
<tr>
<td></td>
<td>Research Design</td>
</tr>
<tr>
<td></td>
<td>Participant Selection and Context</td>
</tr>
<tr>
<td></td>
<td>Sandy</td>
</tr>
<tr>
<td></td>
<td>Rachel</td>
</tr>
<tr>
<td></td>
<td>Data Collection Methods</td>
</tr>
<tr>
<td></td>
<td>Observations</td>
</tr>
<tr>
<td></td>
<td>Interviews</td>
</tr>
<tr>
<td></td>
<td>Documents and Artifacts</td>
</tr>
<tr>
<td></td>
<td>edTPA Materials</td>
</tr>
<tr>
<td></td>
<td>Data Analysis Procedures</td>
</tr>
<tr>
<td></td>
<td>Research Question One</td>
</tr>
<tr>
<td></td>
<td>Research Question Two</td>
</tr>
<tr>
<td></td>
<td>Trustworthiness</td>
</tr>
<tr>
<td></td>
<td>Chapter Summary</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Four</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RQ1: The Characteristics of MAT Preservice Science Teachers’ Pedagogical Content Knowledge throughout Student Teaching</td>
</tr>
<tr>
<td></td>
<td>Sandy’s PCK Characteristics throughout Student Teaching</td>
</tr>
<tr>
<td></td>
<td>Rachel’s PCK Characteristics throughout the Student Teaching Experience</td>
</tr>
<tr>
<td></td>
<td>Commonalities between the Characteristics of Sandy and Rachel’s PCK</td>
</tr>
<tr>
<td></td>
<td>Assertion 1: The quality of PCK was weak and unstable throughout the semester</td>
</tr>
<tr>
<td></td>
<td>Assertion 2: The PSTs’ PCK made minimal changes between class periods</td>
</tr>
<tr>
<td></td>
<td>Assertion 3: The PSTs’ OTS were not greatly reflected in their lessons</td>
</tr>
<tr>
<td></td>
<td>RQ 2: The Impact of the Cooperating Teacher on their MAT Preservice Teachers’ Pedagogical Content Knowledge throughout Student Teaching</td>
</tr>
<tr>
<td></td>
<td>Assertion 1: Regardless of the Instruction Types (i.e., co-teaching or PST lead teaching) the CTs did not Greatly Impact PSTs’ PCK during the Implementation Stage</td>
</tr>
<tr>
<td></td>
<td>Assertion 2: The Influence of the CT on PCK Usually Happened During the Planning and Reflection Phase of Instruction</td>
</tr>
<tr>
<td></td>
<td>Assertion 3: Avoiding “Offending” the Cooperating Teacher was a Priority in PSTs’ Instructional Decision Making that Hindered the Development of PCK</td>
</tr>
<tr>
<td></td>
<td>Chapter Summary</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>CHAPTER FIVE DISCUSSION</td>
<td>110</td>
</tr>
<tr>
<td>MAT Preservice Teachers’ PCK during Student Teaching</td>
<td>110</td>
</tr>
<tr>
<td>The Influence of the CT on their MAT PST’s PCK</td>
<td>114</td>
</tr>
<tr>
<td>Limitations</td>
<td>117</td>
</tr>
<tr>
<td>Implications</td>
<td>118</td>
</tr>
<tr>
<td>Implications of Future Research</td>
<td>118</td>
</tr>
<tr>
<td>Implications for Teacher Education Programs</td>
<td>119</td>
</tr>
<tr>
<td>Implications for Cooperating Teachers</td>
<td>121</td>
</tr>
<tr>
<td>Chapter Summary</td>
<td>121</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>122</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>138</td>
</tr>
<tr>
<td>Appendix A: PCK Evidence Reporting Table</td>
<td>139</td>
</tr>
<tr>
<td>Appendix B: Clarifying Definitions for the PCK Evidence Reporting Table</td>
<td>141</td>
</tr>
<tr>
<td>Appendix C: Pre- and Post-Observation Interview Questions</td>
<td>144</td>
</tr>
<tr>
<td>Appendix D: Interview Questions for CT-PST Interaction Interview</td>
<td>145</td>
</tr>
<tr>
<td>Appendix E: Interview Questions for Orientations to Teaching Science (OTS)</td>
<td>146</td>
</tr>
<tr>
<td>Appendix F: Example of a PCK Episode</td>
<td>147</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 3.1. Dissertation Data Collection Methods ......................................................... 48
Table 3.2. Dissertation Data Sources and Data Analysis Methods ......................... 55
Table 3.3. A Priori Codes for Data Analysis ................................................................. 57
Table 4.1. Number of Subcomponents Present in Sandy’s PCK over Student Teaching .... 69
Table 4.2. Sandy and Dana’s “Best Day” Description as Expressed at the Beginning and End of the Semester ................................................................. 74
Table 4.3. An Overview of Sandy’s Observations & PCK ................................................. 81
Table 4.4. Number of Subcomponents Present in Rachel’s PCK over Student Teaching ...... 88
Table 4.5. Rachel and Mary’s (her CT) Views on Student and Teacher Roles at the Beginning and End of the Semester ................................................................. 95
Table 4.6. Comparison of Sandy and Rachel’s PCK ......................................................... 98
Table 4.7. PCK Episodes and Connection Changes in Back-to-Back Classes .................. 99
Table 4.8. An Overview of Rachel’s Observations & PCK ................................................ 102
LIST OF FIGURES

Figure 2.1. Pentagon model of PCK for teaching science. .................................................. 23
Figure 3.1. Example of researcher’s field notes during observation 5a for Rachel.......... 53
Figure 3.2. An example of a PCK map. ............................................................................ 59
Figure 3.3. Example of the first step in enumerative analysis. .......................................... 60
Figure 4.1. PCK maps for Sandy over student teaching. .................................................... 66
Figure 4.2. PCK maps for Sandy’s lectures over the student teaching semester .......... 67
Figure 4.4. The presence of PCK subcomponents in Sandy’s observations .................... 70
Figure 4.5. Sandy’s PCK maps of two back-to-back class periods per observation day..... 72
Figure 4.6. PCK maps for Rachel over student teaching. .................................................. 84
Figure 4.7. PCK maps for Rachel’s lectures over the student teaching semester .......... 85
Figure 4.8. PCK maps for Rachel’s labs/activities over the student teaching semester ....... 85
Figure 4.9. The presence of PCK subcomponents in Rachel’s observations .................... 87
Figure 4.10. Rachel’s PCK maps of two back-to-back class periods per observation day.. 89
Figure 4.11. Sandy and Rachel’s OTS interactions throughout the semester ................. 100
CHAPTER ONE

INTRODUCTION

Students in the United States are falling behind academically compared to their peers in other countries (Desilver, 2017), especially in the areas of science, technology, engineering, and mathematics (STEM) (Hollins, 2014; Institute of Education Sciences, 2015a; Institute of Education Sciences, 2015b). For example, the Trends in International Mathematics and Science Study (TIMSS) results in 2015 showed that 4th grade and 8th grade United States science students’ average scores in science were lower than countries such as Japan and Singapore (Institute of Education Sciences, 2015a). Another example involves the Program for International Student Assessment (PISA) (Institute of Education Sciences, 2015a), in which results revealed the United States students’ average score was lower than 18 education systems including Singapore, Japan, and Australia. Although the United States is not at the bottom, there is room for improvement in their education system in regard to science achievement.

Several factors have been considered as contributors to student achievement in science, including gender, self-confidence, home resources, teacher characteristics, and instructional variables (Kaya & Rice, 2010). Notably, teachers have a substantial influence on student achievement, particularly in regard to classroom-level factors. In fact, teachers contribute to student achievement more than any other feature of schooling (RAND Corporation, 2019). High-quality teachers, those who are trained and effective, impact their students’ achievement greatly; consequently, students with higher quality teachers outperform their peers who have teachers of lesser quality (Berry, Friedrichsen, Loughran, 2015; Looney, 2011). Keeping this connection in mind between high-quality, trained and
effective teachers, and student achievement, it is critical to obtain high-quality teachers in the classroom (Clotfelter, Ladd, & Vigdor, 2007; Darling-Hammond, 2010; Hattie, 2008; Zhang & Campbell, 2015). In fact, there is a stated demand for high-quality teachers, especially in the areas of science, technology, engineering, and mathematics (Hollins, 2014) in the United States. In 2010, President Obama called for a national initiative in order to increase the number of mathematics and science teachers in the United States (Gonzalez, 2019), and along with this goal, No Child Left Behind (currently the Every Student Succeeds Act) and the public have also demanded high-quality teachers (Hollins, 2014; U.S. Department of Education).

Many researchers have investigated what makes teachers effective and what constitutes high-quality teachers (Berry et al, 2015; Kind, 2009; Park & Oliver, 2008), and most agreed on the need for high-quality teachers to possess a high level of pedagogical content knowledge (PCK). Shulman (1986) first conceptualized PCK as a specialized knowledge that teachers need to possess in order to be effective and to translate content into an understandable form for their students (Aydin, Demirdöğen, Nur Akin, Uzuntiryaki-Kondakci, & Tarkin, 2015). PCK directly influences a teacher’s instruction, and as teachers obtain higher levels of PCK, they may be able to apply their skills to multiple settings (Schneider & Plasman, 2011). Based on the connection between student achievement and teacher quality, and to address the demand for high-quality teachers in the classroom, teachers should strive to develop their PCK (Brown, Lee, Collins, 2015; Park, Jang, Chen, & Jung, 2011). The development of PCK essentially begins in a preservice teacher’s education program (Lee, Brown, Luft, & Roehrig, 2007), and, in particular, the student teaching period is a critical time during which student teachers can develop their PCK. Research has shown
that classroom experiences can contribute to PCK development (Kind, 2009; Lee et al., 2007; Nilsson, 2008). In addition, during student teaching, they are able to take the knowledge gained from their coursework, especially in regard to pedagogy and content, and apply it to the particular context in which they are immersed (Brown et al., 2015). Research has suggested that preservice teachers, particularly preservice science teachers (PSTs), have limited and fragmented PCK (Aydin et al., 2015). Research has provided evidence of some characteristics of PSTs’ PCK, yet most of these studies have been completed throughout the teacher education program, during particular courses, and during student teaching with an intervention in place (Kind, 2009). Thus, more studies need to be conducted on how PCK develops, particularly during student teaching without any intervention in place.

In addition to student teaching being an essential time for PSTs to develop PCK, cooperating teachers (CTs) have been shown to be one of the most important factors to their PSTs’ teacher education experience (Clarke, Triggs, Nielson, 2014). CTs can positively influence their PSTs’ subject matter knowledge (SMK), pedagogical knowledge (PK), self-efficacy, and preparedness (Matsko, Ronfeldt, Nolan, Klugman, Reinner, & Brockman, 2018; Ronfeldt, Brockman, & Campbell, 2018; Rozelle & Wilson, 2012). Although there is substantial research that shows how CTs can positively impact their PSTs’ development, there is also conflicting research that suggests that CTs can also hinder their PSTs’ development. For example, the CT may not provide enough feedback for their PSTs (Borko & Mayfield, 1995), or conflicts between the CT and PST could cause delays in their growth (Valencia, Martin, Place, Grossman, 2009). The literature provides an overview of how greatly CTs can impact their PSTs during student teaching; however, there is a gap in knowledge of how CTs specifically impact their PSTs’ PCK.
In this regard, as an overview, the purpose of the current study was to explore the characteristics of Master of Arts in Teaching (MAT) PSTs’ PCK over the course of their semester-long student teaching experience, focusing on the interaction among PCK components. MAT programs were designed to pull candidates with a bachelor’s degree in another field (e.g., science) other than education into a graduate education program for teaching (Parker & Brindley, 2008). With a bachelor’s degree in another field, MAT students are able to obtain a teaching certification and a master’s degree in an expedited fashion. Along with observation of MAT PSTs’ PCK, the influence of their cooperating teachers on their PCK was also examined.

Yin (2013) claims that our real-life phenomena cannot be studied without exploring the real-life context. Employing a multiple-case study design (Yin, 2013), this study involved a comprehensive analysis of two MAT PSTs during student teaching, each representing a unique case.

The following research questions guided this study.

1. What are the characteristics of MAT preservice science teachers’ pedagogical content knowledge throughout student teaching?

2. What type of influence, if any, do cooperating teachers have on MAT preservice science teachers’ pedagogical content knowledge development during their student teaching experience?

**What is Pedagogical Content Knowledge and Why Is It Necessary for High-Quality Teaching?**

Students in present-day classrooms possess diverse interests, abilities, and understanding, and in order to address the needs of diverse students, teachers should develop
a special body of knowledge called pedagogical content knowledge (PCK) (Park & Oliver, 2008). PCK was first conceptualized by Shulman (1986) as a category of knowledge “which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge (SMK) for teaching” (p. 9). It has also been described as “the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction” (Shulman, 1987, p. 8). PCK enables teachers to translate the content that they know well into understandable forms for their specific students through informed instructional strategies. Not only is it necessary for teachers to be knowledgeable of the content that they teach, but they should also possess the ability to teach it well so that their students can understand the concepts, especially if the concept is difficult to comprehend (Shulman, 1986).

PCK has become a commonly accepted construct for exploring science teacher learning (Park et al., 2011; Sickel & Friedrichsen, 2017). A reasonable amount of PCK research has looked at the characteristics of preservice teachers’ PCK. This research has suggested that after obtaining teaching experience, preservice teachers have a better understanding of student problems (de Jong, van Driel, & Verloop, 2005), and the experience also can lead to a higher amount of integration between pedagogical knowledge components, which is discussed below (Friedrichsen, Abell, Pareja, Brown, Lankford, Volkman, 2009). In addition, research has shown that preservice teachers, particularly PSTs, align their orientations, which includes “knowledge and beliefs about the purposes and goals for teaching science” (Friedrichsen & Dana, 2005, p. 218), greater with instruction and assessment rather than the knowledge of the student (Demirdögen & Uzuntiryaki-Kondakçı,
These studies focused more on the “what” of PCK in preservice teachers, yet more studies need to be conducted in order to determine “how” PCK develops for preservice teachers (Kind, 2009). Understanding how preservice teachers, especially PSTs, develop their PCK is essential in a time when the public and the United States legislature demand high-quality teachers in STEM classrooms (Hollins, 2014).

High-quality teachers possess training in pedagogy and are effective in the classroom (Underwood, 2012). The high-quality teacher movement can be said to have begun with No Child Left Behind (Darling-Hammond, 2010). The No Child Left Behind (NCLB) Act mandated that, starting in 2002, schools were required to meet adequate yearly progress (AYP), meaning that students should reach one-hundred percent proficiency by 2013-2014, and the law also created a more rigorous teacher evaluation system, requiring more highly-qualified teachers in the classroom. The new version of this law, the Every Student Succeeds Act (ESSA), was authorized by President Obama in December 2015 due to “unworkable requirements” in NCLB (U.S. Department of Education). However, the revised law still requires accountability for schools and districts in which students are not making progress. The law also strives to improve the quality of instruction, especially in low-performing schools (U.S. Department of Education). This demand leads to the need for essential preservice science teacher (PST) preparation in our nation’s universities in order to obtain more high-quality teachers in the classroom and to have a positive impact on students’ achievement. PCK plays a key role in teacher quality (Kulgemeyer & Riese, 2018), allowing for teachers not only to become great at knowing their content, but effective at teaching (Park, Suh & Seo, 2018). Consequently, in order to prepare high-quality teachers for the
nations’ classrooms, understanding how PSTs develop their PCK during student teaching can be critical in developing high-quality teachers before they enter their own classroom.

**Pedagogical Content Knowledge as Necessary Knowledge for Effective Teaching**

The conceptual framework used in this dissertation study is pedagogical content knowledge (PCK). There is wide agreement that PCK is a useful construct for exploring teacher practice and development (Kind, 2016). Since Shulman’s initial conception of PCK, scholars have proposed various PCK models (e.g., Grossman, 1990; Marks, 1990; Park & Oliver, 2008), which are discussed in detail in the next chapter. Many models identify components of PCK; however, some of them do not identify how components interact with each other (Friedrichsen, van Driel, & Abell, 2011). As PCK research has progressed, the more essential integration of components has appeared. Most scholars agree that PCK is the synthesis of underlying components and what results from this is more than the sum of its parts (Abell, 2008). This suggests that the interaction among these components must be critical to the quality of PCK (Park & Chen, 2012). It is vital to examine the interaction among components when PCK is investigated because the development of one component of PCK may not be enough to stimulate growth in practice; however, components may concurrently influence the development of the others (Park & Oliver, 2008). Because of this potential for interaction, the pentagon model for science teaching, which represents that PCK is not just a free-standing type of knowledge, was used in this study (Park & Chen, 2012; Park & Oliver, 2008). This model was built upon the work of Grossman (1990), Tamir (1988), and Magnusson, Borko, and Krajcik (1999). In this model, five components of PCK interact with one another: knowledge of instructional strategies and representations (KISR); knowledge of students’ understanding in science (KSU); knowledge of science curriculum
(KSC); knowledge of assessment of science learning (KAs); and orientations to teaching science (OTS). Each one of these components, briefly described in the next paragraph, is discussed in full detail in the next chapter.

The first component of knowledge of instructional strategies and representations (KISR) represents the knowledge that teachers possess that includes both subject-specific and topic-specific strategies when giving instruction (Park & Chen, 2012; Park & Oliver, 2008). Second, knowledge of students understanding in science (KSU) is a teacher’s understanding of student misconceptions, learning difficulties, motivation, and other needs. Third, knowledge of science curriculum (KSC) includes a teacher’s knowledge of horizontal curriculum (in grade-level), vertical curriculum (across grade levels), and “curricular saliency,” which is the tension between going over the curriculum and teaching students for their understanding (Geddis, Onslow, Beynon, & Oesch, 1993). The fourth component is knowledge of assessment of science learning (KAs), which includes a teacher’s understanding of methods of assessing science learning and which dimensions of science learning to assess. The last component is orientation to teaching science (OTS), which includes a teacher’s beliefs about teaching the nature of science, their decisions in teaching, and their beliefs and purposes of teaching and learning science (Park & Chen, 2012; Park & Oliver, 2008).

In summary, PCK has become a beneficial construct in exploring how science teachers learn and is necessary for effective teaching. Teachers are one of the most important factors in student achievement (National Research Council [NRC], 1996), yet teacher quality is disproportionate across the United States despite the fact that most teachers have earned certification through either traditional means or alternative pathways (Darling-Hammond,
PCK allows teachers to transform content knowledge into an understandable form for students, thus increasing student understanding and achievement (Aydin & Boz, 2013; [NRC, 1996]). PCK has played a significant role in defining effective and capable teachers in the classroom (Aydin et al., 2015), so teachers should possess a solid understanding of PCK (American Association for the Advancement of Science [AAAS], 1993; NRC, 1996). Considering this, the pentagon model of PCK for teaching science serves as an appropriate conceptual framework for this study.

Preservice Science Teachers and PCK Development

What Do We Know About Preservice Teachers’ PCK?

Little is known about the way that PCK develops in PSTs (Kaya, 2009). What is known about PSTs’ PCK development is revealed by studies that have focused on teacher education as a whole (or parts of it), specific courses, or interventions conducted during student teaching. When studies focused on the student teaching experience, the focal point was a particular intervention such as Content Representation (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs), which are instruments that are used to capture and display a teacher’s PCK (Bertram & Loughran, 2012). Chapter two describes such studies in further detail. The literature provides evidence that PSTs do not have a robust PCK (van Driel, Verloop, & de Vos, 1998), but reveals that classroom experiences play an important role in PCK development (van Driel, de Jong, & Verloop, 2002; Veal, Tippins, & Bell, 1999).

Several studies have investigated how PSTs’ PCK develops in their teacher education program, as a whole, or parts of the program, yet many studies in PCK do not include the integration of components, which is discussed in detail in Chapter two (e.g., knowledge of
student understanding, knowledge of instructional strategies and representations, knowledge of assessment of science learning, knowledge of science curriculum, and orientations to teaching science). Kaya (2009) is one exception. Kaya examined 216 undergraduate student teachers in the final year of their program, focusing on the topic of ozone-layer depletion. He looked at the relationship among PCK components of the undergraduate preservice teachers and discovered a strong correlation between those who had more knowledge of one component and their understanding of the other components, with the exception of knowledge of assessment (KA). One key discovery in Kaya’s (2009) study was that in the undergraduate PSTs’ PCK, the stronger subject matter knowledge (SMK) that preservice teachers possessed, the more pedagogical knowledge they held. That is, the more that the PSTs knew about the topic that they were teaching, the better that they were able to teach it to their students. Brown, Friedrichsen, and Abell (2013) also conducted a study during PSTs’ teacher education program, which also included a year-long internship; in particular, they studied four preservice biology teachers in a post-baccalaureate teacher education program. A key finding was that these PSTs became more aware of student learning difficulties during the course of the program (Brown, Friedrichsen, & Abel, 2013). Their teaching was mainly based on transmitting information to their particular students; therefore, the PSTs learned to focus on student understanding more over the course of their program.

