CHALLENGES PRE-SERVICE SCIENCE TEACHERS FACE WHEN IMPLEMENTING A 5E INQUIRY MODEL OF INSTRUCTION

by

RAMYA KRISHNA ENUGU

Bachelor of Pharmacy, 2009
Jawaharlal Nehru Technological University
Hyderabad, India

Submitted to the Graduate Faculty of the
College of Education
Texas Christian University
in partial fulfillment of the requirements
for the degree of

Master of Education

May, 2016

DEDICATION

This is dedicated to my parents (Swaroopa and Venkat Reddy), my husband (Krishna), and my son (Shreyank) whose love, affection, and encouragement motivate me to work with great focus and achieve my goals.

ACKNOWLEDGEMENTS

I owe great gratitude to Dr. Hayat Hokayem for her support and encouragement throughout the completion of my thesis. As the chair of my thesis committee, she guided on every step and steered me in the right direction. Without her guidance this thesis would have not been possible.

I would like to thank my committee members Dr. Molly Weinburgh and Dr. Sarah Quebec-Fuentes, for agreeing to be on the committee and providing their insights throughout the process. I appreciate their time and feedback.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abstract

CHALLENGES PRE-SERVICE SCIENCE TEACHERS FACE WHEN IMPLEMENTING A 5E INQUIRY MODEL OF INSTRUCTION

by Ramya Krishna Enugu, M. Ed., 2016
College of Education
Texas Christian University

Thesis Advisor: Dr. Hayat Hokayem, Assistant Professor of Science Education

Pre-service science teachers (PSTs) trying to implement a 5E inquiry model into their classroom face many challenges. This study examined those challenges and the PSTs' perspective on how to overcome them. The data sample was 55 PSTs enrolled into two sections of a science methods course in a private university in North Texas. The data sources consisted of inquiry-based lesson plans, PST interviews, peer teaching observational notes, and field notes to investigate those challenges. The data were coded through designed rubrics for lesson plans and peer teaching sessions and were analyzed using constant comparative method. All data were triangulated to establish validity and reliability. The results of this study showed that PSTs faced several challenges regarding the content and method. The content related challenges were difficulty with *explain* and *elaborate* phases of the 5E. The method related challenges were managing the time to teach the 5E model, and mapping the lesson to the different parts of the 5E model. The results also showed several solutions such as having solid science content through engaging in different experiences, and having more practice with the 5E lesson planning. This study has implications for the teacher education programs to prepare teacher candidates with strong content knowledge, and to design successful interactions of PSTs with in-service cooperating teachers as mentors.

Chapter 1

Introduction

Recently, as part of the field experience in a science methods course for secondary teachers, I started observing an in-service middle school science teacher. She was in her fourth year of teaching seventh grade science. During the seven weeks of my observation, I noticed her struggles with students' behavioral problems and academic performance. I also noticed that she was facing difficulties while teaching certain topics. The in-service teacher mentioned that, even as a pre-service teacher (PST), she faced many challenges while implementing inquiry-based science lessons. Some of the challenges she mentioned were planning, implementing, and assessing students' content knowledge. In addition, she reported facing challenges with time and classroom management. These conversations with an in-service teacher motivated me to further investigate the challenges PSTs face, their perspective regarding challenges of using inquiry in science teaching, and possible solutions.

Rationale of the Study

Previous research indicates that PSTs develop an ability to teach inquiry if they are prepared and supported in their teacher education programs. For example, Crawford (1999) concludes that PSTs, if supported adequately in their teacher education programs, can establish inquiry-based classrooms without much struggle. At the same time, exploration of PSTs' views about science, and teaching science, can help them in preparing for and setting up the inquiry-based instruction in their classrooms. Creating opportunities for PSTs to observe inquiry-based classrooms, engaging them in investigations, preparing them in writing, and implementing lesson plans help PSTs to apply inquiry in their future science teaching.

Similarly, Fazio, Melville, and Bartley (2010) stated that involving PSTs in science investigations and placing them in inquiry-based classrooms encourages PSTs to teach inquiry in their classrooms. Preparing PSTs to use recent teaching practices such as modeling and argumentation as recommended by the latest science framework (National Research Council, 2012) builds their confidence to experiment with non-traditional instruction. Fazio, Melville, and Bartley indicated that PSTs learn different ways of implementing inquiry to teaching science while observing their cooperative teachers during the practicum.

In another study, McDonnough and Matkins (2010) indicated that if given an opportunity to participate in field experience/practicum along with a science methods course in teacher education programs, PSTs will show greater understanding of research-based teaching practices. Providing PSTs an opportunity to practice various instructional methods and giving timely feedback regarding their performance encourages PSTs to implement inquiry-based teaching. Similarly, Bhattacharyya, Volk, and Lumpe (2009) found a cyclic relationship between the ability to maintain good communication with students, aspiration for personal growth, and excellent subject knowledge. PSTs can develop the ability to teach science using inquiry in their field/student teaching experiences, and thus be prepared to implement inquiry-based lessons as in-service teachers.

The aforementioned examples from past research indicate the necessity of supporting PSTs to teach inquiry. However, despite the success of some preparation programs, using inquiry as a teaching method still poses many challenges. For example, Yoon, Joung, and Kim (2011) posited that despite taking several science content courses during teacher education programs, many PSTs still lack the necessary science content knowledge, which is one of the challenges they face while using inquiry as a teaching method. They argued that PSTs gain complete science content knowledge only while they analyze students' work, and teach science in the classroom. Therefore, before preparing and supporting PSTs to teach inquiry, there is a necessity to thoroughly understand the challenges they face, and this is why I pose the following research questions:

1. What are the challenges faced by PSTs while implementing the 5E inquiry model in their science teaching?
2. What solutions do PSTs propose that can alleviate these challenges?

Chapter 2

Conceptual Framework

Hein (1991) defined constructivism as the philosophy of how a person learns by constructing knowledge from his or her experience. In the process of constructing knowledge, one passes through a series of events such as questioning himself/herself and discovering answers, as well as evaluating those answers. When a person tries to learn something new, he/she matches the new information to existing thoughts and decides whether to change previous thoughts or ignore the new information (“Workshop: Constructivism as a Paradigm”, n.d). The theory of constructivism stipulates that the learners’ minds are not empty vessels, and that when they approach learning, they already have their own ideas and experiences that guide the learning process. Driver, Guesne, and Tiberghien (1985) state:

> Students’ minds are not blank slates able to receive instruction in a neutral way; on the contrary, students approach experiences presented in science classes with previously acquired notions and these influence what is learnt from new experiences in a number of ways (p. 4)

Driver et al. (1985) discussed how children’s ability to learn depends on the ideas which they have from a young age, and the context or environment in which they are learning. Researchers indicated that many cognitive models are based on the theory that information is stored in memory in the form of elements or group of elements called “schemes” or “schemas” (Driver et al., 1985). Thus, learning happens when schemas are formed in the mind. Similar to this view, McLeod (2015) discussed Piaget’s views on schemas as the “basic building blocks of intelligent behavior” (p. 1), which means that schemas are mental representations used to comprehend and react to situations of the world.

Another researcher, Meador (1988) discussed Jean Piaget's intelligence model and its two main aspects: quality of thought and mental functioning. Piaget's intelligence model attempts to explain how learning takes place. He posits that a person grasps ideas from his/her experiences and passes through the existing "mental structures." The mental functioning aspect of Piaget's model explains how learning takes place independently of a person's developmental stage. Mental functioning explains the process of learning in four steps called *Assimilation, Disequilibration, Accommodation,* and *Organization*. In the first step, *Assimilation,* students imbibe ideas from their experiences and pass them through the "mental structures." In the second step, *Disequilibration*, if the existing mental structures (schemas) explain the person's received ideas, then he /she is said to be in equilibrium. If the mental structures cannot articulate the grasped ideas, then that person is said to be "disequilibrated." In the third step, *Accommodation*, students are expected to receive new concepts and reinvent the mental structures. In the final step, *Organization,* students relate and establish their mental structures.

Piaget's model delineates how knowledge is constructed and has implications of how learning takes place. Rather than thinking of learning as filling up "empty slate" minds, learning is thought of as active engagement in the process of constructing knowledge. One way to achieve learning by constructing knowledge through active engagement is through the learning cycle. The learning cycle is a three-phase inquiry model which encourages students to understand a scientific concept on their own by exploring and applying what they understand to new circumstances (Lawson, Abraham, & Renner, 1989; Walbert, n.d.). The learning cycle is also described as a significant and flexible method of instruction where a person constructs knowledge steadily and naturally. Learning happens during the implementation of the three phases of the learning cycle which are exploration, concept construction, and concept application (Lawson, Abraham &

Renner, 1989). Therefore, the learning cycle is an example of how a learner can be active, which aligns with constructivism.

Constructivism is the conceptual framework that has implications for teaching as well. Taking the learning cycle as a model for learning, the 5E inquiry model is a teaching model that aligns with constructivism. Bybee et al. (2006) indicated that 5E instructional model has been used in designing Biological Science Curriculum Standards (BSCS) curriculum materials since late 1980s. He posited that the 5E model has a specific teaching order, which can be used to teach a specific lesson, a particular unit or a complete course. At the same time, the BSCS 5E Instructional Model plays an important role in development of curricular materials in science classrooms (Bybee et al., 2006). Most importantly 5E model allows students to construct knowledge from their experiences which aligns with Piaget's constructivist learning theory.

Figure 1 shows the general conceptual framework that guides my research study, after which I elaborate on each of the learning cycles, the 5E model and how they relate to constructivism.

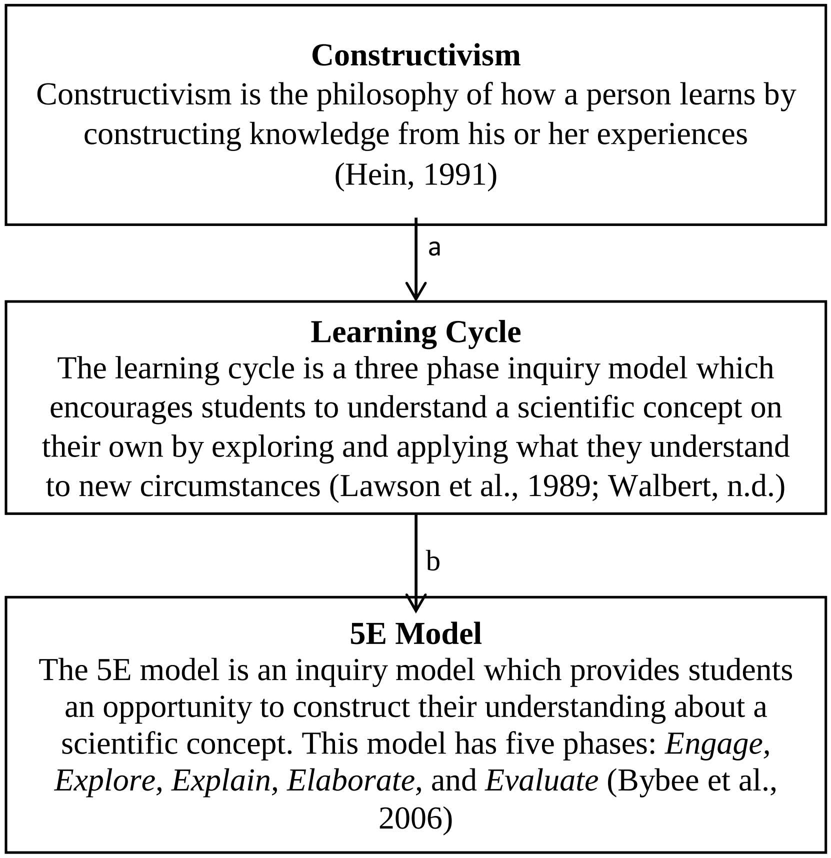

Figure 1. Relationship between constructivism, learning cycle, and 5E model. a = Is the basis for the learning cycle; b = Is implemented through the 5E.

Learning Cycle and Constructivism

Atkin and Karplus (1962) proposed the learning cycle model in the early 1960's which was based on Piaget's work. Later, Karplus, Their, Lawson, Knoll, and Montgomery (1967) indicated that the learning cycle was first used as the model for planning lessons in the Science Curriculum Improvement Study (SCIS). The three phases of the learning cycle are: *Exploration*, *Concept Introduction,* and *Concept Application*. In the *Exploration* phase, students explore the scientific phenomenon, gather information, and develop their own theories. In the *Concept Introduction* phase, teachers introduce concepts to students, and the students share their observations and ideas from the previous exploration phase. In the final, *Concept Application* phase, students apply their own developed theories from the previous phases to new scenarios (Bybee et al. 2006)

Meador (1988) indicated that the learning cycle is based on mental functioning, which is one of the main aspects of Piaget's intelligence model. He described phases of the learning cycle as they relate to the four steps of mental functioning. The relationship between the four steps of mental functioning and the learning cycle phases are: The *Assimilation* step of mental functioning relates to the *Exploration* phase of learning cycle because students explore the scientific content and grasp ideas from their experiences. In the learning cycle, a person becomes "disequilibrated" sometimes in the exploration phase when he/she is subjected to new circumstances. There is a chance of being re-equilibrated, by accommodating new ideas. The *Accommodation* step is related to the *Concept Introduction* phase of the learning cycle. In both of these phases, students are expected to share their observations from previous phases and accommodate new concepts. Students change or redefine existing schemas. Finally, the *Organization* step and the *Concept Application* phase are related because students relate and apply their own theories to new scenarios.

5E Inquiry Model and Constructivism

One way to implement the learning cycle is through the 5E teaching inquiry model. This model can also be linked to Piaget's intelligence model and learning cycle as the 5E inquiry model encourages students to construct knowledge using their prior knowledge and experiences. The 5E inquiry model provides students with an opportunity to construct their own understanding of a scientific concept.

Bybee et al. (2006) indicated that the learning cycle was modified into the 5E instructional model, which is used for inquiry-based science teaching. In addition to the *exploration*, *concept* *introduction*, and *concept application* phases of learning cycle, Bybee et al. added two additional phases which are the *engage* and *evaluate.* Therefore, the 5E model has five phases: *Engage, Explore, Explain, Elaborate,* and *Evaluate*. The three phases of the learning cycle *(Exploration* phase*, Concept Introduction* phase, and *Concept Application* phase) align with *explore, explain,* and *elaborate* phases of the 5E model respectively. The initial *engage* phase is a new phase during which teachers assess students for their prior knowledge and generate students' interest concerning the topic at hand. In the second *explore* phase, teachers ask provoking questions which encourage students to discover. In the process of finding answers to their questions, students get involved in various hands-on and minds-on activities. This phase is akin to the *exploration* phase of the learning cycle when students are encouraged to explore. In the third *explain* phase, teachers encourage students to explain the concept and relate it to the big ideas they learnt from the *exploration* phase. Students are asked to discuss the results of their investigations and together with the teacher provide the necessary explanation regarding the topic. This phase is similar to the *concept introduction* phase of the learning cycle when students are provided with opportunities to explain their ideas. The fourth *elaborate* phase is when teachers provide an opportunity for the students to make connections and apply their newly acquired knowledge to solve problems in real-life situations. This phase aligns with the *concept application* phase of the learning cycle, as they both encourage students to make connections and apply what they have learnt. The final *evaluate* phase is a new phase during which teachers assess students to check their understanding of the concepts and evaluate their progress. Table 1 shows the relationship of the learning cycle to the 5E model and to constructivism.

Table 1

Relation between mental functioning of Piaget's intelligence model, learning cycle and 5E model

Steps of Mental Functioning	Phases of Learning cycle	Phases of 5E model
Assimilation**:** similar to → Students imbibe ideas from experience and pass them through mental structures (Meador, 1988) (similar to → Explain)	***Exploration phase*****:** similar to → Students explore scientific phenomenon, gather information and develop their own theories (Lawson et al., 1989; Walbert, n.d.).	***Engage*** **(new phase):** Teachers assess students for their prior knowledge and generate students' interest concerning the topic they teach. ***Explore*****:** Teachers ask provoking questions which encourages students to explore. In the process of finding answers to their questions, students get involved in various hands-on/ minds-on activities.
Disequilibrium**:** Students are not clear about meaning of some data, it does not fit mental structures (Meador, 1988)	Disequilibration may or may not occur in the exploration phase (Meador, 1988)	
Accommodation**:** similar to → Students are expected to accommodate new concepts, change and reinvent mental structures (Meador, 1988)	***Concept Introduction*** **phase:** similar to → Students share their observations and ideas from exploration phase. Teachers use visual aids to develop the concept (Lawson et al., 1989; Walbert, n.d.).	***Explain*****:** Teachers encourage students to explain the big ideas they learnt from the exploration phase. Students are asked to discuss the results of their investigations and teachers provide the necessary explanation regarding the topic.[a]
Organization**:** similar to → Students relate and organize mental structures (Meador, 1988)	***Concept Application*** **phase:** similar to → Students apply their own theories developed in previous phases to new scenarios (Walbert, n.d.).	***Elaborate*****:** Teachers provide an opportunity for the students to make connections and apply their newly acquired knowledge to solve problems in real-life situations. ***Evaluate*** **(new phase):** Teachers assess students to check their understanding of the concepts and evaluate their progress

[a] Even though the explanation is aligned with concept introduction which gives the impression that it is solely related to accommodation, I clarify that explanation can also be related to assimilation. For example, if a person knows what a mammal is and is shown a cat, he or she may assimilate it to mammal and could explain the characteristics which make it a mammal.

In summation, the 5E model takes a constructivist perspective to teaching, in which knowledge is constructed using the five phases of the 5E model. The teacher facilitates the students' exploration and promotes new patterns of thinking. Students direct and learn from their own explorations which allow them to construct scientific knowledge based on their prior knowledge and experience.

Next, I present the literature about the challenges for PSTs in general and about using inquiry in particular. Then, I present method for investigating my research questions about the challenges teachers face when using the 5E inquiry model.

Literature Review

Generally, novices in all arenas come across unique experiences and face numerous challenges as part of their progress. Similarly, in the teaching profession, novices and PSTs face many challenges in the process of coping with K-12 classrooms. In this review, challenges of PSTs are categorized based on two concepts: 1) the general challenges that PSTs face and, 2) the specific challenges that PSTs face when teaching inquiry.

General Challenges that PSTs Face

This section of the review focuses on the general challenges of PSTs. For example, Ferber and Nillas (2010) conducted a study to observe the challenges and successes faced by PSTs during their student teaching experiences. Some of the challenges were interactions between teacher candidates and their cooperative teachers, time and classroom management issues, and lack of feedback from cooperative teachers. Ferber and Nillas recommended that teacher education programs prepare PSTs to deal with K-12 classroom situations and create opportunities to interact with the cooperative teachers.

Sadler (2006) focused on other challenges, particularly the reflections of PSTs regarding their student teaching experiences. Some of the challenges reported were the difficulty in managing students with special needs and completion of all the documentation (recording progress, maintaining and organizing assignments, and classroom management paper work) apart from teaching. In order to minimize the challenges of PSTs, he suggested preparing PSTs to manage students with special needs, and make them aware of the required documentation. Along with the aforementioned challenges, the researcher reiterated the common challenges of time, classroom management, and lack of constructive feedback from cooperative teachers. Student teachers in this study found teacher education programs accountable for their inability to deal with the challenges aforementioned. The authors recommended that teacher education programs should encourage PSTs to use classroom management strategies and create more opportunities for them to interact with cooperative teachers.

Similarly, Fantilli and McDougall (2009) investigated novice teachers' experiences as they were promoted from pre-service to in-service teachers (beginning teachers). In addition to the common challenges of classroom management, lack of experience communicating with parents, and inadequate classroom resources were additional challenges for novice teachers. The solutions proposed by Fantilli and McDougall were large-scale involvement of the school administration, district boards, and the government, who can effectively support the novice teachers.

Unlike the arguments made by previous studies, Davis, Petish, and Smithey (2006) argue that teacher education programs are not always the reason for the challenges PSTs face. Davis et al. (2006) conducted a thorough literature review related to the challenges of new science teachers. The review showed five issues related to the understanding of the content and disciplines of science, the learners, the learning environments, the instruction, and professionalism. They concluded that new science teachers face difficulty to meet all the high expectations set by national standards. The challenges they faced could not always be overcome by reforming teacher education programs, and there is need for some challenges to be addressed at the institutional or policy level.

Those general challenges stand in the way of teaching excellence. One can think that those challenges lead to the continuation of traditional teaching where teachers disseminate information. Moreover, there are specific challenges for teaching science through inquiry.

Defining Inquiry

As shown in the previous sections, many challenges are common to all teachers. However, when teaching science, more specific challenges exist. In this part of the review, I first present various definitions of inquiry, and the definition that guides my study. Later in this section, I present the challenges for teaching inquiry.

Inquiry is defined in many ways. For example, the National Science Education Standards (NSES) defines inquiry as a “multifaceted activity that varies in structure and guidance” (NRC, 1996). *Inquiry* involves observation, questioning, investigation, analysis of data, and predictions regarding the results (NRC, 2000).

Abd-El-Khalick et al. (2002) defined inquiry as “means and as an ends” (p. 398). They identified that “inquiry as means” refers to the instructional approach envisioned to benefit students’ understanding of science content, and “inquiry as ends” refers to the instructional outcome which helps students learn doing scientific inquiry and understand the nature of science.

NSES recommend the implementation of inquiry and defined *inquiry* as “the activities in which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (NRC, 1996, p. 23). This definition includes inquiry as a "means" and as an "end" in Abd El Khalick et al. (2002) terms. Other researchers such as Stoddart, Abrams, Gasper, and Canaday (2000) described inquiry as "giving the students experience with the development of research questions and testable hypotheses" (p. 1222). Researchers have stated that inquiry "involves the pursuit of open-ended questions and is driven by questions generated by the learners" (Edelson, Gordin & Pea, 1999, p. 393). Yet others defined inquiry as "raising an investigable question, developing methods to answer that question, carrying out those methods, analyzing the data, and reporting the findings and making conclusions" (Akerson & McDuffie, 2002, p. 3). For this study, I use *inquiry* to refer to the "means" of instruction which align with the conceptual frameworks of constructivism, the learning cycle and the 5E model.

Inquiry in science requires a range of "cognitive, social, and physical" practices (NRC, 2012). Inquiry-based science teaching is important for in-depth understanding of science content. In inquiry-based science teaching, students are expected to engage in the practice of constructing scientific knowledge rather than rote memorization of science concepts. The 5E model is an instructional method that uses inquiry to teach students about science content (NRC, 2012).

Recent research has shown that the 5E instructional model is effective in improving the student learning outcomes. For example, Wilson, Taylor, Kowalski, and Carlson (2010) confirmed that students showed better understanding of the subject matter and increased interest in learning science. Similarly, Stotter and Gillon (2010) indicated that in an inquiry-based classroom, students question the teacher or themselves regarding the science content. Questioning is a basic and important component to construct knowledge. Stotter and Gillon (2010) posit that the implementation of inquiry-based teaching stimulates students' interests and, in turn, supports their progress in learning the scientific concepts.

Another recent study suggests that inquiry is not always restricted to classrooms. Inquiry can be implemented outside the classrooms to make learning a better experience for students. Klien (2015) in her recent article described how the 5E inquiry model can be implemented inside as well as outside the classroom in the form of instructional games. She mentioned that instructional games engage students, stimulate them to explore, and incite thoughts and questions. She discussed two such games namely the "salmon" game and the "mating" game. Klien indicated that the two games can be best used in the *engage* phase of the 5E learning cycle. Later, certain terms and incidents related to the game can be used to elaborate on the scientific concept. By asking high-order questions in relation to the game, teachers can evaluate students' understanding.

Challenges faced by PSTs using Inquiry

Despite the importance of inquiry, many challenges stand in the way of its successful implementation. Recent research has shown that in the process of learning to teach science efficiently, PSTs find inquiry and its methods to be perplexing (e.g., Crawford 1999; Windschitl & Thompson, 2006). Novices and PSTs face challenges trying to alter or improvise the instruction in response to a learner-centered inquiry instruction and also struggle with poor content knowledge. For example, one study of an elementary PST group found that the difficulties they face are associated with pre-diagnostic assessment, choosing the appropriate mode of instruction, appropriate implementation of instruction, and improvisation when needed (Zembal-Saul, Starr, & Krajcik, 1997). Most PSTs, for example, find difficulty in linking science content knowledge with pedagogy and fail to make use of their own knowledge to improve students' learning (Ball, 2000).

Not only do American teachers face challenges with teaching inquiry, but also many international teachers as described by Abd El Khalick et al. (2002). He mentioned some of the challenges across different countries, which are as follows: 1) Absence of a clear framework for inquiry and the nature of science in the science curriculum which caused confusion for teachers in Venezuela and Lebanon, 2) More emphasis on the hands-on rather than minds-on component of inquiry in Lebanon, 3) Inquiry based laboratories which require huge financial support, proper training, and massive commitment efforts across the whole educational system in Israel, 4) Lack of proper implementation in Australia, and 5) Inclusion of large amounts of content material in Taiwan.

Past research shows that PSTs and novice teachers have different perceptions of inquiry and face many challenges while implementing inquiry-based teaching. For example, Fazio, Melville, and Bartley (2009) studied perceptions of PSTs towards inquiry-based teaching challenges, and how those perceptions were corroborated when they implemented inquiry-based teaching. Findings of the study indicated marginal resources, curriculum standards, and time management issues as some of the challenges PSTs face while implementing inquiry in their practicum. Researchers purported that learning new ideas regarding how to implement scientific inquiry might help PSTs overcome the instructional challenges. At the same time, the role of constructive feedback from cooperative teachers is crucial in supporting inquiry practices and alleviating many challenges.

In another study, Kang, Bianchini, and Kelly (2013) investigated PSTs' successes and struggles in moving from being a science student to an inquiry-oriented science teacher. They stated that "border crossing is a useful way to understand PSTs' experiences while learning to teach science as inquiry" (p. 444). The researchers expected PSTs to face difficulty in implementing science as inquiry. Thus, helping students realize that they are crossing the border from a science student role to an inquiry-oriented teacher role would support PSTs' use of inquiry.

Results of the study showed that PSTs were willing to implement science as inquiry but found difficulty in bridging their subject knowledge with pedagogy.

Schulz and Mandzuk (2005) examined how teacher candidates in their new pre-service teacher program "defined, understood, and experienced" inquiry (p. 327). PSTs found the ability to multi-task in the classroom while teaching open-ended inquiry challenging. PSTs also noticed a discrepancy between the theories they learnt in teacher education program to what in-service teachers practiced in the K-12 classrooms. Whereas the teaching method courses emphasized extensive planning, the in-service teachers were spontaneously teaching without much planning. This contradiction is yet another challenge for PSTs. Schulz and Mandzuk suggested that teacher educators should prepare teacher candidates for the practical challenges they might encounter while practicing inquiry in the field.

There was one study that recently examined challenges of using the 5E model in the classroom. Sickel and Friedrichsen (2015) conducted a study to understand how a beginning science teacher designed and taught a complete 5E unit. In the first year of her teaching, she taught an inquiry-based unit emphasizing all phases of the 5E model. She identified students having difficulty in discovering the concepts in the *"explore"* and the *"elaborate"* phases of instruction. Sickel and Friedrichsen (2015) examined how her teaching changed over the second and the third years when she moved to another school district. In the second and third years, she emphasized the *explore* phase, deemphasized the *explain* phase, and omitted the *elaborate* phase. She posited that the challenges, like time management and working with colleagues who did not share similar inquiry-based views, as reasons for not implementing all the phases of the 5E model. In addition to these challenges, students also faced problems in explaining and elaborating the concepts, which made her emphasize the *explore* phase rather than blindly explaining the concepts. She firmly believed that learning happens when students explore, discover science concepts and think critically. This case study stands as an example for beginning science teachers to use the “constructivist sequence of instruction” despite several challenges. Sickel and Friedrichsen suggested that teacher education programs need to foreground scientific inquiry and constructivism while preparing teachers. There is also need to support teacher induction programs, which promote collaboration with colleagues and encourages PSTs to implement 5E.

In contrast to other studies, Hanuscin and Lee (2008) conducted a study which showed that PSTs successfully “practiced” what was “preached” in the teacher education programs. Researchers (teacher educators) were aware of the challenges PSTs face while implementing inquiry instruction when they applied the 5E learning cycle model. The activities they developed for their own teaching using the learning cycle helped their students (PSTs) to develop a deeper understanding of ways to choose activities for their own instruction. For example, PSTs with this approach developed the skill of selecting and sequencing activities in a meaningful way for teaching inquiry. This approach helped PSTs learn effective ways to implement inquiry as they observed their teacher educators model inquiry-based instruction, minimizing the challenges associated with teaching inquiry.

Summary

Despite the success of the study (Hanuscin & Lee, 2008) in overcoming some of challenges of teaching using the 5E model, the literature aforementioned demonstrates a plethora of challenges and scarcity of offered solutions. This can be attributed to the fact that the literature does not reveal a fine-grained description of the challenges when using the 5E model. Even the study that targeted the 5E model was based on one case study with one secondary teacher. I conducted a thorough study using multiple data-sources which allowed me to better understand those challenges as well as how PST envision the solutions. The results of this study have implications for improving science teacher education in designing effective science methods courses that better support PSTs in implementing inquiry instruction.

Chapter 3

Methodology

In this chapter, I describe the research methods used in this study. I start with a description of the research design, followed by sample and setting, data sources, and finally the data analysis techniques.

Research Design

This is a qualitative research study. According to Creswell (2008) qualitative research is "a type of educational research in which the researcher relies on the views of participants, asks broad, general questions; collects data consisting largely of words (or text) from participants; describes and analyzes these words for themes; and conducts the inquiry in a subjective, biased manner" (p. 46). In this study I followed 55 PSTs through several phases of their learning to implement the 5E model. This study is designed to depict the challenges for PSTs while implementing an inquiry model, as well as their perspectives on how to overcome them.

Sample and Setting

The participants in this study were 55 PSTs who were specializing in elementary education, and were divided into two sections of the same course. These PSTs were admitted to the college of education in a private university in North Texas. They were expected to complete a science methods course for elementary education which focused on ways to implement inquiry in their science teaching. This science methods course was designed to enable the PSTs to get acquainted with various instructional strategies, classroom practices, and to build the professional knowledge base necessary for teaching science. As mentioned in the course syllabus: "This science methods course enables PSTs learn different areas of science by engaging in scientific inquiry" (Hokayem, 2014, p. 2). The course work was divided into three different parts: inquiry-based lesson planning, peer teaching, and teaching inquiry-based science lessons in the K-12 classroom. PSTs wrote lesson plans and taught to their peers in the university classrooms (peer teaching sessions) and to elementary students in the field (field teaching). They taught in pairs except for three groups of three PSTs. All this was accompanied by classroom discussion of readings about inquiry and recent science teaching practices, activities that model inquiry and its assessment, and field work that allowed PST to gets hands on experience of what was actually happening in the elementary classrooms.

At the beginning of the semester, PSTs were introduced to inquiry and the 5E inquiry model. In groups of two or three, the PSTs were expected to write 5E inquiry-based lesson plans for the peer teaching sessions and for teaching in the field. They received feedback on their lesson plans from the course instructor.