Studies have also been conducted in regard to PCK development in specific courses. For example, Tuan, Jeng, Whang, and Kaou (1995) explored preservice science teachers’ PCK over a one-year long practicum course. As with Brown and colleagues’ (2013) study, these PSTs also focused more on their students’ learning over the time period of the course, particularly their learning styles and characteristics. Another study conducted
by Nilsson and Loughran (2012) observed preservice elementary teachers over a science methods course, with an intervention used to develop PCK called CoRes. As with other studies, these PSTs viewed many items in regard to their students as important, such as why it is important for students to learn, what they intended for students to learn, and specific ways for student understanding. Demirdöğen, Hanuscin, Uzuntiryaki-Kondakci, and Köseoğlu’s (2016) explored 30 PSTs’ PCK of teaching the nature of science in chemistry. These PSTs were enrolled in a research in science education course. Researchers explored the integration among PCK components and discovered that the higher the integration, the more successful teachers were at nature of science practices. Another finding from the study revealed the importance of prerequisite knowledge and beliefs to teach the nature of science (Demirdöğen et al., 2016). More research has been conducted to reveal the impact of prerequisite knowledge and experiences on PSTs’ PCK development. Based on previous experiences, preservice teachers enter the student teaching experience with preconceived notions of teaching (Garza, Werner, & Wendler, 2016). Beginning teachers tend to believe that the best practices for teaching science are based on their own K-12 experiences (Johnson & Cotterman, 2015). Therefore, teachers tend to teach the way that they were taught. Parker and Brindley (2008) stated that preservice teachers’ beliefs are created long before they enter their first teacher education course.

To summarize, research on PSTs’ PCK have focused on characteristics during the whole teacher education program, during certain courses, and during the student teaching experience when an intervention is taking place. Studies have revealed that PSTs’ PCK development is gradual, progressive, complex, and non-linear (Kind, 2009). Research also affirms that teaching experience and teacher preparation courses can influence a teacher’s
PCK development (Davis, Petish, & Smityey, 2006), but how this influence occurs and what particular components of PCK interact still needs to be examined. Not only should such research focus on the development of PCK during the student teaching experience, but also on the interactions between the components of PCK. Considerable findings are waiting to be discovered in regard to PSTs’ approaches to teaching a topic and why they choose this approach (Nilsson & Loughran, 2012). Developing PCK is a complex process that is content and context specific, and the combination of SMK and pedagogy are essential (Magnusson et al., 1999). Regarding the interaction of PCK components, research reveals that PSTs have fragmented PCK, but at the completion of the semester, PCK evolves to be more highly integrated (Aydin et al., 2015); nevertheless, more research needs to be conducted as to how PCK develops during the student teaching experience, and what factors affect this development. There exists a gap in the literature regarding how the student teaching experience can accelerate the development of teachers and their PCK, focusing on the influence of factors that are already present such as cooperating teachers (Anderson & Stillman, 2013).

**Importance of the Student Teaching Experience for PCK Development**

During the student teaching experience, students shadow another teacher, the CT, typically for one semester, sometimes two (Brown et al., 2015). Many student teaching experiences begin with PSTs observing or co-teaching with their CTs for one to two weeks. Once observations by the CT and/or co-teaching experiences are complete, PSTs will acquire additional classes until they obtain a “full load.” A “full load” occurs when the PST accepts most of the responsibilities from the CT, including teaching all classes, lunch duty, grading papers, and helping with lesson plans; however, responsibilities may vary with each
experience. Toward the end of the student teaching semester, PSTs turn over responsibilities and begin observing again. Some student teachers also have the opportunity to observe other teachers in different grade levels and different subjects. Although the student teaching experience occurs over a limited amount of time, PSTs still have the opportunity to engage with particular science topics and students, incorporating prior knowledge, under the mentorship of their CT, which may develop their PCK during the experience (Brown et al., 2014).

PCK development ultimately begins in the PST’s teacher education program (Lee, Brown, Luft, & Roehrig, 2007). Most teacher education programs aim to support PSTs’ PCK development during coursework and other experiences. However, since PCK is deeply rooted in classroom experiences, PSTs are unlikely to develop sophisticated PCK due to limited experience teaching students in actual classrooms (Friedrichsen et al., 2009). Thus, the student teaching experience is viewed as the most critical opportunity for PSTs to develop PCK by integrating different knowledge bases such as content knowledge (CK) and pedagogical knowledge (PK) that they learned during coursework (American Association of Colleges for Teacher Education [AACTE], 2010). Topic and context are of key importance in the development of PCK (Park & Oliver, 2008); therefore, the student teaching experience is essential (Kind, 2009). PCK has served as the skill set of teachers and has become increasingly researched by the science education field in looking at the role of PCK within the context for development (Kind, 2016). Thus, understanding how PSTs develop PCK during the student teaching experience as explored in the current study provides significant insight into how to leverage the impact of the student teaching experience on PCK development.
Cooperating Teachers’ Influence on PSTs’ PCK Development during Student Teaching

In the education literature, scholars have revealed several factors that contribute to successful student teaching experiences, including mentors, specific assignments, activities that preservice teachers complete concurrently with experience, and previous experience (Anderson & Stillman, 2013). Anderson and Stillman’s review on preservice teacher development literature states there is a “need for a more concerted focus on how student teaching contributes to preservice teacher learning and development and on the specific factors that support or constrain that learning and development over time” (p. 56). In particular, student teachers have considered their CTs to be one of the most important factors in their development (Clark, Triggs, Nielson, 2014). CTs serve as “providers of feedback, gatekeepers of the profession, modelers of practice, supporters of reflection, gleaners of knowledge, purveyors of context, conveners of relation, agents of socialization, advocates of the practical, abiders of change, and teachers of children” (Clarke, Triggs, & Nielson, 2014, p. 163).

PSTs appreciate the relationship that they have with their CTs, who help guide them and give them feedback during their student teaching experience (Brown et al., 2015). CTs provide an array of professional influences on their student teachers, including imparting instructional strategy advice, influencing their professional role, and influencing career satisfaction (Altan & Sağlamel, 2015). How effective the CT is also plays a role in their PST’s development. For example, CTs that are more instructionally effective have been revealed to have a greater influence on their student teacher’s instructional effectiveness (Ronfeldt, Brockman, & Campbell, 2018). Consequently, the more knowledgeable that CTs
are in their teaching skills, the greater the positive impact they have on their preservice teachers.

Evidence has pointed to how important CTs are in aiding their PST’s development; however, more empirical evidence is needed, specifically, in how CTs aid in developing PST’s PCK during the student teaching experience. Research has highlighted the need for support to assist PSTs in integrating PCK components and development (Aydin & Boz, 2013; Kaya, 2009; Park & Chen, 2012). Not only do PSTs need this support, but they should also have access to CTs with specific qualities, including being collaborative and efficacious (Anderson & Stillman, 2013). The qualities that make an effective teacher, such as instructional effectiveness (Ronfeldt, Brockman, & Campbell, 2018), should be considered when pairing CTs and PSTs.

**The Significance of the Study**

This study contributes to the scholarship on PSTs’ PCK in the following ways: (a) By examining MAT PSTs’ PCK throughout the student teaching semester, a better understanding of the characteristics and the interaction of all components of PCK was obtained; (b) Contributing to the scant literature of what factors affect PSTs’ PCK development, and discovering more about the “why” than just the “what;” and (c) Providing more empirical evidence that supports an understanding of how CTs contribute to PSTs’ PCK development during their experience as a student teacher.

First of all, there is limited research on PSTs’ PCK characteristics that solely focuses on the student teaching experience. Research affirms that with support, PSTs are able to develop their PCK during the student teaching experience; this support includes PCK instruction, CoReS and PaP-eRs, and mentoring support (Aydin et al., 2015; Demirdöğen,
2016; Kind, 2009). Yet, knowing how PCK could develop in PSTs in average settings, with no interventions, is essential in understanding the most critical aspects to enhance PCK development. This study focuses on PCK development with no explicit interventions, which assisted in understanding the most critical aspects to enhance PCK development during the student teaching experience. There is limited research focusing on the integration of components that examines whether or not PCK is developed during a typical student teaching experience (Aydin et al., 2013; Kaya, 2009). Not only does this study focus on the PCK during the student teaching experience, but it also focuses on the integration of components, which adds to current PCK literature focusing on PCK component interaction, specifically with PSTs rather than experienced teachers. Findings from this study add new understandings to the scholarship on PCK.

Little is known about critical PCK changes that may or may not occur during the student teaching experience (Kaya, 2009). When PCK is explicitly taught in teacher education methods courses, literature has revealed preservice teachers become more aware of their PCK during these courses (Kind, 2009); however, the impact of the student teaching experience on PCK following obtainment of knowledge of the construct has not been clearly explained (Berry et al., 2015). The current study provides empirical evidence to describe PCK changes in PSTs during the vital student teaching period and contributes additional evidence of how particular components of PCK develop and interact with one another. This study also explains implications for teacher education programs to discern where the focus should be situated. PCK is a critical construct for PSTs to develop during their teacher education programs, and most importantly, during the student teaching experience, given its interactive elements between teachers and students. In order to best prepare our teacher
education programs, important items and appropriate interventions should be set in place so that PSTs can develop their PCK during their teacher education experience. This research assists in discovering where those items and interventions are needed.

Second, this study contributes to findings to determine how PCK develops or not during the student teaching period and displays what factors could impact development. There are many factors that impact PSTs during their teacher education program such as certain courses, mentors, and teaching experiences (Anderson & Stillman, 2013; Aydin et al., 2015; Sindelar, Daunic, & Rennels, 2004), but how these changes occur still needs to be examined. These results aim to provide critical information for both teacher education programs and cooperating teachers to know what to focus on in particular during their experience to advance their PSTs’ PCK.

Finally, findings from this study will also contribute to the knowledge of how CTs can leverage this development. The literature has indicated that CTs impact PSTs’ development (Clarke, Triggs, & Nielson, 2014; Kirk, Macdonald, & O’Sullivan, 2006), though the findings of the current study contribute, specifically, to MAT PSTs’ PCK development. There is an incredible amount of research that has been conducted that shows the influence that CTs have on their PSTs, but there is a gap in the literature involving their influence over their PSTs’ PCK; this study seeks to add new understandings that fill this gap while providing essential information for both teacher education programs and CTs.

Chapter Summary

Students in the United States are falling behind in science achievement. As a result, there is a high demand for effective and prepared teachers in the classroom because of their impact on student achievement. Teachers should possess a knowledge base (PCK) that
allows them to translate content into understandable forms in order to be effective, and the
development of this knowledge base ultimately begins in the PST’s teacher education
program. The greatest opportunities for development may occur in their student teaching
experience due to their exposure to an actual context. This study focuses on exploring the
characteristics of MAT PSTs’ PCK over the student teaching experience and how their
cooperating teachers influence their PCK.
CHAPTER TWO
LITERATURE REVIEW

American students are falling behind their fellow peers in other countries, especially in the areas of science, technology, engineering, and math (Desilver, 2017; Hollins, 2014). Many factors impact student achievement in these subject areas including gender, teachers, instructional variables, self-confidence, and resources at home (Kaya & Rice, 2010), yet research has shown that teachers ultimately have the greatest influence on their students’ achievement more than any other “in-school” factor (Hattie, 2008; Visible Learning, 2018). Consequently, this has led to a demand for high-quality teachers who are trained and effective in the United States’ classrooms (U.S. Department of Education).

High-quality teachers have always been essential additions to classrooms, but since the conception of No Child Left Behind (NCLB) in 2002, the demand has increased. NCLB’s focus was on accountability and providing a high-quality education for all children. Revised by the Obama Administration, NCLB became the Every Student Succeeds Act (ESSA) in 2015, and while the focus remains the same, some key differences have emerged (U.S. Department of Education). For example, in regard to accountability measures, NCLB solely focused on student math and reading achievement. Currently, with ESSA, other school-quality factors are considered such as kindergarten readiness, college readiness, school climate and safety, and chronic absenteeism (U.S. Department of Education). Along with NCLB and ESSA, there have been several policies over the past two decades in order to improve teacher education (and thus teacher quality (Darling-Hammond, 2010)) such as the Carnegie Task Force on Teaching as a Profession, the Holmes Group, and the National Board for Professional Teaching Standards.
Many factors contribute to quality teaching, including professional development, intellectual ability, content area knowledge, positive relationships with students, strong classroom management, collaboration with peers, and pedagogical content knowledge (PCK) (Looney, 2011; Shulman, 1986). In order for teachers to be of high quality and effective in the classroom, developing sophisticated PCK should be a goal, because teachers’ high levels of PCK contributes to higher student achievement (Abell, 2007). PCK development ultimately begins in the preservice teacher’s education program, and most critically in their student teaching experience (Ronfeldt & Reining, 2012), wherein preservice teachers are able to apply their content knowledge and pedagogical knowledge learned throughout their program to actual classroom context (AACTE, 2010). This literature review discusses PCK research as well as what research has revealed about preservice science teachers’ (PSTs’) development during their teacher education program along with their student teaching experience. This review also discusses what research has revealed about cooperating teachers’ (CTs’) influence on their PSTs’ development over student teaching.

**Pedagogical Content Knowledge Critical to Teacher Quality**

**Conceptualizations of PCK**

The conceptual framework used in this study is PCK, which was first introduced by Shulman (1986). PCK is a distinct body of knowledge that teachers possess that allows them translate content into understandable forms for the particular students in their classroom. This construct includes an understanding of how topics are organized and how the material should be presented for instruction, with a focus on the diversity and abilities of the learners (Shulman, 1987). Since Shulman’s introduction, PCK has become a common
ly accepted construct to measure teacher knowledge, and has been researched greatly by science researchers (Kind, 2009), which is discussed in this review.

Shulman (1986, 1987) first described PCK with two components: knowledge of student understanding and knowledge of instructional strategies. Since then, researchers have added more components of PCK with some agreement and some disagreement. From the two components proposed by Shulman, other researchers have since included more categories as components of PCK, while placing others outside of PCK as a distinct knowledge base for teaching (Park & Oliver, 2008). For example, other important categories are knowledge of the purposes for teaching a subject matter and orientations to teaching science, which Shulman categorized as a separate category of PCK. Many other scholars placed orientations as a subcategory of PCK rather than a separate category (Fernandez-Balboa & Stiehl, 1995; Grossman, 1990; Hashweh 2005; Loughran, Berry, and Mulhall, 2006; Magnusson et al., 1999; Park and Oliver, 2008; Smith & Neale, 1989).

Shulman (1986, 1987) also labeled curriculum, subject matter, context, and pedagogy as categories that are included outside of PCK. Regarding knowledge of curriculum, many researchers disagree with Shulman and place curriculum as a subcategory (Geddis et al., 1993; Grossman, 1990; Hashweh, 2005; Park & Oliver, 2008; Magnusson et al., 1999; Tamir, 1988), whereas others do not mention curriculum at all (Fernandez-Balboa & Stehl, 1995; Loughran et al., 2006; Smith & Neale, 1989). Subject matter knowledge (SMK) is another component that researchers disagree on. Some researchers see SMK as a distinct category outside of PCK as Shulman did (Grossman, 1990; Smith & Neale, 1989; Tamir, 1988), as others see it as a subcategory of PCK (Fernandez-Balboa & Stiehl, 1995; Hashweh, 2005; Loughran et al., 2006; Marks, 1990). Some scholars did not discuss this in their model
at all (Geddis et al., 1993; Magnusson et al., 1999). Other categories to note that were not explicitly discussed in the conception of Shulman’s PCK were knowledge of media and knowledge of assessment. Marks (1990) proposed knowledge of media as a subcategory of PCK but is not regarded among other researchers. Some scholars also included knowledge of assessment as a subcategory of PCK (Hashweh, 2005; Magnusson et al., 1999; Park & Oliver, 2008; Tamir, 1988), which was used as a component in this study as well.

Although researchers have not reached an agreement on the particular components that constitute PCK, there is an agreement that the integration of these components is important in the development of a teacher’s PCK (Loughran et al., 2006; Park & Chen, 2012; van Driel et al., 2002). The way that each component interacts with others, how they impact each other, and how the development as a whole affects the teacher are all crucial reasons to explore PCK development components separately, as well as the interaction among components.

The Pentagon Model of PCK

In the current study, the pentagon model for teaching science (Park & Chen, 2012; Park & Oliver, 2008), as seen in Figure 2.1, was used, which includes the five components mentioned in Chapter One: knowledge of students’ understanding in science (KSU); knowledge of instructional strategies and representations for teaching science (KISR); knowledge of science curriculum (KSC); knowledge of assessment of science learning (KAs); and orientations to teaching science (OTS), each of which is discussed in detail below. This model was derived from the well-known models created by Grossman (1990), Tamir (1988), and Magnusson and colleagues (1999). This model was chosen for this study on account of its representation that PCK is not just free-standing knowledge, and in
research, the importance of component integration is noted (Abell, 2008; Park & Chen, 2012). This model stressed the importance of the integration of these components, and each one is described below.


Knowledge of instructional strategies and representations for teaching science (KISR). The first facet is KISR, which Shulman (1986) described as one of the most powerful strategies. Teachers should possess the ability to introduce concepts and implement appropriate subject-specific strategies and topic-specific strategies (Magnusson et al., 1999). Subject-specific strategies are approaches to teaching that are harmonious with teachers’
goals for science teaching such as learning cycles and inquiry-oriented instruction. Topic-specific strategies are those that apply to teach certain topics in science (Park & Oliver, 2008). A lecture may be a proper strategy to teach one topic, whereas guided inquiry may be a more appropriate strategy to teach another topic. Teachers should be aware of specific strategies and representations to use for the topics that they teach.

Knowledge of students’ understanding in science (KSU). The second facet is KSU, which is important in that teachers base their instruction on students’ prior knowledge and existing conceptions (Rosenkränzer, Hörsch, Schuler, & Riess, 2017). Teachers should possess the awareness of how their particular students learn, their misconceptions, and other difficulties that they may have (Lee et al., 2007). Many teachers will be faced with diverse learners of various backgrounds, ethnicities, disabilities, and behavior. Teachers must possess knowledge that will help them to best differentiate in the classroom. This component of PCK includes teachers’ understanding and ability to revolve teaching around students’ conceptions of particular topics, motivation, interest, learning difficulties, developmental level, ability levels, and their needs (Park & Oliver, 2008).

Knowledge of science curriculum (KSC). The third facet is KSC, which includes knowledge of science curriculum materials that are available for teaching certain topics in science as well as knowledge of horizontal and vertical curricula (Grossman, 1990; Park & Oliver, 2008). Peterson and Treagust (1995) discovered that this component was an important piece in PSTs’ “pedagogical reasoning” (Rosenkränzer et al., 2017) in their lesson planning and in their instruction. Teachers should understand curriculum goals and materials and how they are implemented in the classroom. Teachers should also be able to make
connections between science concepts, units, and the requirements of the district and state in order to meet curriculum goals.

**Knowledge of Assessment of Science Learning (KAs).** The fourth facet is KAs. Magnusson and colleagues (1999) placed this component into two subcategories: knowledge of the dimensions of science learning and knowledge of the methods by which learning can be assessed. Teachers should possess an understanding of student performance and how to assess it (Ayden et al., 2015). There are several types of assessment including formative, summative, and diagnostic. Teachers should be aware of best practices of creating assessments and be familiar with how to use assessment data to meet the needs of their students. This component includes knowledge of assessment instruments, activities, and approaches (Park & Oliver, 2008).

**Orientations to Teaching Science (OTS).** The last facet is OTS, which refers to teachers’ beliefs in the purpose of teaching science (Demirdöğen, 2016). Park and Oliver (2008) re-conceptualized this term and stated that it consisted of three sub-dimensions: beliefs about the purposes of learning science, decision-making in teaching, and beliefs about the nature of science (NOS). Research in this area has recently gained more attention and researchers are interested in knowing how this component interacts with the other components of PCK (Demirdöğen, 2016).

**PCK Research on In-Service Teachers’ PCK**

**Previous Research on the Impact of PCK on Teaching Practices and Student Learning**

What distinguishes novice teachers from expert teachers is a sophisticated PCK (Park & Oliver, 2008). Studies have demonstrated how PCK and particular components of PCK shape teaching practices as well as student learning; for example, making PCK explicit
(Kind, 2009) can produce changes in teaching practices (Nilsson & Vikström, 2015). Nilsson and Vikström sought to explore how science teachers changed their teaching practices after participating in lesson studies, thereby making PCK explicit. The results of the study revealed that after reflecting upon their own teaching, changes were seen in how lessons were structured, how examples were presented to students, and how the object of learning was defined (Nilsson & Vikström, 2015). Fraser (2016) conducted a similar study that explored how Magnusson and colleague’s (1999) framework resonated with science lecturers in higher education. After making PCK explicit to them, lecturers were aware of PCK’s usefulness and were able to link it to their teaching practices.