In the second part of the course, PSTs taught the 5E lessons to their peers. Peer teaching sessions helped PSTs practice instructional strategies and techniques of doing scientific inquiry. They also received feedback from the course instructor about their teaching and they had to write a reflection about their teaching.

As part of the methods course, PSTs were placed in various elementary schools across an independent school district in North Texas. Every teacher in the field (cooperating teacher) had two or three students with him/her in the elementary classroom. PSTs observed classrooms throughout one semester and finally taught 5E lessons in the field. Field teaching experience encouraged PSTs to plan, implement and analyze various instructional procedures, and also helps them to understand their role as a teacher.

Data Sources

Surveys and semi-structured interviews. Surveys and semi-structured interviews were the main data sources in this study. There were two surveys. First, PSTs were given an open-ended written pre-course survey during the first class of the course to examine their views about inquiry. Then towards the end of the course, after students had the chance to be immersed in learning and teaching using the 5E model, post-course surveys were given. Pre-course survey questions were similar to the post-course survey questions. Appendices A, and B show examples of the completed pre and post-course surveys. Towards the end of the course, out of 55 PSTs a subgroup of 15 PSTs agreed to be interviewed. Semi-structured interviews were conducted for that sub group of 15 PSTs and asked them about the challenges, advantages, and disadvantages of the 5E inquiry model. Those interviews were transcribed verbatim and compared the transcript to the audiotape. Appendix C shows example of a transcribed interview (questions and answers of the participant).

Inquiry-based lesson plans and peer teaching observations. As part of the science methods course, PSTs were asked to write inquiry-based lesson plans. It was the first time, most of the PSTs were writing a standard lesson plan or an inquiry-based lesson plan; therefore, analyzing lesson plans helped understand the challenges PSTs face while writing lesson plans, especially inquiry based ones. To design the lesson plan evaluation rubric, I asked the course instructor whether I could have a sample of anonymous lesson plans from previous years, and she provided a few samples. After studying these samples and relating them to the purpose of this study, I designed a rubric that helped with the analysis. I analyzed the lesson plans based on the lesson plan rubric, which is in Appendix E. The rubric is designed using the five phases of the 5E model. The score on the rubric categorizes PSTs performance of writing lesson plans into three levels: *low*, *medium* and *high*. A lesson plan score of 1-25 points is categorized as *low* level performance, while a score of 25-40 points is *medium* and a score of 40-50 points is *high* level performance. In addition to the above data sources, I also collected observational notes in class. I attended every class in each section and was always observing and taking notes of the PSTs during their discussions or their classroom activities. In particular, I focused on the peer-teaching sessions. I observed those sessions carefully for the difficulties PSTs face while implementing the 5E inquiry-based lesson plans in the presence of their peers. I evaluated the peer teaching sessions based on the peer teaching evaluation criteria, examples of which are in Appendix D. Based on the evaluation of the peer teaching sessions, PSTs performance in the peer teaching sessions was also categorized into three levels of performance namely *low*, *medium* and *high*. The PST scoring from 1-25 points in their peer teaching session is categorized as *low*, while 25-40 points is *medium* and 40-50 points is *high* level performance. The qualitative descriptions of *high*, *medium* and, *low* levels of performance are described in the Table 2 below:

Table 2

Qualitative Description of Levels of Performance

High (40-50 points)	**Medium (25-40 points)**	**Low (1-25 points)**
Excellent content knowledge.	Good content knowledge but having some incomplete explanations.	Poor content knowledge.
Excellent understanding of 5E inquiry model.	Good understanding of 5E inquiry model and mediocrely motivated to implement inquiry in their classrooms.	Poor understanding of 5E inquiry model and not motivated to implement inquiry in their classrooms.
Encouraging students highly to think critically through thought provoking questions.	Some encouragement of critical thinking by asking few thought provoking questions.	Fails to encourage students to think critically.
Having all the 5E phases in place.	Having most but not all of 5E phases in places.	Skipping many phases of 5E and fails in guiding students through five phases of inquiry.
Excellent classroom management practices *(This*	Good classroom management practices *(This criteria is only*	Poor classroom management practices. *(This criteria is*

criteria is only for peer teaching sessions and not for lesson plans.)	*for peer teaching sessions and not for lesson plans)*	*only for peer teaching sessions and not for lesson plans)*

Field notes. I collected field notes while observing an in-service teacher in the field. Bogdan and Bilken (2006) described field notes as “the written account of what the researcher hears, sees, experiences, and thinks in the course of collecting and reflecting on the data in a qualitative study” (p. 118). I observed an experienced in-service science teacher (7 years) teaching 6^{th} grade science and mathematics at a middle school located in North Texas. I collected notes about in-service teacher’s methods, practices, relevant conversations, and comments in the classroom. She also participated in a one -on -one discussion with me. During the discussion, I enquired about her views regarding inquiry, general challenges, inquiry related challenges, challenges she thought PSTs faced, and what solutions would she suggest to overcome those challenges. Bogdan and Bilken (2006) posited that field notes are like “maintained records” which help to track the progress of the study, and to understand how the collected data influences the researcher and the study. Field notes helped me in better understanding of the PSTs challenges, solutions and potential reasons behind the challenges. They also helped me compare the views of PST to the in-service teacher.

Data Analysis

PST interviews, inquiry-based lesson plans, peer- teaching observational notes, and field notes are the important sources of data, which helped me draw conclusions from the data. The audio-taped interviews were transcribed verbatim. I coded the data of this study by using *axial coding*. Strauss and Corbin (1990) defined *axial coding* as a set of procedures which are used for making connections between various data sources. Axial coding is a process of creating categories or themes by grouping codes (tags given to words and phrases) from data. However, as with any qualitative research, the coding is an iterative process. Even though I started with an initial coding scheme, I revised the codes depending on the empirical data and the emerging themes. This procedure aligns with Corbin and Straus's (2014) constant comparative method of examining one piece of data's relationship to another piece. In the constant comparative method, data is broken down into pieces. For example, the constant comparison of pre-course surveys and post-course surveys indicated that the PSTs implementing 5E inquiry model are facing difficulty with the time required to finish implementing the 5E lesson plan. This challenge is categorized as a theme called lesson planning using 5E model is a time consuming process. In my study, I constantly compared the data sources with each other to extract the challenges which are shown in Table 3:

Table 3

Data Analysis Table

Data sources	**Data Analytic Techniques**	**Challenges (Themes) arising as a result of the data analysis**
Pre-Course Surveys, Post-Course Surveys and Interviews	Data was coded axially and constantly compared to extract the challenges. I triangulated the data sources to establish validity.	• Lesson planning using 5E is a time consuming process.
Post course surveys and Interviews	Data was coded axially and constantly compared to extract the challenges	• Making lesson understandable to every student in the classroom is challenging • Transition between phases of the 5E based lesson is challenging
Field, Peer teaching Lesson Plans and Interviews	Data was coded axially and constantly compared to extract the challenges. I triangulated the data sources to establish validity.	• Peer teaching is challenging.
Peer Teaching Lesson Plans, Interviews and Observational notes	Data was axially coded. I compared the challenges in the field and peer teaching lesson plans to challenges while	• Maintaining stringent time slots for phases of the 5E is challenging.

from Peer Teaching Sessions	implementing the lesson plan during peer teaching using the constant comparative method. Data was triangulated for validity.	
Field, Peer Teaching lesson Plans and Observational notes collected from Peer Teaching Sessions.	Data was axially coded. I compared the challenges in the field and peer teaching lesson plans to challenges while implementing the lesson plan during peer teaching using the constant comparative method. Data was triangulated for validity.	• Writing and implementing the *explain* phase of the 5E is challenging. • Difficulty evaluating students understanding. • The *elaborate* phase of the 5E is hard to think of.

As shown in the Table 3, post-course surveys and interviews were constantly compared to each other to find that PSTs face challenges while moving from one phase of the 5E to another. These challenges are categorized as a theme called “transition between the phases of 5E based lessons.” Similarly, all data sources are compared and contrasted to extract the challenges. I categorized these challenges into different themes like peer teaching is challenging, writing and implementing the *explain* phase of the 5E is challenging, etc.

Table 3 also shows how data were triangulated to establish validity. Guion, Diehl, and McDonald (2011) posited that “triangulation is a method used by qualitative researchers to check and establish validity in their studies by analyzing a research question from multiple perspectives” (p. 1). Field lesson plans, peer teaching lesson plans, and observational notes collected from peer teaching sessions were constantly compared to find that PSTs faced challenges while explaining, evaluating and elaborating the 5E lessons. These challenges were categorized into different themes like writing and implementing the *explain* phase of the 5E is challenging, Difficulty evaluating students’ understanding, and the *elaborate* phase of the 5E is hard to think of.

Reliability. I established the reliability using triangulation of multiple data sources. The reliability check also took place with the course instructor. I coded the lesson plans, and she graded them. Any disagreement with the high, middle or low categories were resolved through discussion. We had an agreement of over 90%.

As for the peer teaching sessions, the course instructor gave grades and written feedback to the PSTs for the same criteria I was looking for. After each peer teaching session, I compared my codes with her grades. More than 90% were similar. Any disagreements were resolved through the discussion.

Chapter 4

Results

This section provides a complete presentation of the results obtained from the various data sources. The data sources were pre- and post-course surveys, field and peer teaching lesson plans, observational notes from peer teaching sessions, and semi-structured interviews. There were a total of 26 field lesson plan groups, 26 peer teaching lesson plan groups, and 26 peer teaching session groups. I conducted semi-structured interviews for a subset of 15 PSTs, transcribed verbatim, and analyzed the interviews to find out more about their perspectives regarding inquiry. I qualitatively analyzed the data to detect general patterns in the data and for an in-depth understanding of PSTs views. The results of this study showed general and specific challenges that PSTs faced while implementing the 5E inquiry model of instruction. The results also showed possible solutions for some of those challenges.

General Challenge of Classroom Management

Before addressing the specific challenges of inquiry, I present a general concern that several PSTs mentioned, the classroom management challenge. The analysis of interviews indicates that 26.66% (4) of PSTs indicate that classroom management is one of the general challenges. P-16 said “Maintaining discipline in the classroom was challenging,” P-30 said “Keeping students on task was challenging,” and P-22 said “Classroom management as a whole especially when we were using the 5E model was very challenging.” When I probed P-22 further about the challenges of classroom management while implementing the 5E inquiry model she said: “Kids are not always in the best mood I have noticed. Sometimes you walk in and you have this great lesson planned but, the kids are not up for learning and that throws everything off. It is a lot of time spent on getting the kids to listen and from there explaining things." Apparently, PSTs find classroom management to be one of the main concerns of teaching.

Inquiry Definitions by PSTs

One way to understand the students' challenges with inquiry is first to probe how they defined and talked about inquiry. After comparing the pre and post course surveys, the results showed that the PSTs had different definitions of inquiry before and after the course. Table 4 shows how students talked about inquiry in the pre-course survey.

Table 4

Definitions of Inquiry in Pre Course Survey

% of the PSTs	Name of the PSTs	Excerpts
20% **Miscellaneous definitions of inquiry**	P-49	"Inquiry is thinking about different ways to teach"
	P-16	"Inquiry is an experiment"
	P-28	"Inquiry is making inferences and acquiring new knowledge"
	P-9	"…looking into something deeply"
	P-50	"Inquiry involves probing students with questions"
60% **Inquiry is students asking questions**	P-11	"…letting students ask questions to learn"
	P-20	"…allowing students to ask questions"
20% **No idea about inquiry**	P-47	"I have no idea, I don't think I have ever learned what inquiry is."
	P-54	"An inquiry is an educated idea?"

As shown in Table 4, 20% of PSTs indicated that they did not know what inquiry is in the pre-course survey. For instance, P-47 said, “I have no idea, I don’t think I have ever learned what inquiry is.” P-54 asked, “An inquiry is an educated idea?” Out of those who knew what inquiry was, most of them indicated that the inquiry is students asking questions. For example, P-11 said that inquiry is “letting students ask questions to learn more about topics” and P-20 said inquiry is “allowing students to ask questions by engaging their curiosity”. The remaining 20% of the PSTs believed that the inquiry is teachers asking questions, doing experiments, coming up with explanation, and creating knowledge by interpretation.

Compared to their perception of inquiry prior to the taking the course, PSTs’ perceptions of inquiry in the post-course survey after taking the methods course are presented in Table 5 .

Table 5

Definitions of Inquiry in Post Course Survey

% of PSTs	**Name of the PSTs**	**Excerpts**
36.36% **Inquiry is student directed**	P-32	“In my opinion inquiry means that students are handling science, they are manipulating it, working it into new shapes and formats, integrating it into every part of their world, and discovering it in new ways”
	P-18	“Inquiry is a student’s way of seeking and exploring the concepts of the natural world, connecting personal experiences and overcome misconceptions”
27.27% **Inquiry is teacher directed**	P-47	“Inquiry is asking questions in order to gather as much information as possible”
	P-41	“Teacher asks questions to probe students and push them along without telling them the answer”
21.82% **Inquiry is investigation**	P-36	“Inquiry is the investigation of scientific concepts through observations and other forms of information”
	P- 23	“ Inquiry is the act of investigation and questioning”
14.55% **Inquiry is constructing knowledge**	P-54	“Inquiry is the process of constructing scientific knowledge”
	P-4	“is when you take the knowledge that you have and put it into practice to see if it is accurate”

During the post course surveys, PSTs had various definitions and different ideas about inquiry. All students gave a definition of inquiry. For example, as shown in Tables 4 and 5, P-47 and P-54 did not have any idea about inquiry during their pre-course surveys. However, in the post-course surveys, P-47 said, “Inquiry is asking questions in order to gather as much information as possible” and P-54 said, “Inquiry is a process of constructing scientific knowledge.” In addition to mentioning experimenting and teachers asking questions, many pre-service teachers shifted their focus to defining the inquiry in relation to students’ perspectives. In their post course surveys, 36.36% of PSTs defined inquiry as students learning from their own experiences, 27.27% of PSTs defined it as teacher directed learning by asking questions, 21.82% of PSTs defined it as a process of investigation, and 14.5% indicated the construction of knowledge. The way they talked about inquiry in the post survey was more sophisticated because they included the thinking part of constructing knowledge. Moreover, the analysis of surveys not only indicated that PSTs had various definitions for inquiry but also expressed that inquiry has challenges.

Challenges of Inquiry

The surveys indicated that the PSTs expressed challenges of inquiry in general. About 80% of PSTs said inquiry has challenges in the pre-course survey, whereas, the number had increased to 96.36% in the post-course surveys. They changed their mind from not being sure about whether inquiry has challenges to discussing the challenges of implementing inquiry. For example, P-23 said, “I don’t know what you mean by inquiry” in her pre-course survey when asked about the challenges of inquiry. Later, in the post-course survey, she said, “Main challenge that comes with inquiry is that sometimes it can be hard not to go too far off track.” In another example, P-35 defined inquiry as the “Process of gaining an understanding of the scientific world through questioning and wonder” in her pre- and post- course surveys. When writing about the challenges, P-35 went from saying “no challenges” in her pre-course survey to “Inquiry has disadvantages, a person might not be fully satisfied by the answer they receive from using inquiry” in her post-course survey.

Challenges from the Field and Peer Teaching Lesson Plans and Peer Teaching Sessions

Apart from the surveys, analysis of other data sources like field lesson plans, peer teaching lesson plans, and peer teaching sessions also indicated certain patterns of inquiry challenges in general. Qualitative analysis of the lesson plans (field and peer teaching) and peer teaching sessions indicated specific challenges of inquiry.

Qualitative analysis of lesson plans and peer teaching sessions. I coded the lesson plans (field and peer teaching lesson plans) and peer teaching sessions using specific rubrics (Appendices D and E). The rubrics helped in evaluating lesson plans and peer teaching sessions to allot certain scores. The evaluation was based on certain criteria like having an interesting introduction, planning a purposeful activity, asking critical questions, and having assessment questions specific to the science concept.

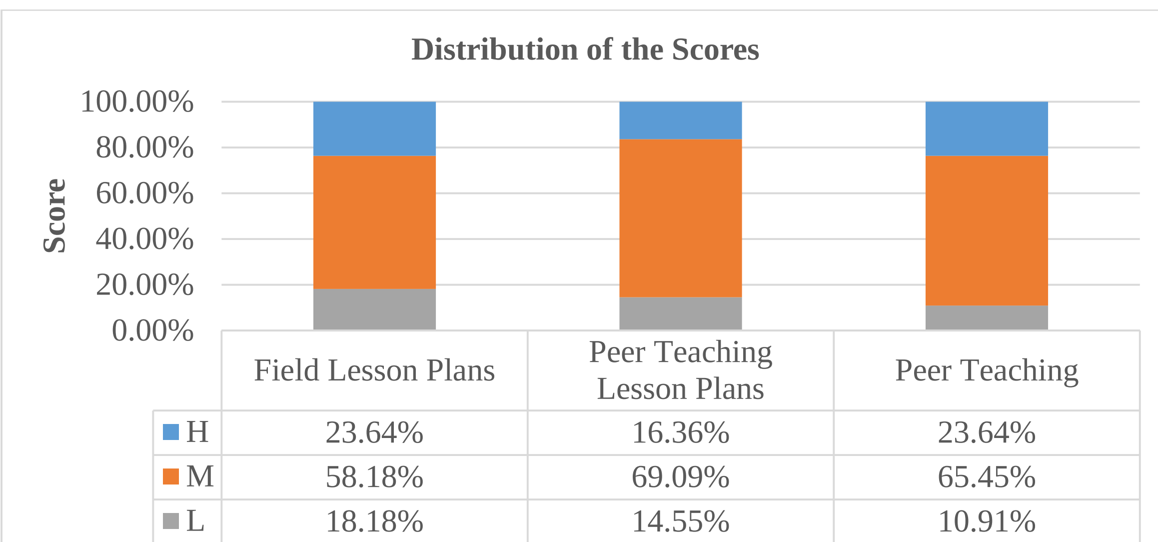

Figure 2. Field, Peer teaching lesson plans and Peer teaching sessions Score Distribution.

Figure 2 shows that 58.18% (field lesson plans, 15 groups), 69.09% (peer teaching lesson plans, 18 groups), and 65.45% (peer teaching sessions, 17 groups) of the PSTs scored medium on the evaluation rubrics. This pattern indicated that the PSTs are struggling to write 5E lesson plans and teach those lessons to students in the field and to their peers as well. The data also demonstrates that 23.64% (6 groups) of PSTs scored high on the field lesson plan evaluation rubric and only 16.36% (4 groups) of PSTs scored high on the peer teaching lesson plan evaluation rubric. This can be related to the fact that the peer teaching lesson plans had to be designed for fifth or sixth grade content levels whereas the most students were designing lower elementary lesson plans for the field. Those results bring up the importance of content knowledge which I explore in the next section.

Specific Challenges of the PSTs while Implementing 5E Inquiry Model

This section presents a detailed description of specific challenges PSTs faced while implementing the 5E inquiry model of instruction.

Writing and implementing the *explain* phase of the 5E model. Various data sources like field lesson plans, peer teaching lesson plans, and peer teaching sessions indicated that the *Explain* phase of the 5E model is challenging for PSTs. When probing closely about this challenge, I found that PSTs' reference to the explanation was classified into three categories. The first refers to those having a complete explanation (PSTs had the complete and correct scientific explanation), the second refers to those having good scientific explanation but not totally complete (PSTs had partial scientific explanation), and the third refers to those having incomplete and poor scientific explanations (PSTs had incorrect scientific explanation). Percentages of PSTs struggling with the *Explain* phase are reported in Table 6.

Table 6

Percentage of PSTs struggling with Explain phase

Data Sources	Indicated Complete Scientific Explanations	Indicated Partial Scientific Explanations	Indicated Incomplete and Poor Scientific Explanations
Field lesson plans	41.82% (11 groups)	50.91% (13 groups)	7.27% (2 groups)
Peer teaching lesson plans	30.91% (8 groups)	54.54% (14 groups)	14.55% (4 groups)
Peer teaching sessions	23.64% (6 groups)	65.45% (17 groups)	10.91% (3 groups)

Table 6 shows that 30.91 % (8 groups) had complete scientific explanations in their peer teaching lesson plans but only 23.64% (6 groups) had complete scientific explanations during their peer teaching sessions. Similarly, 54.54% (14 groups) had partial scientific explanation in their peer teaching lesson plans, but 65.45% (17 groups) had partial scientific explanation in their peer teaching sessions. This discrepancy between peer teaching lesson plans and peer teaching sessions (Table 6) indicates that the PSTs who wrote the peer teaching lesson plans could not successfully implement them as expected during the peer teaching sessions. For example, P-10 and P-23 in their peer teaching lesson plan on plate tectonics, indicated partial explanations ("We will discuss results of experiments, give definitions of different types of plate movements.") However, in the peer teaching session, they failed to implement the lesson as planned. Rather than discussing the results of the experiments as mentioned in their lesson plan, they skipped the discussion part and read out definitions directly from the slides. They failed to motivate students to relate graham cracker movements to tectonic plate movements. The overall *explain* phase was very vague, as they did not explain deeply how the tectonic plates interact, which made it an incomplete and poor scientific explanation.

To better illustrate those three categories, I will focus on the lesson plans and present the details in specific lesson plans that explain each case. Table 7 presents a case of a PST group having a complete scientific explanation.

Table 7

Data showing Complete Scientific Explanation

Name of the PST and Objective of the Lesson	Complete Scientific Explanation
P-40 and P-43 **Peer teaching lesson plan** **Objective:** Students will be able to identify fossils as evidence of past living organisms and evidence of history.	"We will begin introducing the topic of fossils by first asking students to define the term fossils, discuss their definitions. We will define the term fossils and discussing the attributes of fossils. Fossils are what is left from living things in the past Fossils can be prints of animals or plants Some fossils are parts of things that were once living (Bones, Teeth) The next main idea we will address is where geologists can find fossils. • In rock • Ice • Tar • Amber (hardened tree sap) The final main idea we will discuss is how fossils are made. Animals die, their remains stay behind Over many, many years the remains are buried • Soil • Clay • Mud The layers turn to rock and the remains leave an imprint in the rock This imprint is called a _________.

	We will then ask students to write down what they learned, making sure to point out our key idea which is that fossils are evidence of past living organisms.”

The example in Table 7 shows a complete scientific explanation. The lesson was about fossils. PSTs divided the *explain* phase into three parts where they asked students to come up with the definition for fossils, PSTs accepted and discussed students definitions in the first part. They explained where the fossils were found in the second part, and finally, they addressed the main idea of how fossils were formed. At the same time, the PSTs asked students to write down what they learned from the lesson to check whether students understood the big idea. I called this a complete scientific explanation because they had the right balance of questions, discussion and appropriate explanations.

Many students had partial explanations, which mean that they did not push students for the complete scientific explanation. Table 8 represents such a case.

Table 8

Data showing Partial Scientific Explanations

Name of the PST and Objective of the lesson	**Partial scientific explanation**
P- 30 and P-53 **Peer Teaching Lesson Plan** **Objective:** The students will be able to identify different states of matter and distinguish between them.	• “After sorting the pictures we all reconvene as a class. • On the whiteboard we will have constructed a chart and as a class fill it in together. • Groups will be called on one at a time to give an example and reason why they sorted in certain way. • After giving their example if any groups dispute their thoughts, we will discuss as a class.”

The example in Table 8 shows partial scientific explanation. The lesson was about states of matter and the ability to distinguish between them. PSTs planned to discuss the activity (sorting pictures according to the state of matter) and the criteria by which students sorted the pictures. Even though PSTs provided students with the opportunity to explain their criteria (shape, texture, etc.) for sorting objects, they neither addressed the reason behind choosing those criteria, nor did they provide students with the appropriate explanation of representation of the molecules in solids, liquids, and gases. At the same time they did not have any critical questions which could further help students to think deeply about the differences between the different states of matter. Some students had very poor scientific explanations, and one case is represented in Table 9.

Table 9

Data showing Incomplete and Poor Scientific Explanations

Name of the PST and Objective of the Lesson	Incomplete and Poor Scientific Explanation
P-5 and P-9 **Peer teaching lesson plan** **Objective:** The students will be able to engage in the experiment of layering different liquids and after be able to explain the concept of density, understanding that different things have different densities.	• Bring the class together and draw a table on the board with each group's name on it. • Record each group's initial prediction of which liquids were more or less dense. Based on their final product, ask students how they arrived at that by discussing which liquids the students found to be successful in layering and how it compared to their initial prediction. • Next we will reveal the identity of the liquids that the students were using. • Ask the students whether they were surprised after knowing what the real liquids were (encourage class discussion)

The example in Table 9 shows incomplete and poor scientific explanations. The lesson was about the concept of density and understanding how different liquids have different densities. For the explanation part of the lesson, PSTs chose to discuss which liquids were more or less dense but failed to explain why liquids have different densities. They did have a few questions, but the questions did not motivate students to think that density was the reason behind why liquids layered the way they did. At the same time, they failed to provide students with the scientific explanation behind the concept of density and its relationship with the mass and volume.

Difficulty evaluating students' understanding. Similar to the *explain* phase of the 5E, PSTs struggled with evaluating students' understanding of the scientific concepts. During the interviews, 13.33% of the PSTs said that assessing/evaluating students understanding at the end of the lesson was challenging. For example, P-13 in her interview said that, "the challenge was the assessment piece…most of the assessment like making sure that they participated and making sure that they did the worksheet that we gave them."

The PSTs in their lesson plans were supposed to have an assessment question that is specific to the content they taught and the question had to be clearly written for students to understand as well as include a sample answer and grading criteria. They were supposed to implement this assessment question during the peer teaching sessions. I found that PSTs evaluations or reference to the evaluations were classified into three categories. The first refers to those having a complete evaluation, the second refers to those having good evaluation techniques but not specific for what they expected students to learn in the objective, and the third refers to incomplete evaluation when PSTs skipped the evaluation phase.

Table 10

Percentage of PSTs struggling with the Evaluation phase

Data Sources	Indicated Complete Evaluation	Indicated Partial Evaluation	Indicated Incomplete Evaluation
Field Lesson Plans	80% (21 groups)	12.73% (3 groups)	7.27% (2 groups)
Peer Teaching Lesson Plans`	74.54% (19 groups)	14.55% (4 groups)	10.91% (3 groups)
Peer Teaching Sessions	69.09% (18 groups)	23.64% (6 groups)	7.27% (2 groups)

As shown in Table 10, 14.55% (4 groups) had partial scientific evaluation in their peer teaching lesson but the number increased to 23.64% (6 groups) during their peer teaching sessions. Similarly, 74.54% (19 groups) had complete scientific evaluation in their peer teaching lesson plans but only 69.09% (18 groups) had complete scientific evaluation in their peer teaching sessions. This discrepancy between peer teaching lesson plans and peer teaching sessions indicates that the PSTs who wrote the peer teaching lesson plans could not successfully implement them as planned during the peer teaching sessions.

In order to better understand the challenges PST faced with the evaluation phase of the 5E, I present a case for each category. Table 11 presents a case that shows complete evaluation in the lesson plan.

Table 11

Data showing Complete Evaluation

Name of the PST and Objective of the Lesson	**Complete Evaluation**
P-43 and P-40 **Peer Teaching Session** **Objective:** Students will be able to identify fossils as evidence of past living organisms and evidence of history	"Very Good Extend activity to assess what they learned. They had very good questions to push students thinking" -They gave each table one fossil mold and have students create a story about the fossil followed by few questions. -What animal do you think the fossil is from? -Where do you think it was formed? -How do you think this could have been made? -Create a story about how this fossil was formed, incorporate the above three questions. -Have groups share their story and information about their fossil to the entire class. -Reveal what the fossil actually represents and a few facts about the fossil"

In Table 11, the example shows the complete evaluation. The lesson was about fossils. PSTs asked students to create a story by incorporating some questions which motivated students thinking about fossils, and how they were formed. The different groups in the class were able to support their story with logical evidence and information about the fossils (e.g., formed in sedimentary rocks over a long period of time) that they learned in the lesson. One could see that this assessment perfectly aligned with the lesson objective and instructional method. Another case shows how PSTs had partial evaluation as presented in Table 12.

Table 12

Data showing Partial Evaluation

Name of the PST and Objective of the Lesson	Partial Evaluation
P-12 and P-26 **Peer Teaching Lesson Plan** **Objective:** Students will describe and illustrate movement of the water above and below the Earth through water cycle and explain role of the Sun.	“Why does it rain more in some places?” Students answer “We’re going to watch a video about the rain shadow effect and why it rains more in certain places.” Rain shadow effect video: https://www.youtube.com/watch?v=YWZ6yEv-gI4 “Now when you see it rain, you will know exactly how it’s happening!!

The example in the Table 12 shows partial evaluation. The lesson was about movement of water in the water cycle and the role of the Sun in the water cycle. PSTs in the evaluation section chose to ask questions and show a video about the rain shadow effect. The video and questions were not very specific to the objective of the lesson. This is partial evaluation because instead of assessing students for their understanding about the water cycle, and the role of different elements (e.g., sun) in the water cycle, this group of PSTs asked students why it rains more in some places and showed a video about rain shadow effect. Such questions reinforces the idea of saturation in the atmosphere and condensation to produce rain (one phase of the water cycle), but it does not allow one to assess students’ understanding of the different phases of the water cycle and relationships among them. The third case shows incomplete evaluations as presented in Table 13.

Table 13

Data showing Incomplete Evaluation

Name of the PST and Objective of the Lesson	Incomplete Evaluation
P-3 and P-33 **Field Lesson Plan** **Objective:** Students will be able to define and distinguish the four different season and weather that occurs in each season.	**"**We will pass out a short quiz that we have found. We expect the students to finish this quiz pretty quickly and will help read if necessary. We also expect the students to have little issues with understanding what the quiz is asking and hope that the students are able to answer all these questions correctly. We will give the students 10 minutes to take this quiz."

The example in the Table 13 shows an incomplete evaluation. The lesson was about different seasons and weather that occur in each season. As part of their assessment, the PSTs mentioned that they would pass out a short quiz to assess student understanding. They indicated in the lesson plan that they will give students a quiz, but nowhere did they include any specific questions for this quiz. This is an *incomplete evaluation* where PSTs missed writing questions which would assess students understanding of the concept.

Lesson planning using the 5E is a time consuming process. In the pre course surveys, 0.54% of PSTs said that writing the 5E lesson plans needs a lot of planning. However, 18.18% of PSTs in the post course survey said that lesson planning using the 5E model takes a lot of time. For example, P-38 in the post survey said, "it takes a lot of planning and preparation on the teacher's part" and P-53 said, "5E lessons take a lot of time and planning to carry out." Another PST, P-15 mentioned that "Inquiry takes some time and could potentially take more time for students to learn and more time for a lesson to take place." Moreover, P-34 said, "One big issue with inquiry is time. By exploring each concept, it takes up a lot of time."