Other researchers have explored the impact of interventions on PCK and, in turn, on teaching practices. Heller, Daehler, and Kaskowitz (2004) explored case discussions and how they support growth in PCK. After participating in six case discussions, many teachers in the study were able to make more connections between student difficulties and made appropriate changes to their instructional interventions and teaching strategies (Heller, Daehler, & Kaskowitz, 2004). Other types of interventions, such as Content Representation (CoRes), also impact teachers’ teaching practices (Bertram & Loughran, 2012; Hume, 2010; Nilsson & Loughran, 2012; Williams & Lockley, 2012). CoRes was created by Loughran and colleagues (2006), initially for secondary science teachers, and is widely used to capture PCK in diverse contexts (Berry et al., 2015). It is a blank template that the teacher fills out that includes prompts such as to answer major ideas in particular science content areas. Prompts include, “What else do you know about this idea (that you do not intend students to know yet)?” and “What are your teaching procedures (and particular reasons for using these to engage with this idea)?” As teachers worked as individuals to complete tasks such as
CoRes, they often struggled in constructing the big ideas that are required; however, when collaborating to complete prompts, teachers were often able to better articulate ideas. Consequently, research displays that, with these types of cooperative interventions, teachers were able to rethink how they conducted instruction in the classroom and why they chose particular methods (Berry et al., 2015).

Not only have interventions and making PCK explicit helped to develop PCK and impact teaching practices, but a developed PCK is also critical for student learning (Baumert et al., 2010; Park, Suh, & Seo, 2018; van Driel et al., 1998). Several studies have presented evidence that teacher quality plays an important role in student learning gains (Ball, Lubienski, & Mewborn, 2001; Borko & Livingston, 1989). Ball and colleagues (2001) suggested that PCK allows teachers to interpret student responses and check for their understanding; in turn, teachers are able to correct for and adjust their instruction to address students’ difficulties. Student learning does not automatically arise from instruction, but teachers must possess the skills to adjust their teaching practices for student learning (Berry et al., 2015). Park and Oliver (2008) explain that an essential skill for teachers to possess is the ability to “read” students because they are able to influence teaching practices. Science literature also reveals that science teaching orientations play a role in a teacher’s knowledge of students’ learning (Wei and Liu, 2018), which can impact their teaching practices.

In summary, PCK has been shown to have a positive impact on both teaching practices and student learning. Growth in specific components can produce changes in teaching practices (Nilsson & Vikström, 2015) as well as making PCK explicit for teachers and implementing other interventions such as CoReS and PaP-eRs (Bertram & Loughran; 2012; Kind, 2009). A teacher that possesses a more developed PCK and adjusts their
teaching practices has a positive impact on student learning gains. Teachers can have the ability to “read” their students (Park & Oliver, 2008), thereby allowing teachers to adjust their lessons to address students’ needs (Ball et al., 2001).

**Previous Research on the Interaction of PCK Components**

Exploring the interaction among PCK components is a critical piece in measuring PCK (Friedrichsen et al., 2011; Magnusson et al., 1999; Park & Oliver, 2008); however, in PCK studies, the interaction of components is often neglected (Padilla & van Driel, 2011). Magnusson and colleagues (1999) discussed the importance of integration but declared that this occurs in a linear fashion. Similarly, Fernandez-Balboa & Stehl (1995) argued the significance, but stated that it is not a linear process, and that multiple items may happen simultaneously. Marks (1990) also stressed the importance of integration, which makes capturing and modeling PCK so difficult. Chapter One argued that the absence of coherence among PCK components impacts the development of PCK (Park & Oliver, 2008). The growth of one component in PCK may concurrently enhance the development of others.

In their review of the literature, Friedrichsen and colleagues (2011) discussed how several studies capture particular components of PCK models yet do not relay how components relate to one another. Although there is a lack of PCK research that focuses on the interaction of all components of PCK, there are some investigations that are the exception; however, the results are inconsistent. One of these studies, conducted by Padilla and Van Driel (2011), revealed that prominent orientations linked with KSU or KISR had an assessment component. Using a modified version of Magnusson and colleagues model (1999), they specifically looked at the connections that could be found between PCK
components from quantum chemistry university teachers. When they examined the assessment components at a detailed level, researchers discovered the strongest relationships with orientations, knowledge of science curriculum, and knowledge of students’ understanding. Park and Chen (2012) declared that KA connected with KSU and KISR more than any other component, although it was not highly integrated.

Park and Chen (2012) explored the nature of five components of PCK based on the pentagon model that was used in this dissertation study. They studied four teachers working at the same high school, focusing on the context of teaching photosynthesis and heredity. Along with the discovery that KA connected with KSU and KISR more than any other component, it was also revealed the KSC had the most limited connection with other components (Park & Chen, 2012). Another important finding was the connection between components, implying that the stronger the connection between components, the stronger the structure of the PCK map.

Research has shown that there are important connections between individual components of PCK, but more research should be conducted to discover where the strongest connections are and how the weakest connections can be developed. More research should also be conducted to see how the connections are developed, both for preservice teachers and in-service teachers. Questions still remain about the nature of PCK at different levels in teaching careers (Abell, 2007; Nilsson & Vikstrom, 2015), and the aim of this study is to add to the literature by exploring MAT PSTs’ PCK development during student teaching.

Preservice Teachers’ Development during Student Teaching

The student teaching component is most central to teacher education programs (Rozelle & Wilson, 2012): It is the “most beneficial, authentic, or practical aspect of teacher
education” (p. 1126). Specifically, teacher educators have noticed the important knowledge that student teachers gain from being able to observe and work with their CTs, with the knowledge gained being greater than what they learn in their coursework (Téllez, 2008).

During the student teaching experience, preservice teachers have the opportunity to shadow another teacher as well as co-teach or solely teach for a few weeks in order to gain experience teaching content to actual students. Students also have the opportunity to practice teaching skills, implement curriculum instruction, and interact with students. Although student teaching has proven to be a critical piece in preservice teachers’ development, it is still poorly understood (Clift & Brady, 2005; Rozelle & Wilson, 2012). Although research has suggested that PCK development requires classroom teaching experiences (Evens, Elen, & Depaepe, 2015; Grossman, 1990; van Driel et al., 2002), it still remains uncertain how teaching experiences influence PCK development. It is known that classroom experiences contribute to the development of PCK, but more research should be conducted on the “how.”

Interest in the knowledge bases of preservice teachers and their development has widened (van Driel et al., 2002), yet there are still inconsistencies in the knowledge of preservice teachers’ learning and development (Anderson & Stillman, 2013). Researchers have explored preservice teachers’ conceptions of teaching and learning science, teaching science to students of different cultures, and the way that preservice teachers construct practical knowledge (van Driel et al., 2002). There is substantial literature on preservice teachers’ development as well as explorations of preservice teachers’ PCK (discussed in another section). Studies have explored preservice teachers’ development in their teaching practices, preparedness, self-efficacy, self-confidence, professionalism, and mediating factors that influence their development.
In regard to teaching practices, research has revealed the preservice teachers have preconceived notions based on their own experiences, and they are influenced by their prior experiences (Garza et al., 2016). This has been shown to impede learning in their analysis of observations and experiences (Kagan, 1992). This includes from the time of their entrance into the teacher education program until the end, which is their student teaching experience. The student teaching experience has as contributed to a positive development of preservice teachers’ practice such as learning how to engage students and increasing student achievement using particular pedagogical approaches. As with beliefs, some research that focused on student teaching’s impact on practice also presents problems such as learning “what not to do” than learning positive practice; however, this could be seen as a positive because they are able to learn from others’ mistakes (Anderson & Stillman, 2013).

Concerning teacher preparedness, self-efficacy, and self-confidence, the quality of student teaching has proved to be more effective than the quantity of student teaching (Ronfeldt & Reinner, 2012), meaning that preservice teachers who are placed within an effective teaching environment with a capable CT fare better than those whose student teaching experience was extended over a longer period of time. During the period of time that preservice teachers are participating in the student teaching experience, they face many challenges (Kind, 2009). Preservice teachers must understand content, learners, instruction, learning environments, and professionalism. Not only do they have to face being overwhelmed by learning all of these items, but studies have shown that anxiety has been found in preservice teachers along with lack of self-confidence (Kind, 2009). Yet when they are placed in an effective environment, the development of their self-confidence is positive (Ronfeldt & Reinner, 2012).
With respect to professionalism, some preservice teachers commented that they were more aware of how they dressed and also how they presented themselves after their teacher education program (Garza et al., 2016). In addition, preservice teachers have talked about how critical punctuality and time management are during the transition from student to professional. Frederiksen, Cooner, and Stevenson’s (2012) research suggested that providing preservice teachers with experience in the school can change their dispositions about professionalism, whereas the coursework in their teacher education program may not provide the correct tools to do so.

Regarding mediating factors that influence preservice teacher development, the vast majority of the literature only focused on a particular setting and particular time; however, the literature did highlight contributions to preservice teachers’ development based upon particular assignments or activities that preservice teachers completed during student teaching. Other mediating factors that are shown to impact preservice teachers’ development include connections with models, mentors, and community members. Feedback from CTs and students was also shown to be a mediating factor (Anderson & Stillman, 2013). More about CT impact is discussed later in the chapter.

The literature has provided science education researchers with a vast amount of knowledge about preservice teachers’ development during student teaching; however, there is a lack of literature that has contributed to the knowledge of PSTs’ PCK development, especially during student teaching. The next section discusses what is known about PSTs’ PCK development, both during student teaching and in the teacher education program.
Preservice Science Teachers’ PCK Development

Little is known about the way PCK develops in PSTs (Kaya, 2009); however, some studies provide insight. In reviewing the literature, five themes emerged: (1) there are instabilities in PSTs’ PCK development, and PSTs’ PCK is not robust; (2) during student teaching or another teaching experience, PSTs’ knowledge of students’ understanding increased; (3) PSTs’ lack of knowledge of curriculum and subject matter knowledge (SMK) impact PSTs’ PCK development; (4) PSTs’ orientations to teaching science (OTS) are both informed and naïve but can shift; and (5) interventions can assist in PSTs’ PCK development, especially the KISR component.

There are Instabilities in PSTs’ PCK Development, and PSTs’ PCK is Not Robust

Science education literature affirms that PSTs do not have robust PCK (van Driel et al., 1998); however, their PCK does develop. It is revealed from research that this development is gradual, progressive, complex, and non-linear (Kind, 2009), and that there are instabilities in their development (Lederman, Gess-Newsome, & Latz, 1994). Lederman and colleagues (1994) reported that PSTs developed their perceptions of teaching subjects through teaching experience, moving towards integrations between PK and SMK; however, there were instabilities in PSTs’ PK and SMK thinking. Kaya (2009) specifically explored the relationships among the components of PSTs’ PCK surrounding the topic of ozone layer depletion. When this research was conducted, he claimed that there was no study investigating the relationships among the components of PSTs’ PCK (Kaya, 2009), so he investigated 75 PSTs enrolled in teacher education programs in Turkey. Kaya quantitatively and qualitatively explored the relationships among six components of PCK: SMK, PK, KSC, KSU, KISR, and KA. Results revealed that there was a significant relationship between
SMK and PK as well as PK and other components with the exception of KA. There was also a significant difference in the degree of PK and SMK of the PSTs. As the previous section mentioned, not all PCK researchers agree that PK and SMK are subcategories of PCK, but this information still adds empirical evidence that supports how PSTs develop PCK.

**During Student Teaching or another Teaching Experience, PSTs’ Knowledge of Students’ Understanding Showed an Increase**

Many studies have revealed that PSTs develop greater insight into their students’ understanding during student teaching or another teaching experience. PSTs also learn to adapt to their learners' needs (Angell, Ryder, & Scott, 2005; Kind, 2009; Tuan et al., 1995) during their development. For example, Tuan and colleagues (1995) conducted a case study of preservice chemistry teachers and tracked their PCK development during a one-year practicum course (as is done in this study on a smaller scale). Researchers discovered that at the end of the practicum, the PSTs focused more on students’ characteristics and learning styles than they did at the beginning of the course (Tuan et al., 1995). In addition, PSTs gained an awareness of PCK and how they could use it as future chemistry teachers.

A study conducted by de Jong and van Driel (2004) with eight PSTs examined the PSTs’ PCK of macroscopic, microscopic, and symbolic meaning of chemistry topics. The focus of the study was to explore what development occurs with PSTs’ PCK when teaching multiple meanings. From interviews with PSTs before and after lessons, de Jong and van Driel discovered that the PSTs’ knowledge of difficulties in teaching developed, PSTs had a dominant orientation toward the micro-meaning of topics, and they gained a deeper understanding of students’ difficulties.
Along with knowledge of students’ understanding, van Driel and colleagues’ (2002) research also investigated PSTs’ knowledge of instructional strategies. Their analysis showed that all but two out of 12 of their teachers exhibited growth in their PCK concerning macro- and micro topics. PSTs reported that specific use of teaching strategies such as visualizations and representations were successful. They also revealed that they had to use specific language in order to reduce confusion with students and became aware of how instructional strategies would influence their students’ learning (van Driel et al., 2002).

**PSTs’ Lack of Knowledge of Curriculum and Subject Matter Knowledge (SMK) Impact PSTs’ PCK Development**

PSTs should possess an understanding of the content in order to transfer that information to students (van Driel et al., 2002), yet studies have shown that a student teacher’s lack of understanding the SMK and/or curriculum could impede their PCK development. For example, van Driel and colleagues’ (2002) study of 12 preservice chemistry teachers revealed, as mentioned above, that there are relationships between the development of SMK and student learning difficulty and instructional strategies. PSTs have been revealed to possess a limited understanding of the curriculum as well as SMK, which also can result in low-confidence and impede PCK development (Nilsson, 2008; Parker & Brindley, 2008). Johnson and Cotterman (2015) conducted research that included an intervention of video clubs in which PSTs observed videos to learn science content. In their analysis, researchers used knowledge of content and knowledge of curriculum as one code. Their findings suggested that video clubs allowed for PSTs to deepen their understanding of science content (Johnson & Cotterman, 2015). They also discussed Ball, Thames, and Phelps’ (2008) term *horizon content knowledge*, which is how ideas and topics are connected
within a discipline. This may occur in the curriculum across grade levels. In their results, it was discovered that PSTs did not initiate discourse around content and horizon content knowledge, yet, in order to solve problems, they had to unpack their content knowledge, meaning that the PSTs focused more on the present content that they were teaching greater than prior content knowledge as well as future content knowledge that their students needed to know.

**PSTs’ Orientations to Teaching Science are Both Informed and Naïve but Can Shift**

Research involving PSTs’ orientation to teaching science (OTS) suggests that PSTs’ OTS can shift over time and can either be informed or naïve. Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) described both informed and naïve beliefs about science. In their study, many PSTs stated that science is distinguished by the scientific method. An example of naïve beliefs included that knowledge can be gained only through precise experiment, whereas a more informed belief was labeled that experiments are not always critical, such as when teaching evolution, Darwin’s theory cannot be tested experimentally. Some of the earlier literature (Doyle, 1997; Richardson, 1996) discussed how PSTs believed that teaching science is a process of giving and receiving content (Parker & Brindley, 2008); however, more recently, a study conducted by Parker and Brindley (2008) revealed that PSTs in their MAT program possessed more progressive beliefs. These teachers viewed teaching science as engaging and having active learners in the classroom. They were interested in a more student-centered learning orientation, when students are in control of their learning, rather than a teacher-centered, when teachers lead the learning (Parker & Brindley, 2008).

De Jong and colleagues (2005) explored how engaging PSTs in a project that focused on their thinking produced shifts in their own orientations. Using an intervention with 12
PSTs that introduced how to use particle models to help students understand particular phenomena, it was revealed that participants became more aware of how the models could be used in these specific teaching situations. The particle model intervention was useful in the development of orientation thinking (de Jong et al., 2005).

**Interventions Can Assist in PSTs’ PCK Development, Especially the KISR Component**

Research on PSTs’ PCK during student teaching mostly involves an intervention to see how it impacts the development. Much of the research shows that certain interventions can help PSTs develop their PCK, especially their knowledge of instructional strategies and representations (KISR). For example, research on how scientific models impacted knowledge of instructional strategies and the development of PCK was conducted by Nelson and Davis (2012). Their focus was on using a modeling-based intervention to investigate how 35 preservice elementary teachers evaluated scientific models and how their knowledge, skills, and self-efficacy for model evaluation changed over the semester. Confidence was also considered essential when PSTs developed their PCK teaching with a scientific model. It was found that the preservice elementary teachers were able to adapt their delivery of the lesson to include a model-based instructional strategy, and there were positive changes in knowledge, model evaluation skills, and self-efficacy (Nelson & Davis, 2012).

Johnson and Cotterman (2015) also studied an intervention—video clubs. Their main focus was on how video clubs impacted PSTs’ science knowledge for teaching, yet results from this study also have implications for knowledge of instructional strategies. For example, one participant stated in regard to mitosis, “And these pictures, I don’t like these pictures. Because they’re between two phases. They’re not distinct...for this purpose of identifying what stage it is...it’s between telophase and cytokinesis” (Johnson & Cotterman,
Because the teachers were able to analyze instructional resources, they were aware of what is best used, or not used, to teach a particular topic.

There are two interventions that assist in the development of PCK, CoRes, as mentioned above, and Pedagogical and Professional-experience Repertories (PaP-eRs), and PSTs find these tasks challenging (Hume & Berry, 2010; Nilsson & Elm, 2017), but added that they were useful. Participants in Bertram and Loughran’s (2012) intervention study highlighted the use of CoRes in the development of their professional practice, student learning, and content. In Nilsson and Loughran’s (2012) study using the CoRes tool, the explicitness of PCK was stressed as essential, and the focus was on how the tool can contribute to support and empowerment for student teachers learning to teach science. PaP-eRs is a multi-form approach to the teacher’s choosing (Bertram & Loughran, 2012). It can be used in the form of a discussion from an interview group, journal, flowchart, or reflective writing, allowing the capturing of PCK for a particular lesson. PaP-eRs extends from a particular CoRe. Both tools are worthwhile, valid, and have had an essential part in PSTs’ PCK development (Bertram & Loughran, 2011).

Another example of research using the CoRes intervention was by Aydin and colleagues (2015), who studied how the interactions of PCK components developed for PSTs in a CoRe-based practicum course, specifically looking at the topic of the rate of reaction. Researchers looked at the interactions between orientations to teaching science, knowledge of the learner, knowledge of curriculum, knowledge of instructional strategies, and knowledge of assessment, which are the five components that were examined in the current study. From the primary data source, teachers’ CoRes, analysis revealed four features in regard to interaction: (a) the interaction among PCK components were fragmented
in the beginning but became integrated at the end; (b) the development of the integration of components was idiosyncratic; (c) the most significant interaction occurred between knowledge of curriculum and other components; (e) knowledge of assessment and knowledge of instructional strategy displayed zero connections (Aydin et al., 2015). This study was important to display that PSTs are able to develop their PCK and components interact to an extent.

**Cooperating Teachers’ Impact on PST Development**

Many teaching strategies and interventions that have influenced PSTs’ development have been discussed, and literature has also revealed sources essential to the development of PSTs’ PCK: disciplinary knowledge and education, apprenticeship of observation and observations of classes, classroom teaching experiences, specific courses and workshops during the education experience, PCK courses, cooperation with colleagues, and reflection on practice (Evens, Elen, & Depaepe, 2015; Grossman, 1990). In this section, research about the teaching experiences and apprenticeship of observation, in particular, cooperating teachers (CTs), is discussed.

CTs are viewed as a critical influence on PSTs’ development (Clarke, Triggs, & Nielson, 2014). Even PSTs themselves consider their CT to be one of the most important factors in their teacher education experience (Clarke, Triggs, & Nielson, 2014). CTs have been shown to influence PSTs in their self-efficacy and preparedness, teaching practices, pedagogical knowledge, and content knowledge.

In regard to self-efficacy and teacher preparedness, student teaching with a cooperating teacher provides more instances of modeling and feedback that helps PSTs in their teaching ability (Clarke, Triggs, & Nielson, 2014). Research has even shown that
whether or not a CT has training in preparing for their student teacher has no relationship with the novice’s self-efficacy (Gareis & Grant, 2014). Preservice teachers feel more prepared to teach when their CTs provide an effective model followed by “more instructional support, frequent and adequate feedback, collaborative activity, job-search support, and a balance of autonomy and encouragement” (Matsko et al., 2018, p. 1).

Preservice teachers’ teaching practices are also strongly influenced by their CTs. Many preservice teachers follow the patterns of their CTs in regard to teaching practices. For example, in Rozelle and Wilson’s (2012) study, all six of the student teacher participants attempted to follow the model their CT set forth in the lesson before following “lesson structures and borrowing representations, anecdotes, and jokes” (p. 1196). Preservice teachers have also been shown to be more instructionally effective when their CT was more instructionally effective (Ronfeldt, Brockman, & Campbell, 2018), meaning CTs that have higher observational ratings serve as better mentors to influence their PSTs’ teaching practices in a positive way.