Similarly, during the interviews of 15 PSTs, 20% of the PSTs opined that the 5E lessons and lesson plans require a lot of planning and time. For example, P-22 said, “Planning the 5E lesson is very time consuming.” While many expressed general time consuming challenges, some expressed their concern with specific challenges related to time. For example P-31 said that “5E lessons take a lot of planning to get all the materials set up.”

Making sure every student in the classroom understands the lesson. The results showed that 14.55% of PSTs in the post course survey and 20% of the PSTs in their interviews expressed concerns about supporting each and every student’s understanding of the science content. Even though the 5E model provided students with opportunities to think and work at the same time, PSTs did not see how this model can help them check for the understanding of every student. P-11 said, “The challenge would be making the lesson plan for all the students to understand it.” P-18 said, “Altering things for each student is difficult.” Similarly, P-28 said that “Working with individual kids is the hardest thing.” All these excerpts show that PSTs had concerns about meeting the needs of each and every student in the classroom while planning and implementing 5E lessons.

Mapping the lesson to the different parts of the 5E. In their interviews, 13.33% of PSTs found that dividing any lesson into the 5Es is challenging. P-7 said, “We had a problem in dividing the lesson into the different 5Es.” The PSTs faced difficulty while choosing which part of the lesson should align with the *engage, explore, explain, elaborate,* or *evaluate* phase of the 5E lesson plan.

Transition between phases of 5E based lesson. In their post-course surveys, 5.45% of PSTs said that deciding when to move from one phase of the 5E to another while teaching is challenging. Similarly, 6.66% talked about difficulty in deciding when to transition from one phase to another in their interviews. For instance, P-42 said in the interview that “It is hard to decide when to move on may be, if you are explaining when to stop and when to go, elaborating the topic."

Stringent time slots for phases of the 5E model. During their interviews, 13.33% of PSTs opined that following strict timelines for each of the 5E phases is unrealistic and challenging. P-30 said, "Having a specific time for each 'E' is kind of hard because it is based on individual lessons. Some lessons might take less time but some might go over." At the same time, a close look at the lesson plans also showed that the PSTs could not estimate the approximate duration for the lesson. For example, P-28 and P-32 in their peer teaching lesson plan estimated their teaching about "Structure of the Earth" would take 45 minutes, but they completed the lesson in 32 minutes.

These results motivated me to analyze the time it took PSTs to finish their lesson. I performed further analysis on peer teaching lesson plans and the peer teaching sessions. I noted the time taken by each PST group to complete the peer teaching lesson, and compared that with the time they had predicted to finish teaching as noted in their lesson plan. The results are presented in Table 14.

Table 14

Table comparing difference between Predicted and Actual time taken to finish the lesson.

Time predicted in the peer teaching lesson plans			**Actual time taken during peer teaching sessions**		
30-35minutes	**35-40 minutes**	**40-50 minutes**	**Over time**	**On time**	**Under time**
36 PSTs (17 groups) (65.45%)			4 PSTs (2 groups) (7.27%)	7 PSTs (3 groups) (12.73%)	25 PSTs (12 groups) (45.45%)
	11 PSTs (5 groups) (20%)				11 PSTs (20%)
		8 PSTs (4 groups) 14.55%)			8 PSTs (14.55%)

As shown in Table 14, 65.45% of PSTs (17 groups) estimated the time range of 30-35 minutes, 20% (5 groups) estimated 35-40 minutes, and 14.55% (4 groups) estimated 40-50 minutes to implement their lessons in their peer teaching lesson plans. When predicted time ranges were compared to actual time it took PSTs to implement the peer teaching sessions, only 12.73% (3 groups) of the PSTs were on time, 80% (21 groups) of the PSTs were under time, and 7.27% (2 groups) of them were over time.

Knowing that many pre-service teachers did not estimate realistic time periods for their teaching, I further probed their lesson plans to analyze how they allocated time for each of the 5E phases. Table 15 shows examples of unrealistic time slots that were estimated for each of the 5E phase.

Table 15

Excerpts showing unrealistic time slots for different phases of the 5E as shown in their lesson plans

Name and Title of the Lesson	**Phase**	**Description**	**Time Slot as predicted by student**
P-10, P-23 **Lesson Title**: Plate Tectonics	*Engage*	"Show a funny video to introduce the lesson. Relate it to the topics by explaining, "This was a funny video, but it shows an event that happened over time millions of years ago and is still happening today. What do you think happened in the video?" Link: https://www.youtube.com/watch?v=TzzGPfVx32M"	3 minutes
P-18, P-25 **Lesson Title:** Complete and Incomplete Metamorphosis	*Explore*	"Then, I will give each group an insect and they have to research and discover if this animal goes through complete or incomplete metamorphosis. Each group will then come to the front and act out the different stages so that the rest of the group can guess.	10 minutes

		Complete: Ant, Flea, Ladybug, Mosquito Incomplete: Termite, Walking Stick Bug, Dragon Fly”	
P-13, P-14,P-21 **Lesson Title:** Gravity	*Elaborate*	“Show video… despicable me antigravity serum example In this video we noticed… that gravity was “turned off” after the minions drank the purple antigravity serum so they floated to the ceiling! They participate in discussion by reporting what they noticed and how it relates to what we talked about”.	2 minutes
P-40, P-43 **Lesson Title:** Fossils	*Extend*	**“After the section of the video is played ask the students** **to discuss as a group:** 1. What would have to be true about these imprints to consider them fossils? 2. How could the whale fossils have ended up in the marble slabs? 3. Where do you predict the fossilization of bones the whale took place? **Next section of the video: (0:58 seconds)** 4. Does your prediction of where the fossilization could have taken place match the video? 5. How could the fossilization of a whale possibly take place in the dry desert of Egypt? (connect to the importance of history and time period) **Play next section of video: (1:081:** **26)** This part of the video should answer the question of how a whale fossil could have been found in Egypt.”	5 minutes

The first example in Table 15 shows that P-10 and P-23, while engaging students to teach them about "Plate Tectonics", allocated a three-minute time slot for engaging students in the classroom to show and discuss the YouTube video. This time slot seemed unrealistic as the duration of the video is 2 minutes 34 seconds and there are only 30 seconds left for the whole class discussion.

The second example in Table 15 shows that P-18 and P-25 allocated a 10-minute time slot for the students to explore complete and incomplete metamorphosis. Each group had to explore the animal given to them, and to prepare a story and act it out to the class. The class had seven groups so allocating just ten minutes for all this activity was not realistic.

The third example shows that while writing a 5E lesson plan to teach "Gravity; P-13, P-14, and P-21 allocated a two-minute time slot for the *elaborate* phase. PSTs expected the students to watch a 45-second video and then discuss their observations in the short span of 2 minutes. The estimated time slot seemed very unrealistic.

The last example in Table 15 shows that P-40 and P-43 while writing a 5E lesson plan to teach "Fossils" allocated a five-minute time slot for the *extend* phase. PSTs expected the students to watch a video and participate in the discussion in a short span of 5 minutes which is unrealistic.

The *Elaborate* phase of the 5E lesson is difficult. The results showed that 20% of the PSTs found the *elaborate* phase to be difficult. For example P-31 said in her interview that, "The Elaborate part for me was always a little bit more vague or harder to do." Similarly, P-49 said, "We kind of struggled with '*elaborate*' and '*extend*'. We kind of got those confused and, what we should do for each part." I therefore performed a qualitative analysis to find out more about this challenge. The PSTs, in their lesson plans, were supposed to mention one or two examples of how they would elaborate the lesson and relate the lesson to real life. Many PSTs failed to do so. I analyzed the field and peer teaching lesson plans closely to report percentage of PSTs facing difficulties in the *elaborate* phase. I decided the level of difficulty based on the following: whether or not they included the *elaborate* phase, whether they related the lesson to appropriate real life examples, whether they elaborated by showing videos related to the objective of the lesson, and whether the activities transferred the ideas to a new scenarios. Table 16 shows the percentages.

Table 16

Percentage of PSTs facing Difficulty in the Elaborate Phase

Phase of 5E	Interviews	Field Lesson Plans	Peer Teaching Lesson Plans	Peer Teaching Sessions
Elaborate	20% (3 PSTs)	30.91% (8 groups)	43.63% (12 groups)	52.72% (14 groups)

As shown in Table 16, 43.63% (12 groups) of PSTs struggled with the *elaborate* phase of the 5E model. A more qualitative analysis of this challenge shows that students may have misunderstood the *elaborate* phase. For instance, in a lesson where students were supposed to learn the difference between conductors and insulators, P-1 and P-55 in the *elaborate* phase wrote that they would "introduce the terms conductor and insulator through a short PowerPoint." This excerpt clearly shows that the PSTs were introducing terms in the *elaborate* phase rather than relating the context of the lesson to real-life situations or transferring the knowledge they learned to explain a new scenario. In another example of a lesson about classifying objects based on their observable properties including size, mass, shape, color/shade, and texture, P-33 and P-40 wrote that they would show a video about using physical properties in the world. They neither mentioned the link to video nor did they have any critical questions/example scenarios which would push students to connect the concept to the real life situations.

Peer teaching is challenging. A qualitative analysis of the interviews revealed that, 53.33% of the PSTs indicated that teaching to their peers is challenging when compared to teaching to students in the field. For example, P-42 in her interview said, “Peer teaching is much harder, because you are being like, children won’t judge you as your peers will do so I think it was harder for us to teach here.” P-22 said, “It was a lot easier to teach little kids than the peers. For our classmates, we are writing for fifth graders but we knew that it is going to be easy, but keeping them engaged was way different like you would do way simpler 5E to engage little kids.” Similarly, P-50 said, “Teaching to peer was more challenging because they did not take it seriously.” All the excerpts above show that the audience they were teaching influenced how stressed or relaxed the PSTs felt.

Suggested Solutions

In this section I present solutions to some of the challenges that the PSTs mentioned during their interviews.

Using multiple resources. PSTs perceived 5E lesson planning as a time consuming process. In their interviews, some of them (6.66%) proposed a solution of this challenge by seeking help from cooperative teachers and using available online resources to save some time. P-31 said, “Not only talking to field placement teachers but online resources are super great way to overcome that challenge.”

More practice. Many students faced difficulty writing the lesson plan using the 5E model. During their interviews, 20% of PSTs stated that more practice writing lesson plans is a solution to this challenge that may help them to improve and develop ease about implementing the 5E teaching model. For instance, P-16 said, “Just more practice, and it will become natural for you to include each part without putting on paper," and P-7 thinks, "Having more time spent on it in class especially when we were about to teaching it to our students helps."

Being flexible with 5E divisions. Earlier in this section, I reported that the PSTs faced difficulty with the *elaborate* phase of the 5E model. In their interviews, 6.66% of PSTs believed that being allowed to merge some of the 5E phases would help them alleviate this challenge. For example, one could combine the *elaborate* phase with *explain* phase. P-42 said, "Doing more of flexible lesson plan or you can combine Es to make it like the teacher can understand they can intervene each Es while they are teaching."

Incorporating different instructional strategies in the classroom. Many PSTs thought that making sure each and every student in the classroom understands the lesson is challenging. During their interviews, 6.66% of the PSTs indicated that adopting different instructional strategies may help in meeting individual student needs in the classroom, and can be a solution to this challenge. For example, P-28 mentioned that, "Encouraging students to work in groups is kind of like self-teaching, so you don't have to be on top every single kid, you have a little breathing room."

Relating the science concepts to the real life experiences. Many PSTs found the *elaborate* phase challenging. Relating science concepts to students' real-life experience rather than always including more classroom activities might be a solution to this challenge. During the interviews, 13.33% of the PSTs said that students should not only explore activities related to the science topics, but should also connect the science concepts to real-life experiences and situations. For example, P-22 said, "Aside from just kind of tying things to activities within a classroom tying things back to recess or going to the zoo, field trips might help." P-30 said, "I would actually make the connection for them with the science in the real world so they are not kind of just going through the motion."

Acquiring a solid science content knowledge. The most important and biggest challenge PSTs faced while implementing 5E inquiry model of instruction is the *explain* phase. During the interviews, 6.66% of the PSTs indicated that having a strong science content knowledge builds confidence and helps PSTs to overcome the challenges related to the *explain* phase. For example, P-49 said, "One of the solutions is I guess just better understanding of our topic." PSTs with solid science content knowledge have an ability to explain the science concept in many ways, which helps students to better understand science.

Overview of the Results

The PST teachers taking a science method course observed several 5E model lessons implemented in the classroom and had plenty of opportunity to discuss, read, and teach using this model several times. However, the results of this study reveal that they still faced many challenges to successfully implement this model. The data showed nine specific challenges of implementing the 5E inquiry model, which can be classified into challenges that concern the instructional method and challenges that concern the content. Table 17 shows these different challenges.

Table 17

Method and Content related Challenges

Method related Challenges	**Content related Challenges**
Making sure every student in the classroom understands the lesson is difficult.	Writing and implementing *explain* phase of the 5E model is difficult.
Lesson planning using the 5E is a time consuming process.	Thinking of creative ways for the *elaborate* phase of the 5E lesson is difficult.
Teaching to peers is more stressful that teaching young students.	Having proper evaluation for students understanding is challenging
Transition between phases of 5E can be confusing	
Mapping the lesson to the different parts of the 5E can be confusing.	
Stringent time slots for phases of the 5E model can be hard to implement.	

After close analysis of the semi-structured interviews, the PSTs proposed five possible solutions for some of the challenges. Those solutions were:

1. Using multiple resources to reduce the time taken to plan 5E lessons.
2. Practicing the 5E-based lesson plans and becoming experts in blending or splitting phases to become fluent in designing this teaching method
3. Incorporating different teaching strategies in the classroom in order to meet the needs of every student in the classroom.
4. Relating the science concepts to real life experiences helps to overcome the confusion of writing the *elaborate* phase.
5. Having an adequate science content knowledge to overcome the scientific explanation related challenges.

A detailed discussion about the challenges, the possible reasons behind the challenges, possible solutions, and the relation between challenges and solutions are presented in the discussion section next.

Chapter 5

Discussion

This section discusses the challenges and the solutions PSTs proposed in light of the literature, in-service teacher's views, and my personal reflections.

Discussion of the Challenges and Solutions Proposed by PSTs

As indicated in the results section, PSTs proposed possible solutions to the challenges they faced. Table 18 shows how the solutions proposed could be related to the challenges found in this study.

Table 18

Relating Proposed Solutions to the Challenges of PSTs

Challenges	Solutions
Lesson planning using the 5E is a time consuming process.	• Using multiple resources to reduce the time taken to plan 5E lessons.
Mapping the lesson plan to different parts of the 5E.	• Practicing 5E lesson plan writing which helps PSTs to map the lesson plan easily to the different phases of the 5E
The *Elaborate* phase of the 5E lesson is hard to think of	• Being flexible with 5E division, and merging phases of 5E aids in planning the *elaborate* phase. • Relating the science concepts to real life experiences to overcome the confusion of writing the *elaborate* phase. • Having a solid science content knowledge aids in planning the elaborate phase.
Making sure every student understands the lesson	• Incorporating different teaching strategies like direct instruction, indirect instruction, and independent study helps PSTs to meet the needs of all students in the classroom.

Writing and implementing *explain* phase of the 5E	• Having a solid science content knowledge allows PSTs to focus on appropriate scientific explanations

As shown in Table 18, analysis of the lesson plans and peer teaching sessions clearly indicated that the PSTs struggled with the 5E lesson planning in terms of the time taken to prepare the high-quality lessons that follow this model. Sadler (2006) agrees with this and states that PST "felt overwhelmed by the amount of time required to develop lesson plans, classroom activities and parental communications via e-mail" (p. 225). Similarly, Fazio, Melville, and Bartley (2010) reported on time constraints as one of the challenges of PSTs teaching inquiry based science lessons. They reported about one pre-service teacher who said: "to do an experiment and planning the process it takes a lot of time, and as a teacher you have such limited time" (p. 676). To handle an inquiry-based classroom, one has to plan activities, ways to engage students, and critical questions to push their thinking. Consequently, inquiry-based lessons definitely require a lot of time to plan which is a potential challenge for the PSTs.

As a solution, PSTs posit that they can use online resources like lesson plans, activities, and creative experiments posted by experienced teachers. PSTs also believed that seeking help from cooperative or experienced teachers about what works best in the classroom will help in reducing the time taken for 5E lesson planning. Giebelhaus and Bowman (2002) also posit that the PSTs who team up with trained cooperative teachers, demonstrate better lesson planning and implementation in the classroom. During my conversation with an in-service teacher (who was also a mentor to a few PSTs in this study), I found that she welcomed PSTs' questions and offered help when needed. She recommended that PSTs should be more proactive, ask questions, and seek help whenever they feel unsure about a certain issue. She also opined that feedback from the cooperative teachers/experienced colleagues will help the PSTs to improve their teaching and learn new and creative ways of teaching science.

During the interview analysis, PSTs indicated that mapping a lesson to different parts of the 5E is challenging. The possible solution PSTs offered is more practice with writing 5E lesson plans. They believed that the more lesson plans one writes, the more easily one maps a lesson to the five phases of the inquiry model.

Another challenge was that the PSTs find the *elaborate* phase of the 5E model challenging. The PSTs offered three possible solutions for this challenge. The first solution is being flexible while dividing a lesson into the five phases of the lesson plan. One can merge phases of the 5E inquiry model, especially the *elaborate* and the *extend* phases, which avoids the confusion of what to do in the *elaborate* phase. The second solution is relating the science concepts to students' real-life experiences and not always to the classroom activities. Many agree with this point. In fact, the in-service teacher I interviewed in this study posited that the life experiences of students (visit to museums, zoos, planetariums, magic shows, etc.) make a lot of difference in understanding science concepts. She proposed that the science concepts should be sometimes related to student's experiences outside the classroom and not always to the activities in the classroom. Tamir (1990) in his study also posited that, "Knowledge of science and attitudes towards science develop as a result of children's experiences in and out of school" (p. 34). Supporting the in-service teachers' views, Gerber, Cavallo, and Marek (2001) said, "Participation in intellectually and socially instructive activities may stimulate the development of logical thinking skills useful to students' future careers and everyday life" (p. 547). The third solution offered is having a good science content knowledge. Good grip on the subject helps one to divide the lesson easily into 5Es.

Another very common challenge of PSTs is making sure every student understands the lesson. Every student learns differently, so to meet the needs of every child in the classroom PSTs should develop an ability to incorporate different teaching strategies. This is in line with how McDonnough and Matkins (2010) believe that various instructional methods help in implementing inquiry-based teaching. Grant and Gillette (2006) agree with this and believe that an effective teacher develops a “pedagogical skill” that is an “ability to successfully implement teaching strategies to meet the educational and social needs of students” (p. 296). Similarly, Ferber and Nillas (2010) posited that pre-service teachers should develop an ability to implement teaching strategies to meet the needs of students during their student teaching experience. During my conversation with the in-service teacher, she mentioned that teaching requires thinking of innovative ways to address many challenges. She recommended that PSTs need to think creatively and find out of the box ideas to teach. She advised the use different teaching strategies like direct instruction, indirect instruction, and independent study to support different learning styles of students.

Writing and implementing the *explain* phase of the 5E inquiry model was yet another important challenge that appeared in the results. The possible solution for this challenge is having adequate science content knowledge. Strong science content knowledge helps PSTs design good science lessons and provide complete scientific explanation. The in-service teacher also posited that, as novices, many teachers face issues related to content and fail to explain the science concepts. Thus, an adequate science content knowledge is very important to be a good science teacher and design effective science lessons.

Potential Reasons for PSTs Challenges

Taking into consideration the literature, PSTs' and in-service teachers' views and my personal reflections, I discuss potential reasons for why these challenges exist. The challenges could be related to three main issues: classroom management, science content knowledge, and disjunction between what teacher education programs preach and what the PSTs practice.

Classroom Management Strategies

As indicated in the results, PSTs find classroom management challenging. Some PSTs also indicated that lack of classroom management is the reason for time-related challenges. Classroom management skills are the skills acquired by teachers to handle certain situations which arise in the classroom and maintain an environment conducive to learning. Good classroom management skills are very important for the teachers to master the art of teaching. According to Grant and Gillette (2006):

> Excellent teachers have skill in planning and managing the learning environment. They provide structure with flexibility, freedom within parameters, and options for projects and assignments. They actively involve students in learning and classroom decision making and set clear academic and social goals. Students' ideas, opinions, and knowledge are woven into the fabric of the classroom through democratic classroom management strategies. (p. 297)

For any classroom to run smoothly, a good classroom management plan is a must. For instance, Sadler (2006) mentioned how PSTs "adopted relaxed approaches to the classroom management and found that this created immediate problems" (p.225). He also mentioned how PSTs struggled with the "decision of how and when to impose rules, when to step in and encourage students to change their behaviors, and difficulty establishing tolerances" (p.225). Along with these struggles, the researcher also mentioned how few PSTs thought that students in the classrooms did not take PSTs seriously due to their young looks and how they have already walked into improperly managed classrooms that they can do nothing about.

Results indicated that the PSTs had to try hard to keep students on task, and they also struggled with discipline related issues. Lotter (2004) mentioned how PSTs “dealt with students on/off task behavior, teacher control issues, and students discipline issues” (p. 34). The author also mentioned how one PST said that “The activity didn’t go as smoothly because of my lack of complete control” (p.34). If a PST uses good management strategies, students will stay focused on the task and finish work on time, which helps PSTs to implement a lesson as planned.

During my conversation with the in-service teacher, she mentioned that classroom management is the biggest challenge that the PSTs will face. She believes that classroom management strategies are not very easy to adopt and without a good classroom management plan managing a classroom is impossible. So, until the PSTs develop good management skills, disciplining students will be the challenge. The in-service teacher also proposed that the PSTs should try a classroom management plan and check what is working and what is not working for that particular group of students. This helps PSTs in developing classroom management skills. PSTs need to tailor different skills towards different groups of students because the same sets of skills do not work for every group. If PSTs design and implement a good comprehensive classroom management plan, students learn not to cause disruptions while transitioning from one phase of the 5E to another. Ferber and Nillas (2010) propose a solution that pre-service teachers mentioned: “Teacher education programs could create more discussion on classroom management or even offer a class, increase communication of expectations, provide exposure to education vocabulary, and earlier field work in their subject at secondary level" could have helped in overcoming challenges related to classroom management (p. 73).

Science Content Knowledge

Science content knowledge is very important for the teachers to design effective science lessons, use different instructional strategies, and help students understand the science concepts in the classroom. Grant and Gillette (2006) posit that "Effective teachers need depth and breadth of content knowledge" (p. 295). Especially in the case of PSTs, who are novices in the classrooms, adequate science content knowledge boosts their confidence and helps them stand face to face with the challenges. Sadler (2006) posited that the undergraduate participants believed that content knowledge is one of the causes of concern during student teaching. He even mentioned how one of the participants in his study said that "A lot of preparation in the content area helps me feel confident to teach" (p. 232).

Teachers with good science content knowledge have an ability to implement inquiry. Lee, Hart, Cuevas, and Enders (2004) in their study said, "To enable students to engage in science understanding, inquiry, and discourse, teachers require adequate knowledge of science content and effective instructional strategies" (p. 1022). This shows that PSTs need to master the subject before teaching it to students. Lack of content knowledge enhances the persistence of misconceptions for students and teachers as well.

Luera, Moyer, and Everett (2005) recognized that "Science content knowledge is fundamental in designing 5E inquiry-based lessons" (p. 22). The in-service teacher emphasized this point during my conversation with her. She posits that without adequate science content knowledge one cannot successfully plan or implement a 5E- based lesson. She explained that if someone is unsure about the content, he/she has difficulty using it properly and mapping it properly to the different phases of an inquiry model.

In this study, all the students had taken a required science course which covered the basics of physical, biological and earth sciences. However, as shown in the results, many students were not very comfortable with the sciences. This is in line with Yoon, Joung, and Kim (2011) as they believed many PSTs lack science content knowledge even after taking many science content courses. The results of this study suggest that more content courses are required for PSTs.

Disjunction between Theory and Practice

In teacher education program, PSTs are not fully prepared for the K-12 class rooms. Novice teachers are usually surprised by the idea of how demanding the teaching profession could be and how it is different from what they expected (Kagan, 1992). When PSTs enter the K-12 classrooms and try to implement what they have learned in teacher education programs, they face many hurdles. Schulz and Mandzuk (2005) posited in their study that the “Teacher candidates mentioned about the disjunction between what they learned in the university classrooms and what they encountered in their student teaching placements” (p. 327). One of the participants (teacher candidate) in their study opined that there is a “disconnect” between the theory he learned in the university to its practicality in the K-12 classroom. He said, “I assumed that the theory we’re taking here at the university would transfer over into practice in the school, things like teacher as researcher that just isn’t happening” (p. 322). The idea here transfers to 5E inquiry model for this study. For example, PSTs in this study learned to implement the 5E inquiry model in their college classrooms but they may not be observing the same 5E model in the K-12 classrooms. PSTs might find this disjunction to be overwhelming. So, convincing PSTs that they need to change the way they teach all the time will be hard. In another study, Hong and Greene (2011) posited that the

"Pre-service teachers perceived a gap between educational theories learned in college and the demanding reality in the classroom and in school" (p.494). This shows that all the theory and practices taught in the university classrooms might not all be applicable, and this creates yet another challenge for PSTs. Teacher education program need to think of innovative ways to bridge the gap between what the practices they teach and different practices in K-12 classrooms.

Even though the results of this study did not directly indicate the disjunction between what PSTs learned in the teacher education program to what is actually practiced in the K-12 classrooms, they indirectly referred to it. As part of the interviews, I inquired about PSTs' teaching experiences in the field and in their college classroom. Some indicated that K-12 classrooms are very different from their college classrooms. For instance, P-28 in his interview said "it is just lot different when you actually have young kids who are trying to work with you versus when we are teaching to peers." Few mentioned that apart from implementing inquiry, they have to manage a classroom, meet standards. Similarly, the in-service teacher also strongly believed that K-12 classrooms are very different from what teacher educators pictured in the universities. She posited that colleges only teach ideals and not real-life situations and PSTs find fitting those ideals into K-12 classrooms difficult. She indicated that mentors in the universities should create more opportunities for the PSTs to observe the K-12 classrooms, in-service teachers, their practices, and develop a good rapport with them. Ferber and Nillas (2010) posited that "Cooperative teachers, university supervisors, and teacher education programs all play a role in helping the pre-service teacher mold a functional understanding during the student teaching experience" (p. 66). This means that teacher education programs need to seriously revisit how to map the theory and practice they teach into K-12 classroom practice.

Conclusion

After presenting and discussing the results of this study, I conclude by discussing some of the implications of these results, the limitations of the study, and future research.

Implications for Teacher Education Programs

Previous research investigated some challenges that PSTs face when implementing inquiry, but there was an absence of fine-grained description of the challenges when using the 5E model of instruction. This study teased apart the specific challenges PSTs face while implementing 5E model of instruction in their science classrooms. In addition, this study reported possible solutions that PSTs offered to overcome those challenges. As a result, this study has implications for designing a successful science methods course. I present some recommendations for teacher educators and teacher education programs.

Help PSTs acquire strong content knowledge. One of the main results of this study is that PSTs face a challenge with the content knowledge. As a result, teacher education programs can help PSTs acquire strong content knowledge by offering more science content courses and some interdisciplinary courses. Adams and Krockover (1997) also posited that “One possibility is the creation of interdisciplinary science and mathematics courses as interdisciplinary coursework offers an opportunity to develop skill, while at the same time broaden the knowledge base in the sciences” (p. 48). Knowing that the participants of this study have already taken a content course, I recommend that more opportunities should be available to them to reinforce content knowledge. This can happen through formal channels such as creating more specialized science courses that teach PSTs through inquiry. It can also happen through creating credit hours where PSTs can intern in museums, zoos, or botanical gardens and learn about science content and how to interact with young children in informal settings. Even though participants in this study had one session about informal learning, it is important to build such experiences in a more organized ways to support PSTs' understanding of specific science content.

Create opportunities for PSTs to interact with the cooperative teachers. Cooperative teachers/field placement teachers play an important role in carving the PSTs' career of teaching. For example, Graham (2006) in her study mentioned that the cooperative teacher, who guides and supports, is one of the important component for success of the intern (teacher candidate). Cooperative teachers are basically mentors who guide PSTs throughout their student teaching period and help them cope with the K-12 classrooms. This supports the crucial role of a cooperative teacher in shaping PSTs' views, beliefs and practices. Consequently, teacher education programs need create opportunities for PSTs to interact with cooperative teachers and learn from them. Ferber and Nillas (2010) also recommended the teacher education programs create opportunities for PSTs to interact with the cooperative teachers. Teacher education programs should design a course in which PSTs receive opportunities to: 1) exclusively interact with the cooperative teachers on a weekly basis, 2) plan and teach a whole science unit (usually 4 to 6 lessons) in collaboration with cooperative teachers, 3) write assignments about their observations and interactions, and 4) get feedback on their lessons. As part of the same course, teacher educators could make arrangements for guest lectures by a group of exemplary cooperative teachers every week. At end of the lecture, cooperative teachers can interact with PSTs.

Reward experienced cooperative teachers. Cooperative teachers are busy with their own duties of lesson planning, teaching, and communicating with parents. Sometimes, cooperative teachers are not very cooperative and indirectly create challenges for PSTs by not helping them get familiarized with students and their needs, not providing timely pointers, and not providing resources. In some situations, cooperative teachers discourage the PSTs to try new methods or spend time on hands-on activities, which causes a negative impact on the PSTs views about inquiry and their teaching. For example, one of the PSTs in a study mentioned that “His cooperative teacher said that science laboratories are activities and not much time should be spent on them” (Lotter, 2004, p.35). Such views imposed on PSTs by their cooperative teachers might become a cause of poor implementation of an inquiry. Moreover, Ferber and Nillas (2010) mentioned that the “Pre-service teachers encounter challenging situations where conflicts and poor communication prevent cooperative teachers to give valuable feedback that PSTs need for the professional growth” (p.71). To overcome such situations teacher education programs should take the responsibility of rewarding the cooperative teachers in a timely manner. Cooperative teachers should be rewarded monetarily (cash awards, quarterly bonus, etc.), non-monetarily (time-off from work, flexible schedules, etc.) or by professional recognition (Teacher of the Year, Employee of the Month, etc.). Rewards encourage cooperative teachers to maintain cordial relationship with the PSTs and share their knowledge and experience.

In addition to implications for teacher education programs in general, this study has specific implications for teacher educators.

Encourage PSTs to implement inquiry. Teacher educators should encourage PSTs to implement inquiry in general rather than one particular inquiry model. In teacher education programs, teacher educators should give emphasis to inquiry in general and teach more about it. During the data analysis, I realized that PSTs in their post course surveys were still a little confused about the definition of inquiry and had different interpretations of it. Teacher educators must make sure PSTs understand what inquiry is and how to implement it correctly. PSTs in their methods courses should be exposed to teaching methods that can incorporate inquiry (e.g., cooperative learning, lab work, small group discussion). Teacher educators should create opportunities for

PSTs to learn about inquiry as well as be aware of its challenges and some of the solutions to those challenges.