CTs also influence their preservice teachers’ subject matter knowledge (SMK) and pedagogical knowledge (PK). Individual novice-cooperating-teacher relationship has played a major role in determining how much knowledge a beginning teacher gains (Chamberlin & Vallance, 1991; Jacknicke & Samiroden, 1991; Kagan, 1992). PSTs also learn more about their SMK when they have to explain certain concepts, such as scientific concepts, to their CT (Nilsson & van Driel, 2010). Not only do CTs have an influence on their preservice teachers’ SMK, but on their PK as well. CTs assists their preservice teachers with handling conflicts in the classroom and making sure that the preservice teachers have the opportunity
to participate in activities that may help them gain experience in this area and providing feedback for their preservice teachers to aid in this area (Nilsson & van Driel, 2010).

Although there is substantial research that shows how CTs positively impact their preservice teachers, there is also literature that suggests that CTs could hinder their preservice teacher’s development. Sometimes there is a lack of opportunities for student teachers to try out their new ideas in the classroom, and when they are able to try out ideas, CTs may not provide the appropriate feedback for them to grow (Borko & Mayfield, 1995; Valencia et al., 2012). Also, at times, there could be a conflict with CTs, university supervisors, and preservice teacher beliefs that could hinder their development in areas such as their knowledge, teaching strategies, and beliefs about teaching (Valencia et al., 2012).

In regard to PCK, there are currently limited studies that explore CT and PST relationships and how they affect PSTs’ PCK development, and there are even fewer studies that explicitly explore science PSTs (Barnett & Friedrichsen, 2015; Nilsson & van Driel, 2010). In the next section, what is known about CTs’ impact on preservice teachers’ PCK will be discussed.

**CTs’ Influence on PSTs’ PCK Development**

Few studies examine what contributes to PSTs’ PCK, specifically the contribution of CT (Nilsson & Van Driel, 2010); however, there have been studies conducted that show CTs’ impact on the five components of PCK that are used in this study. In regard to orientations to teaching science, as a mentor, research has revealed that CTs expect student teachers to “model their practice after their own” (Clarke, Triggs, & Nielson, 2014, p. 177). Feedback usually stems from a “traditional follow-me model” (Clarke, Triggs, Nielson, 2014, p. 175). Many preservice teachers believe that CTs disapprove of some of the methods taught in the
teacher education program (Altan & Sağlamel, 2015), and when collaboration occurs with CTs and student teachers, CTs dominate the discussion. CTs model how to teach from a classroom management standpoint as well as orientations to science teaching (Brown et al., 2015).

For knowledge of science curriculum, PSTs often use or modify lesson plans created by their CT (Beyer & Davis, 2012), and although knowledge of the curriculum and creating lessons from it is a critical skill in teaching, novice teachers lack in this area. Some research has indicated that knowledge of curriculum increased with PSTs when they were under the right mentorship (Goodnough, Osmond, Dibbon, Glassman, & Stevens, 2009). Nilsson and van Driel (2011) found that CTs help provide their PSTs with instructional strategies appropriate to teaching the particular curriculum.

Knowledge of assessment of science learning infrequently arises in a teacher’s PCK (Park & Chen, 2012) and is not linked as often with other components (Aydin & Boz, 2013). In regard to CTs’ influence, along with curriculum, PSTs often receive their assessments from the CTs (Beyer & Davis, 2012). CTs assist in their PSTs’ knowledge of assessment by helping them to “critically analyze and revise previous examinations to better align with the current curriculum units” (Barnett & Friedrichsen, 2015, p. 663).

In regard to knowledge of instructional strategies and representations, one of the roles of a CT is to be a provider of feedback (Clarke, Triggs, & Nielson, 2014). In this feedback, CTs are able to share their knowledge of instructional strategies and representations that are best used to teach the content. A common type of feedback results from a traditional “follow-me” model (Clark, Triggs, & Nielson, 2014, p. 175). CTs can help their PST gain knowledge by stating strategies that they have used that have been successful while inviting
the PST to try and reflect upon their own strategies (Barnett & Friedrichsen, 2015). Another type of feedback can be seen in van Driel and colleagues’ (2002) research that studied PSTs’ PCK development of macro- and micro-level chemistry topics during a specialized course that is not available to all teachers. Results indicated that mentors who supervised these teachers were considered one of the strongest factors in their PSTs’ PCK development; mentors also suggested specific strategies to teach specific topics, using multiple representational roles (van Driel et al., 2002).

There is a gap in the literature in regard to CTs’ influence on the development of KSU in PSTs. Cooperating teachers’ primary role is to be “teachers of children,” and this takes priority over the student teacher (Clark, Triggs, & Nielsen, 2014, p. 185). Many times, because of this role, CTs are afraid to mentor their preservice teacher, when, in fact, they could be training them to teach the child and help develop this area of their PST’s PCK. CTs are undoubtedly important in PST development; however, more research should be conducted on the CTs’ impact on the interaction and development of PCK components and through the theoretical PCK lens.

**Chapter Summary**

The students in the United States are falling behind their peers in STEM areas, and in order to improve student achievement in these areas, there is a demand for high-quality teachers who possess a more sophisticated PCK. The development of PCK ultimately begins in a PSTs’ teacher education program. PSTs’ PCK is known to be gradual and complex; however, more research should be conducted in order to determine “how” their PCK is developed during student teaching. In addition, CTs mostly have a positive influence on preservice teachers’ development; however, future research should focus more on,
specifically, PSTs’ PCK development, where there is a gap in the literature. Chapter Three details the research methods that lead to findings that address these gaps (Chapter Four) and a discussion of implications (Chapter Five).
CHAPTER THREE

METHODS

This study employed a multiple-case study approach in order to examine MAT PSTs’ PCK characteristics and the impact of the CT on their PCK. In this chapter, the methodology is outlined, including the rationale for a multiple-case study qualitative research design, participant selection and context, data collection methods, data analysis procedures, and how trustworthiness was maintained throughout the research study.

Research Design

This study employed a multiple-case study research design (Creswell, 2013; Yin, 2013). A multiple-case study is a type of qualitative research approach, which allows researchers to study complex phenomena in particular contexts (Baxter & Jack, 2008). A qualitative approach was used for this study because PCK is a complex construct that should be researched in detail, and obtaining comprehensive information is crucial to explore the context-specific situations that are involved (Abell, 2008). In addition, qualitative research allows for a glimpse into others’ experiences through the researcher’s own perceptions (Merriam, 2009). A case study, a qualitative research approach that is prevalent in the education field (Merriam, 2009), details the particularity and complexity of a case (Stake, 1995). A case study assists in answering questions from specific contexts in a more explanatory fashion that are otherwise too complicated to complete with experimental designs (Yin, 2013).

The specific case study in this dissertation employed a multiple-case study design which can also be labeled as collective, cross-case, multi-case, multi-site, or comparative case studies, all of which are used to collect and analyze data from multiple cases (Creswell,
Seeing that PCK is context-specific (Park & Chen, 2012), it is important to explore, in detail, characteristics using the multiple-case study model. A multiple-case study design is a comprehensive investigation of bounded cases that is established in extensive data collection (Creswell, 2013; Merriam, 2009; Yin, 2013). A bounded system indicates that each case is separated in terms of time, place, or physical boundaries (Creswell, 2013). Using these parameters, this study explored the characteristics of MAT PSTs’ PCK over the course of student teaching, with each MAT PST and their CT representing one case. This case was bounded by setting and timeline and was investigated in a specific classroom during one student teaching semester.

**Participant Selection and Context**

The participants in this study were two female MAT PSTs (Sandy and Rachel) enrolled in a university in the southeastern United States who completed their student teaching in Fall 2018 with their CTs (Dana and Mary, respectively). All MAT PSTs who were enrolled in their student teaching semester during Fall 2018 at this university were contacted via email to participate in the research. In the email, details of what the research would entail, how many times they were to be observed, and what data that the researcher would be collecting was communicated. Participants who chose to take part in the study, Sandy and Rachel, met with me face-to-face and filled out a written consent form. The following paragraphs contain information about each participant and their CT.

**Sandy**

Sandy, a Latina female in her mid-20’s, completed her student teaching experience in a 6th-grade middle school classroom under the mentorship of Dana, an Asian female in her late 40’s. Sandy came into the student teaching experience with a bachelor’s degree in public
health with a concentration in community education and no formal teaching experience. Dana had been teaching for 28 years and has taught at all levels in both private Catholic and public schools in addition to teaching GED classes. She graduated with a bachelor’s degree in biology and a master’s degree in teaching from the Philippines. Sandy felt very comfortable in the student teaching classroom and was eager to try new things. Sandy and Dana both felt that their relationship with each other was positive and they were willing to work together and learn from each other.

Rachel

Rachel, a White female in her mid-20’s, completed her student teaching experience in a high school chemistry classroom under the mentorship of Mary, a White female veteran teacher who was in her 33rd year of teaching. Rachel came into student teaching with a bachelor’s degree in animal science with a minor in genetics and no formal teaching experience. Mary had a bachelor’s degree in Chemistry and a master’s degree in secondary science education. She was also a National Board Certified Teacher.

Data Collection Methods

Creswell (2013) states that “the data collection in case study research is typically extensive, drawing on multiple sources of information, such as observations, interviews, documents, and audiovisual materials” (p. 100). In accordance, data for this study were gathered from multiple sources including interviews, observations, documents and artifacts, edTPA documents, and researcher field notes as summarized in Table 3.1. As mentioned, to understand PCK fully, PCK should be examined throughout three phases of instruction: planning, implementation, and reflection (Park et al., 2011). Thus, data collection was planned to encompass all of the phases. For example, for each observation, pre-and post-
observation interviews were included along with the observation itself to examine PCK revealed in planning and reflection phases as well as the implementation phase. Details for each data collection source are presented in the following sections.

Table 3.1.

Dissertation Data Collection Methods

<table>
<thead>
<tr>
<th>Data Sources</th>
<th>Participants</th>
<th>Sandy</th>
<th>Rachel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>6 lectures (What Makes Earth Habitable?, Tides, Physical and Chemical Changes, The Periodic Table, Elements, Compounds, and Mixtures, and Waves)</td>
<td>5 lectures (Fission and Fusion, Energy Levels, VSEPR Model Lesson, Molar Conversions, Thermodynamics Lesson)</td>
<td></td>
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<tr>
<td></td>
<td>3 labs/activities (Moon Phases and Oreo Lab, Planet Project, Triple Beam Balance Lab)</td>
<td>4 labs/activities (Water in a Hydrate Lab, VSEPR Theory Lab, Limited and Excess Reactants Lab, Boyle’s Law Lab)</td>
<td></td>
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<tr>
<td></td>
<td>Observations #5-9 included observations of back-to-back classes.</td>
<td>Observations #3-9 included observations of back-to-back classes.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PCK Evidence Reporting Table: Collected for each observation</td>
<td>PCK Evidence Reporting Table: Collected for each observation</td>
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</tbody>
</table>

Interviews

- 7 pre-observation interviews with PST
- 9 post-observation interviews with PST
- OTS interview (twice, at the beginning and at the end of the semester) with PST and CT separately
- Interview about CT-PST interaction (twice, beginning and at the end of the semester) with PST and CT separately
- 7 informal interviews (throughout the semester and at the end of the semester) with PST

- 5 pre-observation interviews with PST
- 9 post-observation interviews with PST
- OTS interview (twice, at the beginning and at the end of the semester) with PST and CT separately
- Interview about CT-PST interaction (twice, beginning and at the end of the semester) with PST and CT separately
- 5 informal interviews (throughout the semester and at the end of the semester) with PST
Table 3.1 (continued).

<table>
<thead>
<tr>
<th>Documents and Artifacts</th>
<th>4 Lesson Plans</th>
<th>5 Lesson Plans</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>6 PowerPoint Slides</td>
<td>4 PowerPoint Slides</td>
</tr>
<tr>
<td></td>
<td>5 Student Handout</td>
<td>8 Student Handouts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Long-Term Planning Schedules</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Researcher’s field notes</th>
<th>Collected throughout the semester</th>
<th>Collected throughout the semester</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Task 2: 1 4:45 minute video clip, 1 14:28 minute video clip, Instructional Commentary</td>
<td>• Task 2: 1 9:31 minute video clip, 1 9:36 minute video clip, Instructional Commentary</td>
</tr>
<tr>
<td></td>
<td>• Task 3: Student Work, Assessment Commentary, Evaluation Criteria</td>
<td>• Task 3: Student Work, Assessment Commentary, Evaluation Criteria</td>
</tr>
</tbody>
</table>

PCK: Pedagogical Content Knowledge, OTS: Orientations to Teaching Science, CT: Cooperating Teacher, PST: Preservice Science Teacher

Observations

Case studies allow for an in-depth analysis of observations, which is critical in qualitative research (Creswell, 2014; Merriam, 2009). Observations are an essential source for studying PCK (Berry et al., 2015) and provide data for the instructional phase, implementation, which is how participants deliver the lesson they prepared for. The first source of data collection for this study came from observations of the MAT PSTs throughout the semester.

Each participant was observed on nine different days over the course of the semester, and each observation was confirmed by the participants in order to increase their comfort in sharing a lesson they believe best represents their PCK. During many observations, two class periods were observed back-to-back in order to analyze PCK characteristics between class periods. Sandy was observed a total of nine days (observations #1–#9), and of those nine days, there were six lectures and three labs. Sandy was observed in
back-to-back lessons during observations #5–#9, with a total of 14 class periods being observed altogether. Rachel was observed a total of nine days, and of those nine days, there were five lectures and four labs. Rachel was observed in back-to-back lessons during observations #3–#9, with a total of 16 class periods being observed altogether.

While observing, the researcher recorded evidence of PCK components that appeared using a modified version of Park and Oliver’s (2008) PCK Evidence Reporting Table as seen in Appendix A. Park and Oliver’s PCK Evidence Reporting Table consists of the five components of PCK and are presented in categories. In each component, subcategories are listed for the researcher to determine if they were present the observation. For example, under the component KISR, there are specific types of language devices that were searched for during observations. For example, during Sandy’s observation #1, she asked “Does air leave Earth?” which is a reasoning question. For each occurrence during an observation of such activities, it was marked with a check mark and evidence was written down for each incident. For this particular example, I checked the reasoning box and then wrote down the question as evidence in the section provided. Clarifying definitions for this instrument are provided in Appendix B. The PCK Evidence Reporting Table instrument provided additional data to compare with other observation information during data analysis.

Interviews

The first set of interviews conducted were pre- and post-observation interviews, modified from Sickel and Friedrichsen (2018), wherein each participant was interviewed after each observation (see Appendix C), and for the majority of the observations, before the observation. Sandy was interviewed before her observations seven out of nine of times, and Rachel was interviewed before her observations five out of nine times. Each participant was
interviewed after every one of their observations, totaling nine post-observation interviews each. These formal interviews were semi-structured to allow for information to be gathered for specific situations (Merriam, 2009), and the interviews allowed for participants to answer a few open-ended questions to obtain the participants’ point of view and begin a fruitful conversation between the interviewer and interviewee (Creswell, 2014). For the interview protocol, I considered the demands and constraints of the participants being occupied with various activities; therefore, pre- and post-observation interviews were brief but allowed for richness in data in order to obtain all three instructional stages of PCK: planning, implementation, and reflection. Post-observation interview questions addressed each component of the conceptual framework. Twenty-five percent of the transcripts of pre- and post-observation interviews were emailed to each participant in order to allow for member checking (Creswell, 2014), and participants were given a week to make changes to what they wanted to say and expand if they wish to do so.

The second set of interviews was conducted at the beginning and end of the semester with both CTs and PSTs: interviews about interactions with each other (see Appendix D) and interviews about their orientations to teaching science (see Appendix E). CT and PST interaction questions were modified from O'Brian, Stoner, Appel, and House (2007), and orientations to teaching science questions were modified from Sickel and Friedrichsen (2017). For the CT and PST interaction interview, CTs and PSTs were asked questions based upon what they thought their role during student teaching was, what the most important factor in their learning was during the experience, how their relationship was with their CT or PST, and how the student teaching experience has affected them. For the orientations to teaching science interviews, participants were asked to describe their best day
in teaching science, how the lessons that they taught compared to their best day description, and to describe teacher and student roles in a typical science lesson. For each set of interviews, each participant, both CTs and PSTs, were interviewed separately to allow for comfort and privacy. To allow for member checking, all interview transcripts were sent via email to each of the participants to review and changes if they deemed appropriate.

The third set of interviews, informal interviews, were also conducted throughout the semester with the PSTs. The researcher met with PSTs outside of class via Google Hangouts periodically, and in these interviews, PSTs were given the ability to ask questions and express concerns about their student teaching experience. Informal interviews aided in answering both of the research questions.

**Documents and Artifacts**

Case studies require multiple data sources (Yin, 2009) that allow for detailed information that can be compared. Data was also collected from various items that the PSTs provided including lesson plans, PowerPoint Slides, student handouts, and long-term planning schedules, which aided in answering both research questions. Sandy was able to provide four lesson plans, six copies of PowerPoint Slides, and five student handouts. Rachel was able to provide the researcher with five lesson plans, four PowerPoint Slides, eight student handouts, and three long-term planning schedules. Information from these documents were compared with other sources to determine whether similar patterns emerged.

**Researcher’s Field Notes**

Throughout the semester, I recorded field notes with information that other data sources did not provide, allowing for contextual information (Creswell, 2013). Field notes consisted of outside factors during the lesson, the setting, individuals in the room, the
researcher’s personal comments, or random conversations outside of data collection. Maintaining field notes allowed the opportunity to be descriptive and reflective (Parrott, 2016), and allowed me to record important data at times when other observation tools were not being used. Descriptive field notes recorded details of activities and conversations that occurred during the observations; whereas reflective field notes allowed for the researcher to write down their thoughts and reflections before, during, and after each of the observations. An example of a portion of field notes for Rachel during an observation can be seen in Figure 3.1 below.

As students come up, ST states to class, “You have to have the correct number of holes for the bonds to create the correct Geometry. Pay attention to that, not the color”.

Students are lined up to show their models to the ST. She stamps if they are correct, if they are not, she talks to them, and has them go back to try again. I will ask her in the post-interview what kind of conversations were had.

ST states, “so for the double bond, how many bonds are there? So you need two. That’s why they are so long, so you can create two.”

I will grade your quizzes by midway through 3rd period, so you can come and get them to help study for your test.

Overhear ST tell a student...think about...

“Think about what those shapes are called.”
“Think about what that shape needs to look like.”

*Figure 3.1.* Example of researcher’s field notes during observation 5a for Rachel.

ST: Student Teacher
edTPA Materials

As a part of the MAT program at their university, participants had to complete a teacher performance assessment (edTPA) during student teaching, which is a project that students had to complete in order to graduate wherein they displayed knowledge and skills to teach the students in their classroom for one learning segment, three to five lessons (Pearson Education, 2019). In order to obtain more detailed information to add to existing data, edTPA materials, which included three different tasks, were collected at the end of the semester. Task one included context for learning information, lesson plans, instructional materials, assessments, and planning commentary. Task two included two video clips of their selected lesson and instructional commentary. Task three included student work, assessment, commentary, and evaluation criteria. All of these materials were collected for analysis from each participant.

Data Analysis Procedures

In order to capture the characteristics of the MAT PSTs’ PCK over the course of student teaching, data was analyzed using four approaches: (a) coding with a priori codes, (b) analysis of the PCK Evidence Reporting Table using descriptive statistics, (c) in-depth analysis of explicit PCK (Park & Oliver, 2008) and the enumerative approach (LeCompte & Preissle, 1993) to create PCK maps, and (d) the constant comparative method. In order to capture the influence of CTs on MAT PSTs’ PCK development, the constant comparative method was used. Table 3.2 summarizes data sources and data analysis methods for each of the research questions.
Table 3.2.

Dissertation Data Sources and Data Analysis Methods

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Sources</th>
<th>Data Analysis Methods</th>
</tr>
</thead>
</table>
| **Research Question 1:** What are the characteristics of MAT preservice science teachers’ pedagogical content knowledge throughout student teaching? | • observations  
• pre- and post-observation interviews  
• PCK Evidence Reporting Table  
• OTS interviews  
• informal interviews  
• lesson plans, PowerPoint slides, student handouts, and long-term planning schedules  
• researcher’s field notes  
• edTPA materials | • coding with a priori codes  
• analysis of PCK Evidence Reporting Table using descriptive statistics  
• in-depth analysis of PCK and enumerative approach to create PCK maps  
• the constant comparative methods |
| **Research Question 2:** What type of influence, if any, do cooperating teachers have on MAT preservice science teachers’ pedagogical content knowledge development during their student teaching experience? | • observations  
• pre- and post-observation interviews  
• OTS interviews  
• CT-PST interaction interviews  
• informal interviews  
• lesson plans, PowerPoint slides, student handouts, and long-term planning schedules  
• researcher’s field notes | • the constant comparative method: open, axial, and selective coding |

PCK: Pedagogical Content Knowledge, OTS: Orientations to Teaching Science, CT: Cooperating Teacher, PST: Preservice Science Teacher

**Research Question One**

Research question one asks, “What are the characteristics of MAT preservice science teachers’ pedagogical content knowledge throughout student teaching?” To answer this question, data were analyzed through coding with a priori codes, analysis of the PCK Evidence Reporting Table using descriptive statistics, in-depth analysis of explicit PCK, the
enumerative approach, and the constant comparative method. The following data sources were collected and analyzed: (a) observations, (b) pre- and post-observation interviews, (c) the PCK Evidence Reporting Table, (d) OTS interviews, (e) informal interviews, (f) lesson plans, PowerPoint slides, student handouts, and long-term planning schedules, (g) researcher’s field notes, and (h) edTPA materials. A description of the five analysis approaches to answer research question one are described below.