Create opportunities to write and teach unit plans. As part of the methods course, teacher educators should create opportunities for the PSTs to write and teach unit plans (a sequence of related lesson plans) rather than single lesson plans. In a unit plan, teachers get more practice writing the lesson plans using 5E and also have more freedom to include the 5Es across a unit, rather than in one lesson. Doing 5E unit plans will also help students understand the concept at a deeper level, make connections between different ideas at the content level, and map the different lessons of the unit to the different 5E phases. For example, when planning to teach "The Water Cycle" unit, writing a unit plan helps focusing on individual concepts of evaporation, condensation, and precipitation will help the PSTs understand and connect those ideas better than if they were to plan and teach teaching about only one of those concepts.

Limitations

Although the results of this research study showed a fine-grain description of the challenges of teaching a 5E inquiry model and some solutions to those challenges, I am aware of some limitations of this study.

First of all, I conducted a research with 55 PSTs enrolled into two sections of the Science Methods course. They were placed into different elementary schools in North Texas for their field placements. They were widely dispersed and taught at diverse times in the schools, so I could not observe all of their field teaching sessions. Having data on how they taught K-5 students would have allowed me to construct yet a finer picture of the challenges and the solutions in the field.

The second limitation of this study is that despite having a sample size of 55 PSTs, I could only interview a subset of 15 PSTs due to the unwillingness of other PSTs to participate in the interviews. A larger number of interviews would have allowed me to probe the challenges and solutions further.

Future Research

Even though this study contributes to our knowledge of the challenges that PSTs face when implementing the 5E inquiry model, the following questions are my future research agenda:

Investigating the challenges of pre-service teachers in the field in addition to peer teaching would create a better vision of the PSTs' struggles. This is important because it can help me understand the challenges PSTs face in the K-12 classroom as opposed to challenges of teaching to peers. This can be supported by more interviews with PSTs to understand the challenges and solutions further.

Investigating the implementation of one of the solutions proposed by PSTs to overcome challenges of the 5E inquiry model and reporting its usefulness is one way to bridge the gap between research and practice. For instance, PSTs in this study proposed that incorporating different teaching strategies in the classroom helps in overcoming the challenge of meeting the needs of every student. For future research, I plan to investigate whether PSTs who incorporated different teaching strategies would truly overcome some of the challenges and how that happens.

References

Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., ...Tuan, H. (2002). Inquiry in science education: International perspectives. *Science Education, 88*(3).

Adams, P. E., & Krockover, G. H. (1997). Concerns and perceptions of beginning secondary science and mathematics teachers. *Science Teacher Education, 81,* 29-50. doi: 10.1002/(SICI)1098-237X(199701)81:1<29::AID-SCE2>3.0.CO;2-3

Akerson, V. L. & McDuffie, A. R. (2002). The elementary science teacher as researcher. Paper presented at the meeting of the Association for the Education of Teachers in Science, Charlotte, NC.

Atkin, J. M. & Karplus, R. (1962). Discovery or Invention? *The Science Teacher, 29*(5), 45–51.

Ball, D. L. (2000). Bridging practices: Intertwining content and pedagogy in teaching and learning to teach. *Journal of Teacher Education, 51*(3), 241-247.

Bhattacharyya, S., Volk, T., & Lumpe, A. (2009). The Influence of an extensive inquiry-based field experience on pre-service elementary student teachers' science teaching beliefs. *Journal of Science Teacher Education, 20,* 199-218.

Bogdan, R., & Biklen, S. K. (2006). *Qualitative research for education: An introduction to theories and method.* Boston, MA: Pearson Education, Inc.

Bybee, R., Taylor, J., Gardener, A., Scotter, P. V., Powell, C. J., Westbrook, A., & Landes, N. (2006). *The BSCE 5e instructional model: Origins and effectiveness*. Retrieved from http://bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_Model-Full_Report.pdf.

Corbin, J. M., & Strauss, A. (2014). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Thousand Oaks, CA: Sage Publications, Inc.

Crawford, B. A. (1999). Is it realistic to expect a pre-service teacher to create an inquiry-based classroom? *Journal of Science Teacher Education, 10,* 175–194.

Creswell, J. W. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (3rd ed.). Upper Saddle River, NJ: Pearson/Merrill Prentice Hall

Davis, E., Petish, D., & Smithey, J. (2006). Challenges new science teacher's face. *Review of Educational Research. 76*(4), 607-651.

Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's ideas in science.* Milton Keynes, PA: Open University Press.

Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *The Journal of the Learning Sciences, 8*(3-4), 391–450.

Fantilli, R. D., & McDougall, D. E. (2009). A study of novice teachers: Challenges and supports in the first years. *Teaching and Teacher Education, 25(6),* 814-825.

Fazio, X., Melville, W., & Bartley, A. (2010). The problematic nature of the practicum: A key determinant of pre-service teachers' emerging inquiry-based science practices. *Journal of Science Teacher Education, 21*, 665-681.

Ferber, T., & Nillas, L. A. (2010). Through the eyes of student teachers: Successes and challenges in field teaching experiences. *National Teacher Education Journal*, *3(2)*, 61-85.

Gerber, B. L., Cavallo A. M. L., & Marek E. A. (2001). Relationships among informal learning environments, teaching procedures and scientific reasoning ability, *International Journal of Science Education, 23*(5), 535-549.

Giebelhaus, C. R., & Bowman, C. L. (2002).Teaching mentors: Is it worth the effort? *The Journal of Education Research, 95*(4), 246-254.

Graham, B. (2006). Conditions for successful field experiences: Perceptions of cooperating teachers. *Teaching and Teacher Education, 22*(8), 1118-1129.

Grant, C. A., & Gillette, M. (2006). A candid talk to teacher educators about effectively preparing teachers who can teach everyone's children. *Journal of Teacher Education, 57*(3), 292-299.

Guion, L.A., Diehl, D.C., & McDonald D. (2011). Triangulation: Establishing the validity of qualitative studies (pp. 1-3). University of Florida. Retrieved from http://edistt.ifas.ufl.edu/pdffiles/FY/FY39400.pdf

Hanuscin, D., & Lee, M. H. (2008). Using the learning cycle as a model for teaching the learning cycle to preservice elementary teachers. *Journal of Elementary Science Education, 20*(2), 51-66.

Hein, G. E. (1991). *Constructivist Learning Theory: The Museum and the Needs of People*. Retrieved from http://www.exploratorium.edu/ifi/resources/research/constructivistlearning.html

Hokayem, H. (2014). *Creative Thinking: Science* [Syllabus]. College of Education, Texas Christian University, Fort Worth, TX.

Hong, J., & Greene, B. (2011). Hopes and fears for science teaching: The possible selves of preservice teachers in a science education program. *Journal of Science Teacher Education, 22,* 491-512. doi: 10.1007/s10972-011-9247-y

Kagan, D. M. (1992). Professional growth among preservice and beginning teachers. *Review of Educational Research, 62*(2), 129-169.

Kang, E. J. S., Bianchini, J. A., & Kelly, G. J. (2013). Crossing the border from science student to science teacher: Preservice teachers' views and experiences learning to teach inquiry. *Journal of Science Teacher Education, 24*, 427-447.

Karplus, R., Thier, H., Lawson, C., Knoll, R., & Montgomery, M. (1967). *Science curriculum improvement study*. Chicago, IL: Rand McNally.

Klein, V. A. (2015). Let's play that again! Engaging students in ecology by using instructional games. *Science Scope.*

Lawson, A. E., Abraham, M. R., & Renner, J. W. (1989). *A theory of instruction: Using the learning cycle to teach science concepts and thinking skills*. National Association for Research in Science Teaching. Cincinnati, OH.

Lee, O., Hart, J. E., Cuevas, P., & Enders, C. (2004). Professional development in inquiry-based science for elementary teachers of diverse student groups. *Journal of Research in Science Teaching, 41*(10), 1021-1043.

Luera, G. R., Moyer, R. H., & Everett, S. A. (2005). What type and level of science content knowledge of elementary education students affect their ability to construct an inquiry-based science lesson? *Journal of Elementary Science Education, 17*(1), 12-25.

Lotter, C. (2004). Preservice science teachers' concerns through classroom observations and student teaching: Special focus on inquiry teaching. *Science Educator, 13*(1), 29-38.

McDonnough, J. T., & Matkins, J. J. (2010). The role of field experience in elementary preservice teachers' self-efficacy and ability to connect research to practice. *School Science and Mathematics*, *110*(1), 13-23.

McLeod, S. A. (2015). Jean Piaget. Retrieved from www.simplypsychology.org/piaget.html

Meador, G. (1988). *The Piagetian Intelligence Model and the Learning Cycle*. Retrieved from http://www.bhsphysics.org/papers/

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national standards in science education.* Washington, DC: National Academy Press.

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

Sadler, T. D. (2006). "I won't last three weeks": Preservice science teachers reflect on their student-teaching experiences. *Journal of Science Teacher Education, 17*, 217-241.

Schulz, R., & Mandzuk, D. (2005). Learning to teach, learning to inquire: A 3-year study of teacher candidates' experiences. *Teaching and Teacher Education, 21*, 315-331.

Sickel, A. J., & Friedrichsen, P. (2015). Beliefs, practical knowledge, and context: A longitudinal study of a beginning biology teacher's 5E unit. *School Science and Mathematics, 115(2)*, 75-87

Stoddart, T., Abrams, R., Gasper, E., & Canaday, D. (2000). Concept maps as assessment in science inquiry learning: A report of methodology. *International Journal of Science Education*, *22*(12), 1221–1246.

Stotter, J., & Gillon, K. (2010, September). *Diversity Challenge Resilience: School Libraries in Action:* Proceedings of the 12th Biennial School Library Association of Queensland, the 39th International Association of School Librarianship Annual Conference incorporating the 14th International Forum on Research in School Librarianship (pp. 1-7), Brisbane QLD Australia.

Strauss, A. & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage Publications.

Tamir, P. (1990). Factors associated with the relationship between formal, informal, and nonformal science learning. *Journal of Environmental Education, 22*, 34-42.

Walbert, D. (n.d.). *The learning cycle*. Retrieved from http://www.learnnc.org/lp/pages/663

Windschitl, M., & Thompson, J. (2006). Transcending simple forms of school science investigations: The impact of pre-service instruction of model-based inquiry. *American Educational Research Journal, 43*(4), 783-835.

Wilson, C. D., Taylor, J. A., Kowalski, S. M., & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching, 47,* 276-301. doi: 10.1002/tea.20329

Workshop: Constructivism as a Paradigm for Teaching and Learning (n.d.). Retrieved from http://www.thirteen.org/edonline/concept2class/constructivism/

Yoon, H.-G., Joung, Y. J., & Kim, M. (2012). The challenges of science inquiry teaching for pre-service teachers in elementary classrooms: Difficulties on and under the scene. *Research in Science Education, 42*, 589-608. doi: 10.1007/s11165-011-9212-y

Zembal-Saul, C., Starr, M., & Krajcik, J. S. (1997). Preparing elementary science teachers: An application of research and practice. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (NARST), Chicago, Illinois.

Appendix A

Pre-course Survey: 1

Name: *P-35*

1. How many science courses did you take in high school? What are they?

A: 3 - Biology, Chemistry, Physics

2. Have you taken any science courses before this semester at TCU? What are they?

A: Yes - Biology, Natural Disasters & Failures

3. What grade level are you planning to teach?

A: 3rd and 4th grade

4. What do you expect to learn in this course?

A: How to successfully teach students different content areas of science and to gain more skills and teaching strategies.

5. In your opinion what is the best way to teach science?

A: With hands-on activities and detailed instructions.

6. Give an example of when you learned a science topic well and why? Explain in detail.

A: I really enjoyed learning about chemical reactions in high school because it was very detailed and hands-on and I could see the content I was learning in front of my face.

7. Have you heard about inquiry? In your opinion, what is it?

A: Not specifically, but maybe asking questions?

8. Do you think inquiry has advantages? If yes, what are they? If no, why not?

A: Yes, I think it is important for students to ask questions when they are confused. Questions help students gain insight and knowledge about a topic.

9. Do you think inquiry has challenges? Why or why not?

A: No

10. What type of challenges do you think inquiry has?

A: I am not sure.

Appendix B

Post-course Survey:

Name: P-35

1. Which grade level did you teach?

A: The two grade levels my partner and I observed this semester were 3rd grade at Dallas Park Elementary School and 5th grade at Westcliff Elementary School. The grade level we taught in the field was 5th grade.

2. What did you learn in this course?

A: This semester, I learned that science is not just experiments, but explaining and making connections. The 5E model is a great tool to use when planning a lesson. I also learned that it is important to use different ways to approach a concept so students get a better understanding.

3. In your opinion what is the best way to teach science?

A: In my opinion, the best way to teach science is by combining hands-on activities with straight-up content (PowerPoints, handouts, etc.). By utilizing multiple techniques, it gives students various ways to understand and absorb the information presented to them. Hands-on activities are so important to incorporate in science lessons. It gives students the opportunity to really figure out the concept for themselves, and allows them to apply it to a real life situation in front of them. It is obviously important to present the students with the information via note taking, etc. because it gives them straightforward information that they can refer back to. Having a balance between the two is important and a great way to teach science.

4. Give an example of when you learned a science topic well and why? Explain in detail.

A: One concept that I learned a lot about in this course this year was the concept of natural selection. When we learned about it, we did a hands-on activity with varying sizes of clips. At our tables, we were supposed to 'eat' the 'food' provided, and each beak size had to get a different amount of calories in order to survive and/or reproduce. This really showed the concept of natural selection because I could see that when a certain food runs out or there are other species that survive easier or are stronger, others will die out. We then review different concepts and vocab words, and

connected it to other real-life examples. This lesson was extremely beneficial to me as both a future teacher and a pretend student. I was able to put myself in the shoes of a student and really see how important it is to use activities to teach a concept. I now remember how my beak size got killed off because there was not enough food that I was able to catch-the perfect specific explanation for natural selection.

5. What is inquiry in your opinion?

A: In my opinion, inquiry is a process of gaining an understanding of the scientific world through questioning and wonder.

6. Do you think inquiry has advantages? If yes, what are they? If no, why not?

A: There are definitely advantages to inquiry. Inquiry allows you to question different concepts, and probe further thinking. It also allows you to wonder about why some things are a certain way, and how and why some things work. There are a lot of possibilities and opportunities with inquiry, and it allows a person to gain a deep and detailed understanding of a concept by asking questions and fulfilling their wonder. You can find out solutions and answers to questions by using inquiry.

7. Do you think inquiry has challenges? Why or why not?

A: There are also disadvantages to inquiry as well. There are disadvantages because, like almost anything in life, inquiry is not a flawless concept, and there is bound to be something that does not work perfectly.

8. What type of challenges do you think inquiry has?

A: One of the disadvantages of inquiry is that sometimes, a person might not be fully satisfied by the answer they receive from using inquiry. Other times, a person might be confused by the findings they receive when using inquiry to understand a concept. A person might also receive more than one outcome, which can be frustrating and unwanted. Inquiry does not always promise an answer or an understanding, so a disadvantage is that there might not be one as well.

Appendix C

Interview Questions

Name: P-28

Interviewer: Which grade level did you teach in your field experience?

Interviewee: I was in both second grade and fifth grade.

Interviewer: What was your best experience while taking this course?

Interviewee: I think probably teaching like coming up with a lesson plan and doing in the class just because I don't know it was really interesting to see like what worked in the class with the big class because when we are in the field, most of the times teachers don't let you to take over the entire class. They only want you to take small group, so you know its lot different working with a small group than a large class. So, I really enjoyed that part of the course.

I really enjoyed doing experiments too at the beginning because they help you get new ideas of how to do stuff in the class and stuff like that. I saw like what really works, what might be changed. I know when we were doing like the density and stuff like that may be do some stuff differently with different grade levels. It was just interesting to see how you modify it for any grade level.