**Coding with a priori codes.** Data were analyzed simultaneously with data collection. Two sets of a priori codes were used in analysis. The first set is drawn from the five components of the conceptual framework used in this study as well as subcategories of these components. For example, one code is Orientations to Teaching Science (OTS), and the subcategories include beliefs about purposes of learning science, decision making in teaching, and beliefs about the nature of science. When coding the data, the appearance of OTS with the appearance of one of these subcategories was noted. An example of this comes from Sandy’s observation #6 post-observation interview when she stated, “. . . I think if the teachers’ took that extra step to explain why it would be helpful, especially like career paths, that could have really motivated or at least engaged students to care”. This particular statement was coded as OTS - beliefs about the purposes of learning science (OTS-A). Analysis of all data focused on the identification of patterns through an established system of codes listed in Table 3.3.
Table 3.3.

*A Priori Codes for Data Analysis*

<table>
<thead>
<tr>
<th>A Priori Codes for the Presence of the PCK Components</th>
<th>A Priori Codes for the Interaction Among the Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTS: Orientations to Teaching Science</td>
<td>A1. OTS and KISR</td>
</tr>
<tr>
<td>OTS-A. Beliefs about Purposes of Learning Science</td>
<td>A2. OTS and KAs</td>
</tr>
<tr>
<td>OTS-B. Decision Making in Teaching</td>
<td>A3. OTS and KSC</td>
</tr>
<tr>
<td>OTS-C. Beliefs about the Nature of Science</td>
<td>A4. OTS and KSU</td>
</tr>
<tr>
<td>KSU: Knowledge of Student Understanding</td>
<td>A5. KISR and KAs</td>
</tr>
<tr>
<td>KSU-A. Misconceptions</td>
<td>A6. KISR and KSC</td>
</tr>
<tr>
<td>KSU-B. Learning Difficulties</td>
<td>A7. KISR and KSU</td>
</tr>
<tr>
<td>KSU-C. Motivation &amp; Interest</td>
<td>A8. KAs and KSC</td>
</tr>
<tr>
<td>KSU-D. Need</td>
<td>A9. KAs and KSU</td>
</tr>
<tr>
<td>KSC: Knowledge of Science Curriculum</td>
<td>A10. KSC and KSU</td>
</tr>
<tr>
<td>KSC-A. Curriculum Materials</td>
<td></td>
</tr>
<tr>
<td>KSC-B. Vertical Curriculum</td>
<td></td>
</tr>
<tr>
<td>KSC-C. Horizontal Curriculum</td>
<td></td>
</tr>
<tr>
<td>KA: Knowledge of Assessment</td>
<td></td>
</tr>
<tr>
<td>KA-A. Dimensions of Science Learning to Access</td>
<td></td>
</tr>
<tr>
<td>KA-B: Methods of Assessing Science Learning</td>
<td></td>
</tr>
<tr>
<td>KISR: Knowledge of Instructional Strategies</td>
<td></td>
</tr>
<tr>
<td>KISR-A. Topic-Specific Strategies</td>
<td></td>
</tr>
<tr>
<td>KISR-B. Subject-Specific Strategies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D1. OTS, KISR, KAs, KSC, and KSU</td>
</tr>
</tbody>
</table>
The second set of a priori codes addressed interactions among the five PCK components. Interactions had the opportunity to occur in pairs, sets of three, sets of four, or a set of five. Component integration possibilities can be also be seen in Table 3.3. An example of an interaction code comes from Rachel’s observation #7 post-observation interview, after a lab on limited and excess reactants, where she stated:

Yes, so because we didn’t get a ton of practice in 3rd period, and not really in 2nd because they had a few minutes, but then they got a little distracted by having to reformat some of their classwork, on the schedule anyways . . . So, I think I will have them work through 2 or 3 examples and then if there is no blaring misconceptions or there is no like people completely struggling, I’ll give them the quiz tomorrow.

This particular statement was coded as the interaction between KISR, KAs, and KSU (B3). Based on her knowledge of the subject, Rachel decided to work through more examples, and then based on her students’ response, she would assess them. The results from a priori code analysis were compared with results from all other analysis measures.

**Analysis of the PCK Evidence Reporting Table.** During observations, the PCK Evidence Reporting Table, described above, was used to record evidence of each of the five components of PCK. The data from this table, analyzed using descriptive statistics, were used as a comparison to themes emerging from a priori codes. A fellow colleague, a doctoral student knowledgeable about PCK research, co-observed one observation, along with completing the PCK Evidence Reporting Table. Initial inter-coder agreement (McHugh, 2012) for the PCK Evidence Reporting Table was 26% and each disagreement was discussed until an 88% agreement was reached.
**In-depth analysis of explicit PCK and the enumerative approach to create PCK**

*Maps.* PCK maps were developed for each observation using all supportive data. A PCK map (Park & Chen, 2012) is a visual representation of the integration of the five components of PCK seen in the pentagon model of PCK for teaching science. Integration among components can be seen in a clear and explicit way using this approach, and an example is given in Figure 3.2 below.

![PCK Map Example](image)

*Figure 3.2.* An example of a PCK map.

In these maps, the frequency of connections between components and the number of connections that each component makes with the others can be visually observed. The PCK map approach was conducted through two steps: in-depth analysis of explicit PCK and enumerative analysis. The first step, in-depth analysis of explicit PCK, was conducted in order to identify PCK episodes, teaching segments that are comprised of two or more component interactions and could range in time from 1 minute to 30 minutes. I first identified PCK episodes during observations that were also supported by other data such as interviews and lesson plans. When identifying PCK episodes, descriptions of what the teacher and students were doing, which components of PCK were integrated, and what
evidence was given in the PCK episode of the integration of components were recorded. An example of a PCK episode can be seen in Appendix F. This approach was completed for each observation.

The next step in creating PCK maps was enumerative analysis. Once all PCK episodes were identified, connections were displayed using the pentagon model as a systematic device (PCK map). As seen in Figure 3.2, all five components of the pentagon model of PCK for teaching science are visually set in a pentagon form. Each appearance of an integration in a PCK episode was recorded between the components involved. For example, if an episode, labeled E1, consisted of KSU, OTS, and KISR component integration, the PCK map was labeled as seen in Figure 3.3. A line was drawn between components, and the episode was labeled in between. This was completed with each episode of the observation.

![Figure 3.3. Example of the first step in enumerative analysis.](image)

Once all episodes were displayed in the PCK map, the number of episodes between each component was condensed into a single number. The strength of the connections was identified by this number as seen in Figure 3.2. Once this step was complete, the number of
connections that each component had with other components was recorded beside each individual component. The maps were used in data analysis in order to explore component integration for each participant over the student teaching semester.

The constant comparative method. To determine what factors may have impacted PCK characteristics, the constant comparative method was used. In this approach, the data analysis focused on common patterns that emerged without the use of an a priori established system of codes. Instead, data was analyzed through a process in which data was constantly compared with previous analysis measures. This process began by using open coding to identify major categories of information, and afterward, axial coding was conducted. First, I identified open coding categories to focus on, then I reviewed data to create categories that surrounded these core phenomena. Lastly, I conducted selective coding to develop themes that described the relationship of the categories developed (Corbin & Strauss, 2008).

Once data were analyzed for each case (within-case analysis), a cross-case analysis, in which I compared cases with each other (Creswell, 2013), was conducted to determine common characteristics in PSTs’ PCK development. Cross-case analysis was conducted for the purpose of determining the characteristics of MAT PSTs’ PCK during student teaching and what factors impacted these characteristics. All data sources listed above were used to answer the research question, which adds to the credibility of the methodology and analysis (Creswell, 2013; Merriam, 2009).

Research Question Two

To answer research question two, “What type of influence, if any, do cooperating teachers have on MAT preservice science teachers’ pedagogical content knowledge development during their student teaching experience?” the constant comparative method
was used. For research question two, the following data sources were collected and analyzed: (a) observations, (b) pre- and post-observation interviews, (c) OTS interviews, (d) CT-PST interaction interviews, (e) informal interviews, (f) lesson plans, PowerPoint slides, student handouts, and long-term planning schedules, and (g) researcher’s field notes. To begin analysis, open coding, axial coding, and selective coding were conducted (Corbin & Strauss, 2008) as described above to determine themes. This was first completed within-cases and then followed by cross-case analysis. Using this analysis method aided in discovering how CTs influence their MAT PSTs’ PCK development.

**Trustworthiness**

Several procedures were undertaken during the research process to verify trustworthiness. There are four items that qualitative research studies are judged by, parallel to those judged in quantitative studies: credibility (internal validity), transferability (external validity), dependability (reliability), and confirmability (objectivity) (Schwandt, Lincoln, & Guba, 2007). A description of how each of these was attained follows.

Credibility was established in the study through both triangulation and member checking. Multiple data sources, such as lesson plans, observations, interviews, and researcher’s field notes, were collected in order to maintain triangulation and were analyzed via a priori codes, PCK Evidence Reporting Table using descriptive statistics, the PCK map approach, and the constant comparative method. Along with triangulation, member checking was employed to establish credibility. As mentioned above, a portion of all interview transcripts were sent to participants to allow them to review what they previously stated and to verify their thoughts and actions.
Because each case was unique, and this is a qualitative study, it is more difficult to extend research findings; therefore, transferability was a more complex task to achieve. Nevertheless, I was able to provide transferability by providing rich descriptions of each case. Multiple lessons were observed over the 15-week semester in order to obtain as much in-depth data as possible. By providing a “rich description” of each case, transferability is possible as stated by Guba and Lincoln (1982): “Some degree of transferability is possible under certain circumstances. Those circumstances exist if enough ‘thick description’ is available about both ‘sending’ and ‘receiving’ contexts to make a reasoned judgment about the degree of transferability possible” (p. 247). In this study, I provided thick descriptions of each unique case in order to provide transferability to specific circumstances (Chapter Four).

Dependability, or reliability, “assumes that there is a single reality and that studying it repeatedly still yields the same results” (Merriam, 2009, p. 220). However, in qualitative research, this is also very complex because working with human-subjects is never constant (Merriam, 2008). Guba and Lincoln (1982) explain that “the naturalist defines the concept of dependability to mean stability after discounting such conscious and unpredictable (but rational and logical) changes” (p. 247). To achieve dependability in the current study, I thoroughly documented each step of the research, as seen in this Chapter, in order for the study to be replicable. In addition, dependability is supported by means of triangulation.

Conformability in qualitative research refers to the degree to which the results of a study could be confirmed by others (Guba & Lincoln, 1982). When conducting data collection and data analysis, I remained as impartial and unbiased as possible. Conformability was also supported by interrater reliability described above as well as another
technique, peer debriefing, which was used to allow another colleague to review data and provide feedback to enhance validity.

Chapter Summary

In this chapter, the research design, participant selection and context, data collection methods, data analysis methods, and how trustworthiness was obtained in the study was discussed. Chapter four reports the results of the study.
CHAPTER FOUR

RESULTS

In this chapter, the results for research questions one and two are discussed in detail. In the first section, the results for research question number one regarding MAT preservice teachers’ (PSTs) pedagogical content knowledge (PCK) characteristics are laid out for individual cases and then across cases. Next, the results for research question number two concerning the influence of the cooperating teacher (CT) on their MAT PST’s PCK are laid out. Data analysis through the constant comparative method revealed patterns in the CTs’ influence on their MAT PSTs’ PCK for each case as well as across cases, discussed in detail in the second section of this chapter.

**RQ1: The Characteristics of MAT Preservice Science Teachers’ Pedagogical Content Knowledge throughout Student Teaching**

PCK maps that were created through the analysis of observations, interviews, and other documents and emerging themes through the constant comparative method revealed several salient characteristics of the MAT PSTs’ PCK in each case and commonalities of both of their PCK characteristics. First, four features of Sandy’s PCK are discussed; then, four features of Rachel’s PCK are discussed; finally, three common characteristics of both MAT PSTs’ PCK are detailed.

**Sandy’s PCK Characteristics throughout Student Teaching**

Analysis of the PCK maps that were constructed from observations, interviews, and other documents, such as lesson plans and student handouts, revealed four salient features of Sandy’s PCK over student teaching: (1) Sandy’s PCK changed little over time and was inconsistent throughout the semester; (2) Sandy’s PCK showed minimal changes between
class periods; (3) Sandy’s orientations to teaching science (OTS) rarely impacted her PCK throughout student teaching; and (4) when given autonomy in the lesson, Sandy showed slightly stronger PCK.

**Assertion 1: Sandy’s PCK changed little over time and was inconsistent throughout the semester.** Figure 4.1 shows Sandy’s PCK maps throughout student teaching and is presented in chronological order. As indicated in Figure 4.1, Sandy’s PCK did not change much over the semester, and this can be viewed by the number of PCK episodes and connections in each map. As a reminder, PCK episodes are teaching segments that include the presence of two or more PCK components in the pentagon model for teaching science (Park & Chen, 2012). The number of connections is based on the number of component interactions in a particular observation.

![Figure 4.1. PCK maps for Sandy over student teaching. (PE: Number of PCK Episodes and C: Number of Connections)](image-url)
Throughout the semester, the number of Sandy’s PCK episodes ranged from two to four, with the highest number of PCK episodes occurring during observation #3 and the lowest number appearing during observations at the beginning and end of the semester. Also, the number of connections ranged from two to twelve with the highest number of connections occurring during observation #3 and the lowest number appearing during observations at the end of the semester. To understand whether Sandy’s PCK was different for various instructional modes, her PCK maps were further examined in terms of two modes: lectures and labs/activities. Figure 4.2 shows the PCK maps of 6 lectures, and Figure 4.3 displays PCK maps of 3 labs/activities.

Figure 4.2. PCK maps for Sandy’s lectures over the student teaching semester. (PE: Number of PCK Episodes and C: Number of Connections)
In both her lectures and labs/activities, Sandy’s PCK was inconsistent and weak, and no patterns in growth of the interaction of components were evident. For example, looking at Sandy’s lectures, in observations #3 and #8, Sandy showed interactions between OTS and knowledge of instructional strategies and representations (KISR), but this was not shown in other observations in the semester. In addition, looking at Sandy’s labs/activities, she displayed an interaction between the components of knowledge of students’ understanding in science (KSU), KISR, and knowledge of assessment of science learning (KAs) in observations #2 and #4, but this interaction was not displayed in observation #5. This is consistent with the statement that there were no growth patterns in Sandy’s PCK among the interaction of components over the student teaching semester.

To explore Sandy’s PCK further, data collected with the PCK Evidence Reporting Table were analyzed in terms of the number of individual subcomponents of each PCK component identified from observations over time. The data revealed from this tool can be seen in Figure 4.3 and Table 4.1 below. The analysis of this data was consistent with the results from the PCK maps that her PCK changed very little over time and was inconsistent throughout the semester. There were no significant patterns that emerged for any individual components just as there were no patterns that emerged with the interaction among components.
Figure 4.3. *PCK maps for Sandy's labs/activities over the student teaching semester.*

(PE: Number of PCK Episodes and C: Number of Connections)

Table 4.1.

*Number of Subcomponents Present in Sandy's PCK over Student Teaching*

<table>
<thead>
<tr>
<th>Observation</th>
<th>OTS</th>
<th>KSU</th>
<th>KSC</th>
<th>KA</th>
<th>KISR</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
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<tr>
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<td>3</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>23</td>
<td>19</td>
<td>15</td>
<td>12</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>

OTS: Orientation to Teaching Science, KSU: Knowledge of Students Understanding in Science, KAs: Knowledge of Students’ Understanding in Science, KISR: Knowledge of Instructional Strategies
Some individual components remained lower or higher throughout the semester in Sandy’s PCK. For example, as seen in Figure 4.4, KISR appeared the most, and remained on the higher end of the spectrum throughout the semester; however, in consistency with other data sources, there were no growth patterns and the frequency of KISR was inconsistent throughout the semester. This trend can also be seen with KAs and knowledge of science curriculum (KSC), which remained on the lower end of the scale. No patterns in the development of the components emerged, and growth was inconsistent.

![Figure 4.4. The presence of PCK subcomponents in Sandy’s observations.](image)

**Assertion 2: Sandy’s PCK showed minimal changes between class periods.**

Towards the middle of the semester, as Sandy began taking on multiple classes, I had the opportunity to observe two classes back-to-back during one observation day, on multiple occasions, to determine how her PCK may have changed based on reflection-on-action,
which is reflection after the first class occurred. During a typical lesson, Sandy wanted to center her lessons around discussions, and she wanted to focus on student interaction, allowing students to gain an understanding of the material by leading them to it, rather than to just feed them the material. Although this is what she strived to do, this was not always the case. The PCK maps for all lessons that were available to be observed twice are seen in Figure 4.5. The results from this data revealed that there were minimal changes in Sandy’s PCK after teaching the same topic back-to-back, and, in fact, there were observations where her PCK showed positive, negative, and neutral changes. For example, three out of the five observations showed no change in PCK between class periods at all (observations #7, #8, and #9). For observation #5, there was an increase in PCK episodes; however, the number of connections actually decreased by one. The only observation that showed positive changes in Sandy’s PCK occurred during observation #6, her lesson on physical and chemical changes, with an increase in PCK episodes and connections by two. Through careful analysis, an explanation for this change was based on the type of students in her second class period observed, a 504 student, a student with a customized learning plan, and an English Language Learner (ELL) student, a student. Sandy had to adjust her lesson based on these particular students’ needs; however, this was not seen between class periods at any other point in the semester.
Figure 4.5. Sandy’s PCK maps of two back-to-back class periods per observation day. (PE: Number of PCK Episodes and C: Number of Connections)
Assertion 3: Sandy’s orientations to teaching science (OTS) rarely impacted her PCK throughout student teaching. Figure 4.1 shows that Sandy’s OTS only made connections with other components in three out of the nine observations, and these were scattered throughout the semester. At the beginning of the semester, Sandy described her “best day,” a portion of her orientations to teaching science, in a science class, as teaching in lecture style for a short period of time, then allowing her students to work on some type of interactive activity collaboratively (Sandy: Pre-OTS Interview). At the end of the semester, she described her “best day” very similarly as noted in her statement below:

I do not like to do a huge chunk of lecture per a set of time. I prefer to break it up, so I like to allow the students to discuss more about the ideas throughout the lesson to kind of break up the silence because I know that it can be really boring and then have some kind of activity where they have to apply what they’ve learned and that could be done in groups because I really enjoy working in pairs and groups while working.

She pictured her “best day” lesson as a small overview of the material and some amount of lecture, but she wanted to allow more time for students to work collaboratively on an activity where they could respond and display what they have learned from the lecture or teaching. However, in many of the lessons, mainly planned by the PLT (Planning Learning Team) and CT, she was unable to apply her “best day” lesson into the class. With the lessons largely being planned by the CT and PLT, it is interesting to note what Dana’s (her CT) “best day” description was. An overview of both Sandy and Dana’s “best day” descriptions can be seen in Table 4.2, and the key points are highlighted in red.


Table 4.2.

*Sandy and Dana’s “Best Day” Description as Expressed at the Beginning and End of the Semester*

<table>
<thead>
<tr>
<th></th>
<th>Sandy</th>
<th>Dana</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-OTS Interview</strong></td>
<td>“. . . teaching formally, in a lecture style, for no more than 10 or 15 minutes . . . so for the rest of the lesson I would like for it to be more open for discussion where the students and I are communicating our thoughts and ideas together. . . I don’t like just giving a student some sort of a worksheet where they just have to fill it out silently, so I would want something interactive that gets them working in pairs and they're really thinking, and I like creative activities that let me see how creative these students can be.”</td>
<td>“. . . teacher should be a facilitator of learning. We let students discover how to learn by themselves, with their peers and collaborative groups”.</td>
</tr>
<tr>
<td><strong>Post-OTS Interview</strong></td>
<td>“I do not like to do a huge chunk of lecture per a set of time. I prefer to break it up, so I like to allow the students to discuss more about the ideas throughout the lesson to kind of break up the silence because I know that it can be really boring and then have some kind of activity where they have to apply what they’ve learned and that could be done in groups because I really enjoy working in pairs and groups while working.”</td>
<td>“teachers should facilitate learning, making sure that students not only learn from me but from their peers as well . . . The best day for me is when all my students have a smiling face as they leave my classroom knowing that they learned something significant in class.”</td>
</tr>
</tbody>
</table>

**OTS: Orientation to Teaching Science**

When implementing the lesson, as mentioned, she wanted the students to reach a deeper understanding and did her best to interact with the students, and lead them to a better understanding; however, this still did not see to impact her PCK. Both Sandy and Dana expressed that they wanted students to learn in groups and learn from their peers, but this was not always apparent in Sandy’s lessons. For example, in observation #6, Sandy and Dana co-taught a lesson on physical and chemical changes. Before the observation, I was informed that the Dana and the PLT “inevitably” changed the plans for that day because there were
visitors coming to the classroom (Sandy: Observation #6, Pre-Observation Interview). The school that they taught at is a magnet school, so visitors often came to view the school, and Dana and the PLT wanted to do something different in their lesson to show off to the visitors. This lesson, with the changes, included a lecture on physical and chemical changes, but when the visitors arrived, they had their students break into two groups, one with Dana, and one with Sandy, and each teacher provided demonstrations in which the students were to decide if they were chemical or physical changes. Although this was an activity that broke up the lecture and was engaging, as Sandy expressed she wanted in her “best day” description, it did not provide the collaborative piece that Sandy or Dana felt was important. Students did have the opportunity to explain what was happening in each demonstration by answering questions; however, it was not collaborative.

As mentioned, only three out of nine observations of Sandy’s lessons involved her OTS connecting with other components of PCK. Another example of how Sandy’s OTS rarely impacted her PCK is seen in the last observation in the semester, observation #9. In this observation, Sandy and her CT co-taught a lesson on graphing waves. Most of the time was spent on lecture, with some opportunity for students to work on a worksheet (Sandy: Observation #9, Field Notes). Sandy expressed her thoughts about the lesson, and when asked how she thought the lesson went, she responded:

As I walked around, it looked like they were good. Most of the students were getting the graphs accurately drawn and plotted, but if we were to put the numbers out in front of them, like as an assessment, have them do it on their own without working in pairs. I’m not confident at this point, that they would be able to do it, so I think they
need more practice, but they are not going to be doing any more practice than we did
today. (Sandy: Observation #9, Post-Observation Interview)

Not only were there issues with her “best day” description not being incorporated, but there
were some disagreements on how to deliver the material. This relationship between the CT,
PLT, and the PST is described in further detail in the results for research question #2.

Another example of a lesson that did not reflect Sandy’s OTS was the periodic table
lesson that was viewed in observation #7, also co-taught with Dana. The lesson was planned
by the PLT, and the implementation of the actual lesson was mainly conducted by Dana, as
Sandy worked on talking to students individually about a project they had been working on.
Consequently, Sandy was unable to really have an impact on how the lesson was conducted
at all but still took part in a portion of the lesson, going over a worksheet at the end of class.
In this lesson, Dana gave a long lecture on the periodic table, allowing a small portion of the
class period for students to work on a worksheet that they did not get to complete fully.
Students did have the opportunity to work in pairs on the assignment, but there was not
enough time to really work on the assignment and this decision did not allow for Sandy and
Dana to be facilitators. In fact, as students were working on the worksheet, Sandy and Dana
were discussing something in the corner of the room. In this particular observation, it is
difficult to determine whether or not the implementation of the lesson, for the most part,
given by Dana, made a difference in Sandy’s PCK regarding OTS. The impact of who
implements the lesson on MAT PSTs’ PCK is discussed further in the second section of this
chapter.

Along with her “best day” description, Sandy provided some of her other beliefs
regarding OTS in other parts of the semester. In observation #6, mentioned above, physical
and chemical changes, Sandy expressed a conflict dealing with her OTS in regard to a video shown as part of the lecture that the PLT wanted to use: “But with the videos, it spoon feeds the entire concept, and the reason the PLT likes using them is that they want a visual representation of the lesson in an animated form for students that need a different presentation of the material which I respect. I feel that maybe that could be used as a summary rather than an introduction” (Sandy: Observation #6, Post-Observation Interview).

Sandy expressed disagreement with her CT and PLT earlier in the semester stating that she preferred that students had a better conceptual knowledge of the material rather than rote memorization. Sandy had a love/hate relationship with the videos and expressed that the videos were good; but the videos “take away their [the students] thinking of what happens next” (Sandy: Observation #1, Post-Observation Interview). The video in observation #6, as well as videos in other lessons including observations #1 and #3 (Sandy: Observation #1, Field Notes; Sandy: Observation #3, Field Notes; Sandy: Observation #7, Field Notes), went against her OTS for conceptual learning, which caused the lack in connections to other PCK components.

**Assertion 4: When given autonomy in the lesson, Sandy showed slightly stronger PCK.** When given autonomy in her lessons, Sandy showed a slight increase in the quality of her PCK and displayed more interactions with her orientations to teaching science than at any other point in the semester. Also, it was apparent that when Sandy was not given autonomy in the lessons, especially when using Dana and the PLT’s resources, her PCK was weaker. For example, only one of Sandy’s observations (#3) stood out above the rest in regard to PCK episodes and connections being at their highest. In the lesson from observation #3, Sandy was given the autonomy to teach as she wanted, for the most part,
which gave rise to more PCK episodes and connections being displayed. This observation was an edTPA lesson, which is a project that students were required complete and pass in order to graduate; during the project, students needed to display knowledge and skills to teach their specific students in the classroom (Pearson Education, 2019). Sandy taught a lesson about high and low tides, partly using what the PLT suggested, but also creating her own activity. Until then, most of the lessons and activities were created or influenced by Dana and the PLT, but because this was one of her edTPA lessons, she was given greater freedom to choose the lesson activities. For example, for this particular topic, the PLT wanted to complete a virtual lab, but Sandy wanted to do something more. She explained:

The original virtual lab was a good learning tool. Students would be able to click on different times of the day and they could illustrate what each time of the day and phase of the moon would be involved. However, the students were not even going to be tested on it. (Sandy: Observation #3, Post-Observation Interview)

She did not like the fact that students would not even be tested on it, so she wanted to do something different for her edTPA. She still used the lesson PowerPoint created by her PLT, yet she chose the activity to be given after the lecture herself to replace the virtual lab. In the activity that she chose, students were able to work in pairs and were given two pictures of the same place, but at different tides. After the lesson was complete, she expressed that it was “one of the best lessons so far” (Sandy: Observation 3, Post-Observation Interview), and her PCK map is consistent with her statement.

Another item to note is that when given autonomy in the creation and implementation of the lessons, in addition to a higher quality PCK in general, there were more connections displayed with her orientations to teaching science, which were rarely exhibited during the
semester, as discussed above. For instance, at the beginning of the semester, Sandy expressed her orientations to teaching science, by saying that a best day would be “teaching formally, in a lecture style, for no more than 10 or 15 minutes . . . . and to really make it collaborative where students are responding to what they are learning throughout the lecture” (Sandy: Pre-OTS Interview).

This is exactly what occurred in the lesson in observation #3 as Sandy provided a formal lesson, provided by the PLT, for a short period of time and afterward gave students the opportunity to collaborate and apply what they learned through the lecture by completing the high and low tide activity she created. She also encouraged her students to “think during the activity” (Sandy: Observation #3, Field Notes), which was consistent with her views to focus on conceptual learning. She also enjoyed the autonomy given in the lesson as well by saying, “While planning that lesson, I really enjoyed the flexibility I had to come up with fun ways for the kids to participate. I personally loved the activity near the end of the lesson about creating their own adapted creature to survive in the tidal regions” (Sandy: Post-Semester Informal Interview).

Table 4.3 provides an overview of all lessons observed and reveals how autonomy in creating and implementing at least part of the lesson impacted Sandy’s PCK. The number of PCK episodes and the number of connections remained relatively low regardless of who taught the lesson; however, as seen in observation #3, when Sandy was given more autonomy in the lesson by creating the activity, the number of PCK episodes and connections were the highest for the whole semester. In observation #2, Sandy was also given the opportunity to create a worksheet to go along with the lesson; however, this worksheet was a part of a lesson called the Oreo lab, where students demonstrated the
phases of the moon by adjusting the frosting on Oreo cookies to match the phases of the moon and placing them in order. This is an activity that Sandy disagreed with doing. Sandy wanted the students to understand the phases of the moon, and she did not feel as if the Oreo lab would achieve this because it was more of a demonstration (Sandy: Observation #2, Post-Observation). Therefore, she was unable to create or implement her lesson as she wished.
Table 4.3.

*An Overview of Sandy’s Observations & PCK*

<table>
<thead>
<tr>
<th>PST lead or Co-Teaching</th>
<th>Lessons/ Materials Source</th>
<th>Observation</th>
<th>Topic</th>
<th>Number of PCK Episodes</th>
<th>Number of Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Teaching</td>
<td>PLT created lesson</td>
<td># 7</td>
<td>The Periodic Table</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>ST did not create any materials</td>
<td># 1</td>
<td>What Makes Earth Habitable?</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>PLT changed lesson last minute</td>
<td># 4</td>
<td>Planet Project</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PLT created lesson</td>
<td># 5</td>
<td>Triple Beam Balance Lesson</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>PLT created lesson</td>
<td># 6</td>
<td>Physical and Chemical Changes</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>PLT created lesson</td>
<td># 8</td>
<td>Elements, Compounds, Mixtures</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>PLT changed last minute.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PLT created lesson</td>
<td># 9</td>
<td>Waves</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td></td>
<td></td>
<td>7 lessons</td>
<td>18</td>
</tr>
<tr>
<td>PST lead</td>
<td>CT chose the lab, but the PST wanted to do something different.</td>
<td>#2</td>
<td>Moon Phases and Oreo Lab</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>ST created a worksheet to go along with the CT chosen lab.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tides</td>
<td>#3</td>
<td>ST created the activity for after the PLT created lesson she adjusted.</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td></td>
<td></td>
<td>2 lessons</td>
<td>6</td>
</tr>
</tbody>
</table>
In contrast to being given autonomy in the creation and implementation of the lessons, for example, at the end of the semester in observation #9, Sandy displayed the fewest number of PCK episodes and connections which could be attributed to the lack of autonomy given. This observation occurred after a holiday break and was one of the last lessons that Sandy assisted Dana with before she moved back into her observation phase in full swing. Sandy had spent that morning observing other teachers’ classrooms, but still helped teach classes for Dana at the end of the day. She was given very little control over the lesson; however, with what freedom she did have, she adjusted Dana’s lesson based on what she knew Dana completed in previous classes. Based on of what Dana stated about students’ difficulties with the lesson in earlier classes, Sandy tweaked it during the classes that she taught. She expressed:

She [Dana] said that they were having trouble deciding how high to go because they weren’t understanding that those were axes, not just a line. So, I tweaked that, and she also did draw out a graph with them, and 1st and 2nd period didn’t get it. They just saw a picture and were left to do it. It was too difficult for them to understand.

That’s why I also tweaked that and did the graph with them. (Sandy: Observation #9, Post-Observation Interview)

Therefore, although she made some connections between KSU and KISR centered on what Dana stated occurred in previous classes, she was unable to make connections with other components during this particular lesson because she did not have the opportunity to create and implement the lesson as she wished.

This feature was also evident in the low number of PCK episodes and connections in observation #8, another lesson that Sandy and Dana were co-teaching. In one particular
lesson about elements, compounds, and mixtures, Dana taught the majority of the class with a PLT-created lesson consisting of a lecture, a video, and a worksheet. Sandy’s portion of teaching was to review the worksheet at the end of the class (Sandy: Observation 8, Field Notes). She expressed knowledge of individual components of PCK such as KSU as seen in the statement below:

They were having trouble understanding that it could only be applied to mixtures.
They thought it had to be applied to both element, mixture, and compounds, and they have trouble distinguishing between compound and mixture because they think if it can be mixed uniformly then it must be one or the other. (Sandy: Observation 8, Post-Observation Interview)

In addition, she displayed knowledge with the component KSC, saying, “I think boiling point, melting point, freezing point, are a part of the curriculum” (Sandy: Observation #8, Post-Observation Interview); however, there was no interaction with other components during this lesson, which could be attributed to the lack of autonomy in creating the lesson. Consequently, it is apparent that observation #3 stands out above the rest due to the autonomy given in the lesson creation and implementation; in the other lessons in which she had less control, the quality of PCK she was able to express was much weaker.

**Rachel’s PCK Characteristics throughout the Student Teaching Experience**

Analysis of the PCK maps that were constructed from observations, interviews, and other documents also revealed four salient features of Rachel’s PCK over the course of her student teaching experience: (1) Rachel’s PCK was inconsistent, weak, and showed little growth over time; (2) Rachel’s PCK showed minimal changes between class periods; (3) KSU played a role in her PCK reflection-on-action; and (4) Rachel’s orientations to teaching
science (OTS) changed only slightly; however, these were not reflected greatly in her lessons.

**Assertion 1: Rachel’s PCK was inconsistent, weak, and showed little growth over time.** Figure 4.6 displays Rachel’s PCK maps over her student teaching semester as presented in chronological order. As shown in Figure 4.6, Rachel’s PCK was inconsistent throughout the semester as seen in the number of PCK episodes and connections. Throughout the semester, the number of Rachel’s PCK episodes ranged from two to five, with the highest number of PCK episodes occurring during observation #7 and the lowest number appearing during observation #2. Also, the number of connections ranged from one to eight with the highest number of connections occurring in observation #6 and the lowest number appearing during observation #2.

![Figure 4.6: PCK maps for Rachel over student teaching](image)

*Figure 4.6. PCK maps for Rachel over student teaching.* (PE: Number of PCK Episodes and C: Number of Connections)
In order to discern whether Rachel’s PCK was different for various instructional modes, her PCK maps were examined additionally in terms of two modes: lectures and labs/activities. Figure 4.7 shows the PCK maps of 5 lectures, and Figure 4.8 displays PCK maps of 4 labs/activities.

**Figure 4.7.** PCK maps for Rachel’s lectures over the student teaching semester. (PE: Number of PCK Episodes and C: Number of Connections)

**Figure 4.8.** PCK maps for Rachel's labs/activities over the student teaching semester. (PE: Number of PCK Episodes and C: Number of Connections)
In both lecture and labs, there were no specific patterns nor positive growth in Rachel’s PCK over time. There was no consistent growth in PCK episodes or connections; in addition, when looking at individual components, no patterns were observed over the semester. For example, in lectures, Rachel displayed an interaction between the OTS and KISR components in observation #4; however, this interaction did not appear in any other observations. Another example was seen in Rachel’s lab/activities, where an interaction between the components KSU and KAs appeared in observation #7 but did not appear in any other observations. In addition, it is interesting to note that in her labs/activities, Rachel’s KISR grew by one connection from observation #3 and observation #5 to observation #7 and observation #8; however, this growth was weak and insignificant.

To explore Rachel’s PCK further, data collected with the PCK Evidence Reporting Table were analyzed in terms of the number of individual subcomponents of each PCK component labeled from observations over time. As with Sandy, it can be noted that some PCK components of Rachel’s remained on the higher and lower end of the spectrum; however, there were no patterns in growth, and PCK among individual components remained weak, which is consistent with other data sources. For example, KISR remained on the higher end of the spectrum, yet did not grow over time. KSC remained fairly constant showing one subcomponent per observation. The data uncovered from this tool can be seen in Figure 4.9 below and Table 4.4. The analysis of this data was compatible with the results from the PCK maps, confirming that Rachel’s PCK was inconsistent, weak, and changed little over time.
Figure 4.9. The presence of PCK subcomponents in Rachel’s observations.
Table 4.4.

*Number of Subcomponents Present in Rachel’s PCK over Student Teaching*

<table>
<thead>
<tr>
<th>Observation #</th>
<th>OTS</th>
<th>KSU</th>
<th>KSC</th>
<th>KAs</th>
<th>KISR</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
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<td>1</td>
<td>1</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>1</td>
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<td>6</td>
<td>14</td>
</tr>
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<td>6</td>
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<td>9</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>TOTAL</td>
<td>21</td>
<td>13</td>
<td>8</td>
<td>12</td>
<td>46</td>
<td></td>
</tr>
</tbody>
</table>

OTS: Orientation to Teaching Science, KSU: Knowledge of Students Understanding in Science, KAs: Knowledge of Students’ Understanding in Science, KISR: Knowledge of Instructional Strategies
Figure 4.10. Rachel’s PCK maps of two back-to-back class periods per observation day. (PE: Number of PCK Episodes and C: Number of Connections)
Assertion 2: Rachel’s PCK showed minimal changes between class periods.

Towards the middle of the semester, as Rachel began to teach multiple classes, I had the opportunity to view two classes back-to-back on a few occasions, during one observation day. The PCK maps for all of the lessons that were viewed twice in one day are seen in Figure 4.10. The PCK maps created for each individual lesson expressed minimal changes from one class period to the other. Two of the observations showed no change at all, three showed negative PCK changes, and two showed positive changes, although they were minimal. The only observations that showed positive changes in Rachel’s PCK were observations #4 and #5. Through careful analysis, it was determined that this was due to reflection-on-action, with a focus on knowledge of students’ understanding, which is discussed in more detail in the next section.

Assertion 3: KSU played a role in Rachel’s PCK reflection-on-action. As discussed in Assertion 2 above, on the majority of the days that Rachel was observed, I was able to capture data from two individual class periods. There were minimal changes in Rachel’s lessons and PCK between classes; however, when a positive change occurred, it was due to Rachel’s KSU, which allowed her to alter her instructional strategies for the next class. At the beginning of the semester, after observation #1, Rachel stated, “It was interesting to see how you have to adjust based on classes . . . When you add in math, they are not used to so much math” (Rachel: Observation #1, Post-Observation Interview). I was only able to observe one class period during observation #1 because Rachel was “phasing-in” and only teaching part-time; however, it was apparent that even at the beginning, Rachel realized that she must adjust her lessons in order to accommodate the diverse needs of different students in each of her classes.
The PCK maps for observation #4a and observation #4b, Valence Shell Electron Pair Repulsion (VSEPR) Model Lesson, can be seen in Figure 4.10. In this lesson, in groups, students created 3D models of 2 different covalent bonds, and then drew a Lewis structure for each of them as a warm-up. Based on students’ different needs in her second period, she made a small change in her third period as she described below:

Something that I changed between my second and third period was in my second period, I noticed that a lot of them were just making flat structures based on their Lewis structures, so I just tried to prompt them better in my third period by saying remember, you are thinking about it as 3 dimensions. Don't just recreate the same flat structure that you did with your Lewis structure. (Rachel: Observation #4, Post-Observation Interview)

Although adjusting her instructions is just a small change, Rachel was sure to adjust her lesson based on her students’ needs in the previous class. This is an example of reflection-on-action, where she reflected after the class was over, and then took a course of action to solve a problem.

This was seen again in the next lesson, observations #5a and #5b (see Figure 4.10), the VSEPR Theory Lab. In this lesson, students continued to work on creating 3-D representations of covalent compounds, along with completing a chart by filling out the Lewis structure, steric number, lone pairs, etc. As with observation #4, Rachel made a change in 3rd period based on of student needs that arose in 2nd period; however, in this particular instance, Rachel asked her CT, Mary, what she should do to address the issue as seen in her statement below:
Some of them still wanted to, you know, use the specific colors for the specific compounds which was making it difficult for them to get the right shape, and it was a big problem in 2nd period, and I sort of asked Mary a better way to tell them . . . she said just to emphasize that all they needed to worry about what to have the right shape, and I think that definitely helped in 3rd period. (Rachel: Observation #5, Post-Observation Interview)

Rachel realized there was an issue after the fact, demonstrating reflection-on-action, and knew she needed to solve the problem. In this case, she asked Mary for assistance in order to make changes, which helped her next class with the lesson. It is important to note that KSU played a role in PCK reflection-on-action. Overall, throughout the semester, Rachel’s PCK changed very minimally between classes, but when a forward change occurred, as seen in observations #4 and #5, KSU was central to the change. The influence of the CT is discussed in the next section.

Assertion 4: Rachel’s orientations to teaching science (OTS) changed only slightly; however, were not reflected greatly in her lessons. Figure 4.6 shows that Rachel’s orientations to teaching science (OTS) were not greatly reflected in her lessons and only made connections with other components in two out of the nine observations, observations #4 and #5. At the beginning of the semester, when asked about teacher and student roles, Rachel described her thoughts as indicated in the following statement:

I think that the teacher should mainly serve as the facilitator for learning like, I think they should give the students the tools they need to learn and have students actively participate in their own learning. Like it differs based on what you are teaching, like sometimes being the role of the facilitator is largest and you need to be more of a
presence and sometimes you can step back and let students figure things out on their own. (Rachel: Pre-OTS Interview)

At the end of the semester, Rachel described these roles very similarly:

I think the teacher's role is to sort of introduce the concept and sort of facilitate the students learning about that except either through showing them examples of real life or having them do a lab or just like giving them the skills they need to work similar problems. (Rachel: Post-OTS Interview)

Her OTS beliefs about student and teacher roles differed from Mary’s only slightly, who also believed that students should learn by doing, and that the teacher should facilitate learning. A summary of both Rachel and Mary’s views on teacher and student roles are seen in Table 4.5, and key points are highlighted in red.

Table 4.5.

Rachel and Mary’s (her CT) Views on Student and Teacher Roles at the Beginning and End of the Semester

<table>
<thead>
<tr>
<th></th>
<th>Rachel</th>
<th>Mary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-OTS Interview</td>
<td>“I think that the teacher should mainly serve as the facilitator for learning like, I think they should give the students the tools they need to learn and have students actively participate in their own learning. Like it differs based on what you are teaching, like sometimes being the role of the facilitator is largest and you need to be more of a presence and sometimes you can step back and let students figure things out on their own.”</td>
<td>“I think that the students have a greater responsibility than they want to have. Students learn by doing . . . showing them how to do it, directing them to the resources to how to learn it, or setting up labs so they can do it. Science is all about doing it to learn.”</td>
</tr>
<tr>
<td>Post-OTS Interview</td>
<td>“I think the teacher's role is to sort of introduce the concept and sort of facilitate the students learning about that except either through showing them examples of real life or having them do a lab or just like giving them the skills they need to work similar problems.”</td>
<td>“. . . facilitate learning, not to be the deliverer of the content, to guide the students to learn the content…sometimes we do a lab where we discover it.”</td>
</tr>
</tbody>
</table>
Rachel’s OTS also appeared in observation #5, the VSEPR Theory Lab. As mentioned previously, students created 3-D representations of covalent compounds, while completing a worksheet by filling out a table. Her instructions to the class were as follows:

You are going to be showing me the 3-D representation of each of the compounds. I will stamp the sheet, like, when you show me “this is number one” . . . . Make sure you are telling me which model is for each number. If it gets a little crowded, so if you want to work at a table, that’s fine, but you can also work in groups of 2-3.

(Rachel: Observation #5, Field Notes)

So, as students created their models, they went to Rachel to have her look over their work as a facilitator. If students were heading in the wrong direction, she would correct them. When asked about what type of discussions she had with them, she said:

Like some of them would have the right idea, like they have the right atom and the right number of bonds, but the way they organized the bonds made the shape wrong, so I would say you have the wrong shape. You need to fix your shape. Sometimes I was looking, and I saw they had the wrong Lewis structure, and that’s what was causing them to have the wrong shape, so I would tell them that they needed to look at their Lewis structure again. (Rachel: Observation #5, Post-Observation Interview)

This was consistent with what she believed the teacher and student roles to be at the beginning of the semester. Students were to figure things out on their own with Rachel available to individual students as a facilitator. The two lessons in which OTS was reflected were given in the middle of the semester, whereas her particular OTS was not completely displayed in lessons before and after this.
Commonalities between the Characteristics of Sandy and Rachel’s PCK

Analysis through the constant comparative method revealed three common features of both Sandy’s and Rachel’s PCK over the student teaching experience: (a) the quality of PCK was weak and unstable throughout the semester; (b) the PSTs’ PCK made minimal changes between class periods; and (c) the PSTs’ OTS were not greatly reflected in their lessons.

Assertion 1: The quality of PCK was weak and unstable throughout the semester. For both MAT PSTs, the quality of their PCK was both weak and unstable throughout the semester, as seen in Figure 4.1 and Figure 4.6. There were moments of small growth at different points in the semester with both Sandy and Rachel; however, any growth in PCK episodes and connections was of little account. In addition, there were no patterns of growth with any particular component as with the interactions among components, as seen in Figures 4.4 and 4.9. You can also see the comparison of both Sandy and Rachel’s PCK in Table 4.6.
Table 4.6.

Comparison of Sandy and Rachel’s PCK

<table>
<thead>
<tr>
<th>Observation #</th>
<th>Sandy’s PCK Episodes</th>
<th>Rachel’s PCK Episodes</th>
<th>Sandy’s PCK Connections</th>
<th>Rachel’s PCK Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Average</td>
<td>2.7</td>
<td>2.8</td>
<td>5.2</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Assertion 2: The PSTs’ PCK made minimal changes between class periods. In addition to minimal changes to their PCK throughout the semester, there was also very little change in their PCK between class periods as seen in Table 4.7 below and in Figures 4.5 and 4.10. The majority of the lessons that they taught remained the same from class period to class period or actually expressed negative changes. Also, they did not make many positive changes based on what they may have learned in the previous classes.
Table 4.7.

**PCK Episodes and Connection Changes in Back-to-Back Classes**

<table>
<thead>
<tr>
<th>Sandy’s Back-to-Back Observations</th>
<th>PCK Episode Changes</th>
<th>Number of Connection Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>#5</td>
<td>+1</td>
<td>-1</td>
</tr>
<tr>
<td>#6</td>
<td>+2</td>
<td>2</td>
</tr>
<tr>
<td>#7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>#8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>#9</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rachel’s Back-to-Back Observations</th>
<th>PCK Episode Changes</th>
<th>Number of Connection Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>#4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>#5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>#6</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>#7</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>#8</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>#9</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Assertion 3: The PSTs’ OTS were not greatly reflected in their lessons.** Another commonality between both MAT PSTs is that their OTS rarely impacted their PCK and were not reflected greatly in their lessons. Overall, both Sandy and Rachel maintained similar orientations throughout the semester as seen in Tables 4.2 and 4.5; however, the orientations that they stated that they believed did not align with all of their lessons. For both MAT PSTs, their orientations were reflected in select lessons, yet it was not consistent throughout the semester as seen in Figure 4.11 below.
Figure 4.11. Sandy and Rachel’s OTS interactions throughout the semester.

RQ 2: The Impact of the Cooperating Teacher on their MAT Preservice Teachers’ Pedagogical Content Knowledge throughout Student Teaching

Through analysis using the constant comparative method, three salient features of how the CT impacted their MAT PST’s PCK throughout the student teaching experience were revealed: (a) regardless of the instruction types (i.e., co-teaching or PST lead teaching) the CTs did not greatly impact PSTs’ PCK during the Implementation Stage; (b) the influence of the CT on PCK usually happened during the planning and reflection phase of instruction; and (c) avoiding “offending” the CT was a priority in PSTs’ instructional decision making that hindered the development of PCK.
Assertion 1: Regardless of the Instruction Types (i.e., co-teaching or PST lead teaching) the CTs did not Greatly Impact PSTs’ PCK during the Implementation Stage

As seen in Table 4.1, whether Sandy’s lesson implementation was conducted through co-teaching or her teaching, the number of Sandy’s PCK episodes and connections did not vary. As a reminder, PCK can be measured in three instructional phases: planning, implementation, and reflection. In Sandy’s case, how the lesson was implemented did not have much influence on her PCK. For example, for the two instances that she was leading the lesson, there was a large gap in PCK episodes and connections, such that in observation #2, there were 2 PCK episodes and 4 connections, and in the next lesson, observation #3, where Sandy also mainly taught, there were 4 PCK episodes and 12 connections. The same pattern occurred with lessons that were co-taught. Sandy’s PCK was very inconsistent, and it did not matter who implemented the lesson that was already planned.

For each lesson, the plan was set beforehand; therefore, it did not matter who, the PST or if they were co-teaching, delivered the information. For example, in observation #2, Sandy expressed that she “didn’t think they had enough time to go over the lesson, but Dana insisted on doing it today” (Sandy: Observation #2, Pre-Observation Interview). The plan was in place, and they were going to go over eclipses and phases of the moon; and although it was not what Sandy wanted to do, Dana sat in the back of the room and allowed Sandy to teach. The planning was already complete, so the implementation phase did not impact Sandy’s PCK. This can also be seen in observation #5. Sandy stated beforehand that the lesson was already created by the PLT, and in this lesson, Sandy and Dana were going to co-teach. Dana and Sandy went through the motions of delivering the content that was provided
in the lesson PowerPoint. Planning and reflection possibly could play more of a role in the PCK than how it is implemented, and this will be discussed in the next section.

As seen in Table 4.8, as with Sandy, how the lesson was implemented, whether she led or co-taught, did not impact Rachel’s PCK. For example, in observation #3 and observation #4, Rachel began to take over and teach the lessons, in both of those lessons her PCK episodes are weak as they were with co-teaching before then. When looking through the table, it is obvious that there is not much change with Rachel’s PCK throughout the semester, no matter who implemented the lesson.

Table 4.8.

An Overview of Rachel’s Observations & PCK

<table>
<thead>
<tr>
<th>PST lead or Co-Teaching</th>
<th>Number of PCK Episodes</th>
<th>Number of Connections</th>
<th>Topic</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Teaching</td>
<td>2</td>
<td>2</td>
<td>Fission and Fusion Lecture</td>
<td>#1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>Energy Levels Lesson</td>
<td>#2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>Thermodynamics Lesson</td>
<td>#9</td>
</tr>
<tr>
<td>Subtotal</td>
<td>5</td>
<td>7</td>
<td></td>
<td>3 lessons</td>
</tr>
<tr>
<td>PST lead</td>
<td>3</td>
<td>3</td>
<td>Water in a Hydrate Lab</td>
<td>#3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>VSEPR Model Lesson</td>
<td>#4</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3</td>
<td>VSEPR Theory Lab</td>
<td>#5</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>8</td>
<td>Molar Conversions</td>
<td>#6</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6</td>
<td>Limited and Excess Reactants</td>
<td>#7</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td>Boyle’s Law Lab</td>
<td>#8</td>
</tr>
<tr>
<td>Subtotal</td>
<td>21</td>
<td>26</td>
<td></td>
<td>6 lessons</td>
</tr>
</tbody>
</table>
The lessons were planned beforehand. For example, in observation #9, a lesson that was co-taught by Mary and Rachel, Rachel built upon Mary’s lessons, and although they co-taught, the number of PCK episodes and connections did not show much difference than those in the previous lessons. The CT obviously impacted PCK, whether positively or negatively; however, this did not seem to greatly occur during the implementation stage. As mentioned, the planning and reflection phases of PCK could possibly make more of an impact on PCK, which is discussed in the next section.

**Assertion 2: The Influence of the CT on PCK Usually Happened During the Planning and Reflection Phase of Instruction**

As seen above, for both cases, during the implementation stage, the CT did not have much influence on their PST’s PCK; however, having autonomy in planning in addition to the reflection piece after the observation seemed to have more of an impact on their PCK. For example, in Sandy’s case, the planning stage had more of an impact on her PCK. When given autonomy in planning and creating the lessons, her PCK episodes and connections were higher as seen in Table 4.3.

Rachel’s reflection on the lessons led to a small growth in her PCK towards the end of the semester based on reflection advice from Mary. As seen in Figure 4.7, something led to a slight increase, although still weak, in Rachel’s PCK around observation #6. After careful analysis, it was apparent that Mary provided more emphasis on Rachel’s reflections after her lessons. Mary felt that her role with Rachel was to “try to guide her and help her to see and help her to reflect” (Mary - Post-CT/PST Relationship Interview). After observation #4, Mary expressed her concern in the area of reflection stating that she should “not only [be] looking for things that have gone bad, but . . . looking for things that went well” (Mary -
Mid-Term Evaluation Interview). She told Rachel to “just be very proactive in your reflection, because that’s how you’re going to grow” (Mary - Mid-Term Evaluation Interview). Two observations after this point in time, Rachel’s PCK episodes and connections increased slightly. Rachel expressed that Mary played a role in her desire to improve:

I would say that I definitely was more reflective of my teaching and asked for feedback from Mary after the 4th week when she brought it up at the evaluation. I think talking with her and reflecting with her helped me to be more proactive as a teacher and definitely improved! (Rachel: Post-Semester Informal Interview)

She realized that reflection in her lessons was one of her struggles, and she began to act to improve her teaching with Mary as her guide:

After the first few units, I think I definitely became more proactive in my approach and if I was trying something new or if I could tell I was struggling I would ask her . . and if I ever asked her how she taught a particular lesson and offered a different way to teach it, she would give her opinion on if she thought it would work or if there might be some difficulties. (Rachel: Post-Semester Informal Interview)

If there was something she was struggling with understanding or needed help in making a decision, at this point in the semester, she was more reflective and approached things differently.

One of the PCK components that stood out after this conversation was knowledge of assessment of science learning, which did not make any connections with any other components until after the advice to reflect, and then was seen through the rest of the semester. Rachel expressed an “a-ha” moment towards the end of the semester, asking for
advice from Mary in regard to assessment. At the beginning of the semester, she tried to do something different from Mary as stated below:

The first unit I taught when they did their assessment, they didn’t do very well, and I was trying not to give quizzes a lot, because that’s what she did, and I was just trying to do something different, so I didn’t give them any quizzes except one at the beginning for their polyatomic ions unit. (Rachel: Post-CT/PLT Interview)

After reflection, she knew that something needed to change because her students were not doing well on the tests, so she decided to ask Mary for advice. She said:

So, I asked Mary if she usually gives a quiz on that, and she said yeah, she would usually give a quiz for that. I think that might have helped, because I realized that’s where a lot of the complications are. At least for the bigger objectives that were more important, I tried to incorporate more assessments for the students, and then when I started doing that the tests grades got better and better. (Rachel: Post-CT/PLT Interview)

Based on reflection and advice from Mary, Rachel expressed that this was an “a-ha” moment in the semester, and it was apparent when reviewing her PCK, and the assessment piece became more of a priority.

**Assertion 3: Avoiding “Offending” the Cooperating Teacher was a Priority in PSTs’ Instructional Decision Making that Hindered the Development of PCK**

As seen in Table 4.1, throughout the semester, it was apparent that Sandy did not have a lot of influence on how the lessons were to be taught. In Sandy’s particular case, she had another influence impacting these decisions, other than her CT. Her PLT had a major impact on what lessons were to be taught and how they were going to be taught. As
discussed earlier, Sandy was not given much autonomy in creating and implementing the lessons that she needed to teach, and because of this, Sandy was sure to do what was expected to avoid offending anyone throughout the semester. She really respected Dana, who was very supportive, so many times, Sandy would go with the flow, even if it did not align with her teaching beliefs. She said, “I can go with the flow. I do not want to create a disturbance” (Sandy: Informal Interview 4). For example, during her lesson in observation #2, the Oreo lab, although Sandy mainly taught this lesson, she implemented it the way that Dana and her PLT wished. Sandy did not feel as if the Oreo lab really helped her students conceptually understand the phases of the moon, as students were just modeling the phases; however, Dana really wanted her students to complete the Oreo lab, so this is what was done.

The majority of disturbance that Sandy tried to avoid arose from the PLT, which was who Dana followed. For example, during observation #8, as Dana was teaching the lesson, Sandy shared with the researcher that both she and Dana were frustrated with an assessment that the PLT created. She showed me the test and explained that the questions that she marked out were worded incorrectly, or that were not even covered. Sandy relied on Dana to help with these disturbances with her PLT in order to make the right decisions in the classroom. To do this, Sandy continually was sure to ask Dana’s permission to do things as well as to clarify any questions or decisions with her. Sandy felt that Dana was the ultimate decision-maker in the classroom, so she was sure to run things by her. For example, for a review day, Sandy said:

I asked permission from [Dana] if I could do a class review of big conceptual misunderstandings . . . and so that was an opportunity for instruction. I know, at the
same time, if there are any big misconceptions about matter, I have to do something outside of predetermined quizzes. (Sandy: Informal Interview 6)

Any idea that Sandy wanted to implement in the class was best run by Dana first to avoid stepping on any toes. For example, she said of Dana, “I told her Monday that I would give her hard copies for her to review and give me feedback on, especially what she feels comfortable in allowing me to do, with what the PLT’s expectations are” (Sandy: Informal Interview #2).

Sandy sometimes adjusted her lessons to avoid offending or creating a disturbance, mainly with the PLT, which is something that the CT showed her how to do. After the first observation, Sandy stated that her “CT will adjust the shard [PLT] PowerPoint as need by making a copy” (Sandy: Observation #1, Post-Observation). Sandy followed suit by saying, I think for my edTPA PowerPoints, I went ahead and re-laid out the slides, or reworded the slides, and took out stuff that isn’t necessary. Tides are really hard for me to break down into easy to understand wording and was a difficult challenge. I may highlight or change the color of the words so it’s not overwhelming to the students. (Sandy: Observation #1, Post-Observation)

Her CT allowed her to see that she could adjust her lessons and her instructional strategies, to a certain degree, to fit her and her students’ needs. This had an impact on her instruction throughout the semester; however, disagreements still arose during the implementation phase when they were co-teaching. For example, after observation #5, Sandy expressed that she was not able to underline items in the lesson as she wished: So, over the last couple of days, we've been having lectures, and nothing is underlined, and the other thing is just for peace of mind. If nothing is underlined, they
are like “what are we copying?” I answered this four times for just one slide in literally a minute and a half. (Sandy: Observation #5, Post-Observation Interview)

Sandy expressed in the beginning that she wanted items underlined or highlighted so that the students would not be overwhelmed, but this did not always occur because Sandy said that she ultimately doesn’t “make the final decisions” (Sandy: Post-CT/PST Relationship Interview).

Rachel was given more of the “reins” in the planning and implementation phases, but this still did not seem to have much of an impact in her PCK and decision-making as compared to her reflection phase. Even though she was given more freedom in creating the lesson, her planning decisions were impacted by the avoidance of offending Mary. At the beginning of the semester, Rachel explained her perspective:

Yea, and I don’t want to [teach in a different way than the CT]. I don’t know how to suggest things to her that are super different without, I don’t know if it would offend her. But I don’t want to say, well I want to do it completely differently. Clearly, she will see that I am trying to do it differently, and I don’t want her to think that it's because I don’t like the way she does it. (Rachel: Pre-CT/PST Relationship Interview)

Throughout the semester, Rachel continued to use Mary’s lessons and plans for the majority of the time, although she did make changes. However, it was apparent that she did not make any drastic changes to do something completely different.

For example, in observations #3 and #7, she used a lab that Mary created. In observations #4 and #6, she used Mary’s lessons, but built upon them, as she explained, “I asked her what she usually does when she teaches it, and she had the idea that she makes the
structures with the modeling kits, and I liked the idea, so I kept that part, but I came up with
the idea that they each make their own Lewis structure” (Rachel: Observation #3, Post-
Observation Interview). In observation #6, she made similar decisions by stating, “I had
observed her teaching this lesson last semester when I was doing an observation, and I
remember that she started with one-step and worked her way to two, but I didn’t actually talk
to her or ask to see her lesson plan” (Rachel: Observation #6, Post-Observation Interview).

For both Sandy and Rachel, not wanting to step on anyone's toes or offend them in
any way was a huge priority that influenced their decision-making in the planning stage,
which could have hindered the development of their PCK. Both PSTs noted that they were
unable to make the decisions as they really wanted to.

Chapter Summary

Overall, the results show that both Sandy’s and Rachel’s PCK was weak and unstable
throughout the semester, and when there was a small amount of growth, it was due to
autonomy for Sandy, and due to the influence of her cooperating teaching for Rachel. For
both Sandy and Rachel, whether the PST taught the lesson alone or co-taught, there was no
impact on their PCK. Chapter five includes a discussion of these results as well as
implications for teacher education programs, cooperating teachers, and science education
researchers.
CHAPTER FIVE
DISCUSSION

The purpose of this study was to examine the characteristics of MAT PSTs’ PCK over the course of their student teaching experience and the influence of their CTs on their PCK. This chapter discusses the results of the study, describes the limitations, and then suggests implications for future research, teacher education programs, and cooperating teachers.

MAT Preservice Teachers’ PCK during Student Teaching

The results of this study showed that the MAT PSTs’ PCK remained weak and inconsistent throughout the semester, that their PCK showed minimal changes from class period to class period, and that their orientations to teaching science (OTS) were rarely displayed throughout the student teaching semester. Teaching experience has been proven to be a critical factor in developing PCK (Evens, Elen, & Depaepe, 2015; Grossman, 1990; van Driel et al., 2002), and student teaching allows for PSTs to obtain that teaching experience that they have most likely never had before. It allows them to apply both the pedagogical and content knowledge that they obtained during their coursework to an actual classroom context (American Association of Colleges for Teacher Education [AECTE], 2010) by which they are likely to improve PCK. However, in both Sandy’s and Rachel’s cases, their PCK remained relatively weak throughout the whole semester, with brief spurts of growth, yet very minimal growth. This is consistent with previous research findings that PSTs’ PCK is not very robust (Loughran et al., 2004; van Driel et al., 1998), and they have a very superficial understanding of teaching (Ayden et al., 2013; de Jong & van Driel, 2011). Although these studies mainly refer to undergraduate preservice teachers, these
results still align with the MAT students in this study. Research has suggested that having a greater subject matter knowledge (SMK) positively contributes to PCK (van Driel et al., 2002), and MAT students may be expected to have a greater SMK since they have already obtained an undergraduate degree; however, this was not the case for Sandy and Rachel. Although Sandy and Rachel may have had greater SMK due to their undergraduate degrees in science, the SMK obtained from their degrees was different from the topics they were teaching. Sandy’s undergraduate degree is in public health, but she taught topics such as Earth Science and Physical Science, and Rachel’s undergraduate degree is in animal science with a minor in genetics, yet she taught Chemistry. Many scholars have noted the topic-specific nature of PCK (Grossman, 1990; Park & Oliver, 2008; van Driel et al., 1998); consequently, in these two cases, the fact that they were MAT students with previous undergraduate science degrees did not make a difference, and their insubstantial PCK aligned more with the research findings about undergraduate PSTs.

Along with being weak throughout the semester, Sandy’s and Rachel’s PCK was inconsistent throughout the semester with no particular patterns of growth. This aligns with previous research that suggests PSTs’ PCK is not robust, yet it does develop (van Driel et al, 1998) and is non-linear, complex, and unstable (Kind, 2009; Lederman et al., 1994). Both Sandy and Rachel exhibited a very complex PCK throughout the semester, with changes occurring positively, negatively, and neutrally got various reasons, and still some that are unknown. Kind (2009) states that “greater consistency [in PCK] may be achieved from understanding more precisely the factors and influences that help produce effective science teachers” (p. 170). There were factors that emerged from this study that contributed to their PCK. For Sandy, during the observation of the class in which she was given autonomy, the
number of PCK episodes and connections were at their highest. Her PCK may have been more consistent or may have developed over time if given the autonomy to teach the lessons as she wished much of the semester. Rachel’s PCK showed growth when she began to reflect on her lessons because of the influence of her CT (discussed below). If she had focused on reflection from the beginning of the semester, her PCK might have displayed positive growth or at least remained stable throughout the student teaching semester.

Another salient feature of Sandy’s and Rachel’s PCK is that their PCK exhibited minimal changes from one class period to the next. Research has suggested that preservice teachers’ PCK is non-linear and complex (Kind, 2009; Lederman et al., 1994; Park & Oliver, 2008), which was the case with Sandy and Rachel’s PCK between class periods. Adjustments made to lessons result from reflection-in-action and reflection-on-action (Park & Oliver, 2008), and when there were positive changes in their PCK between class periods, this resulted from reflection-on-action. For example, in Rachel’s case, there were a few instances that she adjusted her directions and instructional strategies for the next class period based on the student difficulties that arose from the previous class; however, for the majority of her lessons, her PCK between classes actually exhibited a small negative change. This could be due to a number of factors that are still unknown, but the negative changes that occurred dealt with interactions with KSU. Research has suggested that differentiated instruction to adjust to student needs and a higher PCK are related (Park & Oliver, 2008; Rock & Wilson, 2005; Voogt et al., 2011). It could be assumed that the students in each class are very diverse, with particular needs. The first class could have exhibited greater needs than those in the next class period; therefore, the interactions among KSU and other components may have not been as visible because Rachel did not need to adjust for students in her first class.
Sandy also exhibited negative changes in the interactions among components, but this only occurred in one of her lessons. The majority of her lessons that were observed back-to-back resulted in zero changes in the number of PCK episodes and the number of connections. This could be attributed to the strict structure that the PLT provided. Since Sandy, for the majority of the time, did not have autonomy in creating the lessons, discussed in more detail below, she conducted her lessons as she was told to do, and this resulted in minimal changes in her PCK from between class periods.

The last salient feature that Sandy and Rachel shared with their PCK is that their orientations to teaching science were not greatly reflected in their lessons. Both MAT PSTs and their beliefs about science teaching did not always appear in their lessons. As seen in Sandy’s case, what she taught mainly was controlled by her PLT, and she may have not have been given the opportunity to implement her thoughts about her “best day,” the goals of science teaching, or beliefs about the teacher and student roles due to the constraints in her autonomy. Rachel seems to have been given more opportunity to choose her lessons, but she mainly chose to model and build upon her CT’s lessons.

In addition, in both cases, the PSTs’ approach to teaching lessons was more of a didactic style lesson rather than a constructivist and student-centered approach. Previous research has revealed that, in regard to the integration of PCK components, teachers who believe and teach with more of a student-centered approach make more connections among components than those who teach with a didactic approach (Padilla & van Driel, 2011; Park & Chen, 2012). A strong connection between a didactic OTS and KISR can block the connection with other components (Park & Chen, 2012) while a more student-centered approach allows for more connections because other items, such as student understanding,
are considered when designing the lesson, but can also be specific to the teacher involved (Aydin et al., 2015). Sandy’s and Rachel’s beliefs did not align with their implementation of the lesson, and a more didactic approach was taken in the majority of the lessons. For example, Sandy wanted to cut back her lecture time and allow students more time to apply what they learned. However, her PLT and CT had such a huge role in planning, which is discussed in the section below, that her implementation of the lesson was based on what they wanted. She was not able to display her true orientations to teaching science in each lesson due to this constraint. Rachel thought that the role of the teacher was to mainly be a facilitator, and although she was given more autonomy in creating her lessons, she still chose to build on her CT’s lessons and did not want to offend anyone by doing something different. This could have impacted how her OTS was implemented into her lessons.

### The Influence of the CT on their MAT PST’s PCK

The results of this study demonstrated that regardless of the instruction types (i.e., co-teaching or PST lead teaching), the CT did not significantly impact their PST’s PCK. As mentioned, PCK should be measured throughout all three instructional stages: planning, implementation, and reflection (Park et al., 2011). In both Sandy’s and Rachel’s cases, the implementation stage did not seem to have much of an impact on their PCK. The second salient feature that emerged was that the influence of the CT on PCK usually occurred during the planning and reflection phases, as opposed to the implementation phase. In Rachel’s case, her CT had a positive influence on her PCK, and although it was minimal, there was a progressive change towards the end of the semester. Nilsson and Vikström’s (2015) study of in-service science teachers’ PCK revealed that after reflecting on their own teaching, they saw changes in the lesson structure and how the material was presented to students. Rachel’s
CT noticed that reflection was a weakness for her, so after some encouragement to begin reflecting on her lessons, Rachel began to make more connections among the components of her PCK. Reflection has been proven to be critical in a teacher’s PCK development and emerges as an effective source for PCK (Evens, Elen, & Depaepe, 2015; Kenney, Shoffner, & Norris, 2013). The importance of reflection on PCK has been discussed by many researchers. Van Driel and Berry (2012) mentioned the importance of allowing teachers to try innovative ideas and then to reflect upon their experiences. Brownlee, Purdie, and Boulton Lewis (2001) explained how a focus on reflection helped develop preservice teachers’ epistemological beliefs. Evens, Elen, and Depaepe (2015) explain how reflection is a main source for PCK for preservice teachers. Mary realized that Rachel had a weakness in reflecting upon her lessons, so having a CT that recognized the importance of reflection in her practice was valuable for Rachel in her PCK development. For Sandy, the autonomy given in the planning stage resulted in growth in her PCK. Aydin and colleagues (2013) determined that using the CoRes intervention for lesson planning resulted in the PSTs’ PCK developing with all components integrated. In their study, the preservice teachers were given this lesson planning tool to use in addition to giving them an understanding of planning, and this resulted in their PCK development (Aydin et al., 2013). Sandy’s case provides more evidence of the importance of planning stage in the development of PCK. If she was given the opportunity to play more of a role in this stage, instead of being hindered by her CT and PLT restrictions, her PCK could have shown more positive growth.

Lastly, the avoidance of “offending” the CT was a priority in the MAT PSTs’ instructional decisions, hindering the development of PCK. Preservice teachers “lack real power” (Patrick, 2013) in the student teaching classroom due to the hierarchical relationship,
which can have a negative impact on their development (Axford, 2005). Because of this, some studies have suggested that the traditional models should shift to more non-hierarchical relationships (Ambrosetti & Dekkers, 2010; Le Cornu & Ewing, 2008; Patrick, 2013). Although both PSTs claimed that their CTs were very supportive, both Sandy and Rachel did not want to step on anyone’s toes nor offend their CT by trying something different than what their CT or PLT expected, asked, or had done in the past. Rozelle and Wilson (2012) describe two types of preservice teachers: reproducers and strugglers. The reproducer tries to implement their CT’s approaches and may shift their “good teaching” practices to match their CTs. The strugglers begins as the reproducer does; however, they do not end up implementing their CT’s practices and beliefs. Due to the avoidance of “offending” the CT, both Sandy and Rachel seem to fall under the category of reproducers (Rozelle & Wilson, 2012), which leads to a more successful student teaching experience; however, in Sandy’s and Rachel’s case, it did not seem to make much of an impact on their PCK. If a PST has a CT who has poor teaching practices, and the PST chooses to mimic their CT to avoid disturbances, this could potentially hinder their PCK development along with other types of development. In Sandy’s case, avoiding “creating a disturbance” with her CT and PLT played a role in her decision making. In many cases, instead of planning the lessons as she wished, she mainly “went with the flow,” making sure not to step on anyone’s toes. This resulted in a hindrance to her PCK, similar to what Valencia and colleagues (2002) refer to as lost opportunities for learning to teach. In their study on language arts preservice teachers, they discovered that preservice teachers arrive at student teaching with a vast amount of ideas that they are eager to try, but there are few cooperating teachers that are willing to allow them to try out their new ideas. This seems to be what occurred in Sandy’s
case, and it may have not been the CT’s fault completely, yet there were restraints by another school factor, the PLT, in which all teachers in that grade level taught using the same lesson, materials, assessments, etc.

**Limitations**

At the beginning of this study, and at some times during data collection, a few limitations regarding the design were recognized. The first limitation associated with this multiple-case study design is the presence of a small sample size. Due to the small number of teachers in this study, two, it is more difficult to obtain great transferability and the findings are harder to generalize to a larger population. To combat this limitation, I aimed to provide unique cases that will contribute to special circumstances in the field. This study provided “rich, thick descriptions” in the results to aid in comparability to similar conditions (Merriam, 2009, p. 227).

The second limitation is the researcher’s role in this study as the researcher, observer, and university supervisor. As a requirement for their graduate assistantship, in addition to their role as a researcher, I served as a university supervisor for the MAT PSTs who participated in this study. This was seen as a great advantage due to my ability to create a positive rapport with participants, and I thought this was critical in order to fulfill my goals as a researcher. It was important that the participants felt comfortable to share their actual thoughts and feelings as an alternative to communicating what they believe I would like to hear (Merriam, 2009). In the role as “researcher,” I was strictly an observer, on the outside looking in, to reduce any influence and bias. In addition, at the beginning of the semester, I expressed to the PSTs and their CTs my role as researcher and how this was completely separate from my role as their university supervisor. One important item to note is that
triangulation, member checking, interrater reliability, and peer debriefing were also implemented in order to reduce bias and influence.

The third limitation is the pentagon model itself. With many PCK researchers disagreeing about the components of PCK (Park & Chen, 2012), there has not been a consensus on the best model to use in order to track a teacher’s PCK. However, this model was created through an extensive literature review and also reinforced through many empirical tests. It was built upon the works of many well-known PCK researchers including Grossman (1990), Tamir (1988), and Magnusson et al. (1999). This model is a noteworthy approach to exploring PCK in a simpler and more understandable way and through the PCK map approach, interactions among components can be visually observed.

The limitations of this study include a small sample size, multiple roles of the research, and the conceptual framework. Despite these limitations, the contributions of this study gave rise to productive results that provide implications for future research, teacher education programs, and CTs.

**Implications**

**Implications of Future Research**

This study offers implications for science education research. First of all, there is a methodological implication. This is the first time that the PCK map approach has been used to explore PCK development for PSTs throughout student teaching. Park and Chen (2012) reflect on their creation of the PCK map approach explaining that it runs the risk of oversimplifying the construct; however, it is an effective approach to quantify such a complex concept and is potentially very valuable in tracking development for PSTs. For
future research, the approach could be more refined to better track the development for different topics and even different disciplines.

Second of all, this study has implications to better track PSTs’ OTS. In this study, the OTS were only explicitly asked for at the beginning and end of the semester, with some informal comments from the PSTs throughout the semester through interviews. If PSTs’ PCK is to be further explored, with the emphasis on orientations, future researchers are advised to track orientations in each observation to track changes throughout in hopes of identifying which factors may affect their orientations, and, in turn, impact their PCK.

Third, as more studies are being conducted about PSTs’ PCK development with a focus on the interaction of components, there should continue to be a focus on which factors impact this development. In this study, results revealed that reflection and autonomy played critical roles in the progressive changes of PCK, but there are likely more factors at play that should be explored.

**Implications for Teacher Education Programs**

There is still very little known about the way that PCK develops in PSTs (Kaya, 2009), but as more research is conducted in this area, the better that teacher education programs can become in helping their PSTs develop their PCK, thus sending higher quality teachers in the classroom to positively impact student achievement. There seem to have been several factors in play that hindered the PCK development of the MAT PSTs, factors that could not be controlled such as CT and PLT planning of the lessons, not wanting to step on anyone’s toes, or not wanting to offend anyone. Making PCK explicit in the program, and making it a focus, could potentially positively impact PSTs’ PCK, even when there may be
other factors present that could hinder the development otherwise (Nilsson & Vikström, 2015).

If developing PCK is a goal of the student teaching experience, PSTs should know what to look for and reflect on even if they are using the CT and PLT’s lesson plans or building upon them. As mentioned, reflection has been proven to be critical in PCK development, so if PSTs are exposed to PCK and how to reflect upon it, they will know what to look for and reflect on, even when put in situations beyond their control. In a perfect world, PSTs would be placed with CTs who allow their PSTs to try out their own ideas, make their own mistakes, and work to better their teaching because of learning from the mistakes, but this is not always the case. It may not be that the CT is unwilling to allow their PST to try out new things, but they may be looking at the bigger picture. They are the teacher of their students (Clarke, Triggs, & Nielson, 2014) and are ultimately responsible for the success of their student teacher mentees, which could, in turn, result in less autonomy for the preservice teacher.

As with making PCK more explicit, teacher education programs should also put more emphasis on the reflection piece as it has been proven critical in PCK development and, in Rachel’s case, made a positive difference in her PCK. At this particular university, for the MAT students, there was no seminar or class that students had to complete in conjunction with their student teaching experience, so there was no required reflection that these teachers had to complete besides any reflection given in the edTPA. Although the reflection given in the edTPA could have impacted their PCK for that particular topic, other topics throughout the semester were possibly ignored because this project was only implemented during a short portion of the semester.
**Implications for Cooperating Teachers**

This study also has implications for CTs who have PSTs in their classrooms. First of all, PSTs should be given the opportunity to have more autonomy. There are cases where this may be difficult as CTs have their own curriculum that they need to cover, and it is, ultimately, their classroom. Matkso and colleagues (2018) suggest a balance of autonomy and encouragement. Giving PSTs too much autonomy may not be an effective strategy for a CTs’ classroom; however, finding that balance could not only be critical for the development of their PCK, but also the consistency of the classroom.

In addition, there are implications for CTs to focus on reflection. There are several studies that show the importance of reflection in both in-service and preservice teacher development (Davis, Petish, & Smithey, 2014), but this has not been explored greatly in the area of PCK. If teacher education programs could assist CTs in understanding PCK development, this could aid CTs to focus on reflection with their PSTs.

**Chapter Summary**

This chapter discussed the results of the study, described the limitations, and provided implications for future research, teacher education programs, and cooperating teachers. The results from this study provide powerful insights to what factors impact the progressive changes in MAT PSTs’ PCK and also provide implications for future research and directions science education researchers can take to build upon this study.
REFERENCES


American Association for the Advancement of Science (AAAS) (1993). *Benchmarks for scientific literacy*. Washington, DC: AAAS.


APPENDICES
Appendix A: PCK Evidence Reporting Table

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<th>Orientations in Teaching Science (Teacher Beliefs)</th>
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Types of Assessment:
- Diagnostic
- Formative
- Summative

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Appendix B: Clarifying Definitions for the PCK Evidence Reporting Table

**Orientations to Teaching Science (OTS)**

From: Magnusson et al. (1999)

“Goal of Teaching Science”

**Process:** The teacher strives towards developing students’ science process skills.

**Academic Rigor:** The teacher focuses on developing a particular body of knowledge.

**Conceptual Change:** The teacher challenges students to change their previous way of thinking.

**Didactic:** The teacher transmits facts to students and they receive the information.

**Activity-Driven:** The teacher allows students to work with hands-on experiences.

**Discovery:** The teacher provides opportunities to learn science concepts by discovery them on their own.

**Project-Based Science:** The teacher allows students to work with real-world problems to create solutions.

**Inquiry:** The teacher allows students to learn science through investigation.

**Guided Inquiry:** The teacher provides guidance for students to investigate a topic, focusing on higher-order thinking skills.

From: Luft and Roehrig (2007)

“Teacher Beliefs”

**Traditional:** The teacher focuses on transmitting facts to students.

**Instructive:** The teacher focuses on providing experiences for students, yet it is still teacher-centered.
Transitional: The teachers focuses on student/teacher relationships.

Responsive: The teacher focuses on collaboration and feedback.

Reform-Based: The teacher focuses on mediating student thinking to reform and develop their knowledge.

**Knowledge of Students’ Understanding (KSU)**

**Misconceptions**: The teacher is aware of student conceptions of particular topics that are not correct.

**Learning Difficulty**: The teacher is aware of his/her students with diversity in ability.

**Motivation/Interest**: The teacher is aware of his/her students’ motivation and interest in the topic.

**Need**: The teacher is aware of his/her students’ deficits in specific skills or particular timely needs.

**Diversity**: The teacher is aware of his/her students’ linguistic, ethnicity, and cultural diversity.

**Background**: The teacher is aware of his/her students’ prior knowledge background.

**Knowledge of Curriculum (KSC)**

**From: Grossman (1990)**

**Knowledge of Vertical Curriculum**: The teacher has knowledge of what students should have learned in previous grade levels or what they will learn in future grade levels.

**Knowledge of Horizontal Curriculum**: The teacher possesses knowledge of the state and local goals for the particular grade level teachers are teaching.
Curricular Saliency: (Geddis et al., 1993) – The teacher understands the tension between “covering the curriculum” and ‘teaching for understanding’.

Knowledge of Assessment (KAs):

Diagnostic: The teacher understands pre-assessment methods.

Formative: The teacher understands how to monitor student achievement and understanding in process.

Summative: The teacher knows how to observe student achievement and understanding at the end of an instructional unit.

Knowledge of Instructional Strategies and Representations (KISR)

Types of Questioning

From: Martens (1999)

Recall/Factual: The teacher asks students to recall facts.

Attention-focusing: The teacher asks students to focus their attention to particular situations to answer questions.

Problem-posing: The teacher proposes a problem for students to solve.

Action: The teacher asks questions that require students to take action in order to answer.

Reasoning: The teacher asks questions that require students to think on their experiences.

Comparison: The teacher asks questions that allows students to compare and contrast items.
Appendix C: Pre- and Post-Observation Interview Questions

Modified from Sickel and Friedrichsen (2017)

**Pre-Observation Interview**

1) For the lesson you planned for today, what will you and your students be doing?
2) Do you expect your students to have any difficulties with the material?

**Post-Observation Interview**

1) Did the lessons achieve the purpose you intended in regard to the curriculum? [KSC]
2) Tell me about the students in this class. How do you think they did with the material? How do you know? [KSU, KA]
3) Tell me about _____________ strategy. Why did you decide to use that? [KISR]
4) How would you improve this lesson to make it your “best day” [OTS]
5) Where did you get your teaching materials from?
Appendix D: Interview Questions for CT-PST Interaction Interview

Modified from O’Brian, Stoner, Appel, & House (2017)

PST

1. What is your role as a preservice teacher during this field experience?
2. What do you think is the most important factor in your learning as a preservice teacher?
3. Describe your relationship with your cooperating teacher.
4. How has this experience affected you?

CT

1. What do you think is the most important factor in your preservice teacher’s learning during this initial field experience?
2. What is your role regarding your preservice teacher?
3. Describe your relationship with your preservice teacher.
4. How has this experience affected you?
Appendix E: Interview Questions for Orientations to Teaching Science (OTS)

Modified from Sickel and Friedrichsen (2017)

1) Describe what makes it a “best day” for you.

2) How do these lessons that you have taught compare to your “best day” description?

Now consider a typical day of teaching science.

3) What is the teacher’s role in a typical science lesson?

4) What is the students’ role in a typical science lesson?
Appendix F: Example of a PCK Episode

Teacher: Rachel

Day/Month/Year: 9/21/18

Lesson: Observation 2: Energy Level

Description of the Episode

During the lesson, Rachel was at the front of the room working on energy level problems on the board. She would ask the students about a particular element, and then work it out (the electron configuration) on the board. Examples included carbon and lead. After working out problems on the board, Rachel asked if students wanted more examples. They did, so she completed an example with radium, but this time, she let students try it themselves first. After she went over the problem as a class, she asked if students wanted her to do more examples, and the students said yes. She allowed students to work out the electron configuration of radium before going over the problem. (Rachel - Observation 2 - Field Notes)

Evidence of the Presence of the PCK Components Identified in the Episode

- “Do you want to do another example?...students YES...so she went over another one, allowing students to try it themselves first. Atomic number 55”. (KISR, KSU) (Rachel - Observation 2 - Field Notes)
- Once student finishes, ST allows him to write his answer on the board. “Are you confident with that?” “You should be because it is right.”...so does everyone’s match [students]. Do you want more examples? Ok...we’ll do one more...then we are going to learn an easier way of writing it (KISR, KSU) (Rachel - Observation 2 - Field Notes).
- Yes, to an extent, mainly because this particular class has struggled. They tend to be slower to grasp thing, they did better than I thought. This is material that is brand new, so we talked about the atom and nucleus, but we added to it. I like how they recognized that they needed more have. (KSU, KISR) (Rachel - Observation 2 - Post Observation Interview).

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<thead>
<tr>
<th>Components Integrated in the Episode</th>
<th>PCK Map of the Episode</th>
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