Interviewer: After your field experiences and taking this course, what do you think are some of the challenges for teaching science in schools?

Interviewee: I think the biggest one probably is trying to find something that is fun for the kids doing also can get across the content at the same time. Just try to come up with like a good experiment and try to know stuff like before-hand that happens and try to like prepare for that because I know sometimes like something can go wrong that really unexpected. When we are doing lesson in the field, we did give them magnets and they were sticking magnets on the computer. We were like No! no! don't really do that stuff like that but I don't want to hinder them exploring because the point was to see what magnets would stick around the room. Because we started out with a little bag, there is some stuff in there that was magnetic. We want them to take what we talked about with those go outside and find it. So kind of hard preparing and stuff like that in the field.

Interviewer: Did you face any challenges while using the 5E model of instruction? If yes, what are they?

Interviewee: With the 5E model, the *Extend* part, I feel like that it was lot extra stuff, I just thought like sometimes the *extend* thing was not necessary. Sometimes I could like put as little as possible because I thought I got everything I wanted to do with elaborate and explore.

Only these were challenges using 5E model that's because I really like 5E because it really helps you map everything out, so it is really good to plan. She gave us a lesson plan or model lesson plan which was not as detailed, it was basically do this and the 5E model is like you need to have clearly how to introduce lesson and work our way into. So, uh! But the thing is, I don't know usually if you do it over a period of time, because within a one day period it's really hard to fit that entire 5E model in it. When we are teaching our lesson in the class. We kind of went over a time a little bit I noticed because it was so much stuff to do and some activities require a longer time, so the 5E model works best if you have multiple days to do it over within one day period. May be because if you have a longer class periods, we only had 30 minutes. I am sure if we had 50 minutes it would be good. But I feel like in lower grades it's better to do over a period of time, it could be over whelming to some of the students.

Interviewer: In your opinion what can help you in overcoming the challenges of teaching with the 5E model?

Interviewee: The biggest thing is we having more time to think and another thing I think that helps you is if I was able to collaborate with the teacher and tell ok! Here it is! I could not do it. Because for a while e- mail we were trying to send our teacher was not working. Stuff like that. It is really hard for them to like, they taught a lot, so I wanted them to see like you know if it is like first year teacher, are you still like getting into it is to have veteran teacher look it over and just like give some pointers on like change everything be like ok! This is good, Kind of let them, if you like see a mistake, let them go through that and let them experience it. That way for the next time, like still give them points and stuff and then afterwards say this is what I could have done in this situation. I feel like the collaboration is the most important part. It is always best to have as many people can put on what you are trying to teach the kids.

Interviewer: Share your experiences from your field experience during which you felt students learnt better using the 5Emodel.

Interviewee: From what I saw that the kids like they get most is when they work in groups. Individually, they would just talk and do all that kind of stuff. When worked in groups sometimes they might go off task but ultimately they got to the goal lot faster and it is easy for them to understand. If one student doesn't understand something another students can help him. So kind of like self-teaching so you don't have to be on top every single kid, you have little breathing room.

Interviewer: Share the experiences of the challenges of using the 5E in the field.

Interviewee: Just working with individual kids is the hardest thing. The struggle when they don't understand it and you are trying to get it across and you are trying to reword like how you say stuff I think that's more difficult. When I was trying to teach Math lesson they found way to do these fractions but I understand that you guys understand that way but let's try to find another way. When I watched the video I realized maybe I should reword that differently. So, actually when you are in the field talking with the kids it is important how you word everything and communicate ideas in a way each kid can understand.

Interviewer: Was the 5E more challenging the field than in peer teaching? Why or why not?

Interviewee: I felt it was more challenging at the field because, it's just lot different when you actually have young kids who is trying to work with you because they are trying to learn it versus when we are teaching to peers in the classroom everyone knows we did layers of the earth so we are just shrug through the lesson. When I tried to explain how magnets work it took a lot longer so that is just more difficult. It is just because of area between intellects.

Interviewer: Give an example of some of the pros and cons of the 5E Model?

Interviewee: The biggest pro like I said earlier is it really helps you map it out and helps you become thorough with it. As you know with the laboratory you have to go like go on with it. Some stuff with *extend*, sometimes it works well and sometimes its jut like extra fat, which is like we don't need that just shave that off.

Appendix D

Peer teaching Evaluation Criteria:

Name: PSTW-44, PSTW-31 (High)

Title: Parts of a food web

Objective: Students will identify parts of the food web.

Table D1

Criteria	Points	Comments
Was the objective of the lesson clear and did you start by telling us this objective	5/5	Yes! Objective of the lesson was clear and they did start the lesson by saying the objective.
Did you have an interesting and engaging introduction	5/5	They started with the idea and built on it from students' prior knowledge which was very interesting. They asked few questions: Q1: What is food web? Name its parts (ANSWERS: animals are connected, layered) Q2: What do you remember from the food web lesson Dr. H taught us? Q3: Can you give examples of three animals in food web.
Did you give clear instructions for the hands on activities	5/5	Gave clear instructions and the timer on the PPT was a great idea. The PPT was well organized.
Were you well prepared for the lesson, did you have all the materials you needed	5/5	Excellent preparation!
Were the activities purposeful in investigating the concept you want us to learn (hands on part)	5/5	Very purposeful activities, and the students enjoyed the creative elements of the activity Activity: Be an explorer and write an article for National Geographic. Students were supposed to pick an animal and make their own masks, decide which order they need to go in food chain and, divide the Kilocalories. This activity was good as students had fun making masks, at the same time they tried to discover who eats whom.

		Good explanation about the unit (kilo calories)
Were the discussions during and after the activities purposeful in teaching us about the concept	3.5/5	The questions were good, but there is a need for the discussions of how and why energy is lost. They failed to discuss how that affects the ecosystem (energy is not recycled and we're dependent on the sun for energy).
Did you have an interesting and engaging assessment question that pushed our thinking of the concept	4/5	They had good assessment, but I would try to have a question that can push the thinking further.
Did we learn the appropriate and adequate scientific explanation from this lesson	3.5/5	They touched upon a crucial idea Energy Pyramid, but they need to make that explicit as to why this happens. Also there is a need to show the importance of this to the ecosystem (energy is never recycled so we need a constant supply, if no sun, we all die).
Did you have good eye contact, loud enough voice and communicated enthusiasm to the class?	5/5	They had a very approachable and fun personality in the class.
Did you use different instructional strategies and media sources?	5/5	They did not use different media sources but used different instructional strategies.
TOTAL	46/50	
Timing:	32 minutes	

Name: PSTW-30, PSTW-53 (Medium)

Title: Properties of matter

Objective: To identify three states of matter and distinguish them.

Table D2

Criteria	Points	Comments
Was the objective of the lesson clear and did you start by telling us this objective	1.5/5	The objective was not clear. They said, we will talk about matter but were not clear what the objective was, what exactly about matter.
Did you have an interesting and engaging introduction	4/5	Students were asked to imagine that they were in the ice hotel and they

		gave cards with solid, liquid and gas written. Asked students to say what ice block is? Students answered solid. For which they gave positive reinforcement and explained about solids. Continued the activity with liquid, and gas. I also liked how they asked students what matter is, but students ideas such as “stuff” or “something that matter” were not explored.
Did you give clear instructions for the hands on activities	4.5/5	Clear instructions, PPT was very well organized.
Were you well prepared for the lesson, did you have all the materials you needed	4.5/5	Well prepared.
Were the activities purposeful in investigating the concept you want us to learn (hands on part)	4/5	Activity: Students were given bag with pictures like gasoline, books, rain, steam, rocket exhaust and asked to classify using a table(under solid, liquid, gas) They made students explore with pictures, think about the concept of solids, liquids and matter. They asked students the criteria and their explanation for categorizing pictures. It was very interesting to see students come up with explanations.
Were the discussions during and after the activities purposeful in teaching us about the concept	3.5/5	Students asked certain questions (Is cloud gas? They answered saying yes as molecules are more spread out) I think your discussion needs to focus on the strategy of distinguishing states of matter by explaining molecular representation of solids, liquids, and gases.
Did you have an interesting and engaging assessment question that pushed our thinking of the concept	2.5/5	Besides assessing formatively and asking questions, I did not see any scenario or activity in the end that assessed their understanding. They could have been creative with this part of the lesson.
Did we learn the appropriate and adequate scientific explanation from this lesson	2.5/5	Their objective was to distinguish solid liquid and gas, but the criteria

		were not emphasized, and the relationship to the molecules was not explored. This leaves students with some confusion of how we can distinguish solids from liquids from gases.
Did you have good eye contact, loud enough voice and communicated enthusiasm to the class?	4/5	PSTW-30, you act things out with a lot of expression and kids will LOVE that in the classrooms. PSTW-53, I would just add a bit more enthusiasm when you teach alone
Did you use different instructional strategies and media sources?	4/5	Yes they did but no media sources.
Timing	32minutes	
TOTAL	35/50	

Name: PSTM-19, PSTM-7 (Low)

Title: Understanding Animal Cells

Objective: Students will identify parts of the cell and its functions.

Table D3

Criteria	Points	Comments
Was the objective of the lesson clear and did you start by telling us this objective	5/5	Clear objective, they did start the lesson by telling the objective.
Did you have an interesting and engaging introduction	3.5/5	Questions: Difference between plant and animal cell? Some functions of animal cell? Parts of animal cell? They had picture of plant and animal cell and told differences between them. Asking students to find differences could have made a more engaging introduction
Did you give clear instructions for the hands on activities	3.5/5	Not very clear instructions.
Were you well prepared for the lesson, did you have all the materials you needed	2/5	Font on the PPT was very small, too much content on the slides and did not prepare well for the lesson.
Were the activities purposeful in investigating the concept you want us to learn (hands on part)	1/5	Activities were not very purposeful to help students identify the parts as it is difficult for them to identify

		parts without knowledge of how they look or scientific explanation behind why they look like that. I think planning an intermediate activity like giving each table an organelle to study and report to the class could have helped.
Were the discussions during and after the activities purposeful in teaching us about the concept	2/5	I think there needs to be more discussion. The main activity was about the worksheet, and there needs to be more discussion about that. Encouraging students to discuss more helps rather than just delivering lectures. Asked students what they learnt from song and to tell functions of parts in their own words. Few replied as adults but not going to work with kids, find ways to make students talk more.
Did you have an interesting and engaging assessment question that pushed our thinking of the concept	1/5	No explicit assessment question. Lesson was very vague did not push students thinking.
Did we learn the appropriate and adequate scientific explanation from this lesson	0/5	Firstly, parts of the cell and its functions are not easy to teach in one class. It is not easy for anybody to learn so much content in such a little time. If someone already knows the material, it's like a revision. However, if someone is learning it, you need to have more discussion and emphasis on the ideas to help them learn about the lesson.
Did you have good eye contact, loud enough voice and communicated enthusiasm to the class?	3/5	Dull, could have raised your voices a bit higher so that everyone in the room can hear you.
Did you use different instructional strategies and media sources?	2/5	Yes, they did but not effectively.
Timing:	25minutes	
TOTAL	23/50	

Appendix E

Criteria for Evaluating Lesson plans: Field lesson plans:

Name: PSTW-41, PSTW-27 (High)

Lesson Title: What effects does gravity have on objects?

Objective: Students will be able to explain the forces of gravity by exploring how different objects move through air.

Table E1

Phase	Criteria	Grade	Comments
Engage	• Have a clear objective that students will learn after the lesson (5/5) • Interesting introduction (5/5)	10/10	Very clear objective and interesting engagement activity.
Explore	• Clear instructions of the activities (4.5/5) • Organized way of recording data and analyzing it (3.5/5)	8/10	Clear instructions, Asking students to record data in a table could have been helpful.
Explain	• Asking students CRITICAL questions that can lead them to the desired scientific explanation (4/5). • Mentioning how you will lead the discussion at different stages of the lesson and how you will relate the hands on (investigation) to the minds on (scientific explanation)(4/5)	8/10	Could have probed students more with critical questions.
Elaborate	• Mentioning one or two examples of how you will expand on what they have learned by mentioning other examples or relating it to real life.(_9/10)	9/10	Chose a very good way to elaborate the lesson.
Evaluate	• Having an assessment question that is specific to the scientific content you taught. The question has to be clearly written for students to understand it (4.5/5) • Having an sample answer to your specific question and how you will grade if you were to give it to the students (4.5/5)	9/10	Nice extension activity and good questions which push students thinking.
Total		44/50	High

Name: PSTM-24, PSTM-12 (Medium)

Title: Force and Motion

Objective: The objective of this lesson is for students to explore items moving down a ramp, collect information using measurements, record information using measurements, and to measure and compare objects using non-standard units

Table E2

Phase	Criteria	Grade	Comments
Engage	• Have a clear objective that students will learn after the lesson (5/5) • Interesting introduction (3/5)	8/10	Interesting engagement. Clear objective but demonstrating the pushing and pulling would have increased excitement in students.
Explore	• Clear instructions of the activities (4/5) • Organized way of recording data and analyzing it (4/5)	8/10	Good activity and ways to organize data.
Explain	• Asking students CRITICAL questions that can lead them to the desired scientific explanation (3/5) • Mentioning how you will lead the discussion at different stages of the lesson and how you will relate the hands on (investigation) to the minds on (scientific explanation)(3/5)	6/10	Good questions but explanations do not show desired scientific explanation behind the movements.
Elaborate	• Mentioning one or two examples of how you will expand on what they have learned by mentioning other examples or relating it to real life (/10)	5/10	Not interesting elaborate activity, it did not help students tie their understanding to real life situations.
Evaluate	• Having an assessment question that is specific to the scientific content you taught. The question has to be clearly written for students to understand it (4/5)	8/10	Good way of assessing students. Could have mentioned one or two examples.

	• Having an sample answer to your specific question and how you will grade if you were to give it to the students (4/5)		
Total		35/50	

Name: PSTW-40, PSTW-33 (Low)

Title: Classifying Objects

Objective: The objective of this lesson is for students to classify objects based on their observable properties including size, mass, shape, color/shade, and texture.

Table E3

Phase	Criteria	Grade	Comments
Engage	• Have a clear objective that students will learn after the lesson (5/5) • Interesting introduction (1/5)	6/10	Not an interesting way to start the lesson. I don't think 20 secs are enough to find two things which fit in their palms. No clarity in writing. Poor engagement activity.
Explore	• Clear instructions of the activities (2.5/5) • Organized way of recording data and analyzing it (2.5/5)	5/10	Vaguely written lesson plan. Poor exploring activity. No clarity in instructions.
Explain	• Asking students CRITICAL questions that can lead them to the desired scientific explanation (3/5) • Mentioning how you will lead the discussion at different stages of the lesson and how you will relate the hands on (investigation) to the minds on (scientific explanation)(3/5)	6/10	Did not mention how you will lead the discussions, could have added few questions which push students to think.
Elaborate	• Mentioning one or two examples of how you will expand on what they have learned by mentioning other examples or relating it to real life (2/10)	2/10	No link to the video. No examples written or any questions.

Evaluate	• Having an assessment question that is specific to the scientific content you taught. The question has to be clearly written for students to understand it (_2/5) • Having an sample answer to your specific question and how you will grade if you were to give it to the students (_2/5)	4/10	No assessment activity or questions. Simply asked students to discuss. Did not mention any sample answer or grading criteria
Total		23/50	

Peer Teaching Lesson Plans:

Name: PSTM-25, PSTM-18 (High)

Title: Complete and Incomplete Metamorphosis.

Objective: For the students to be able to define metamorphosis and differentiate between complete and incomplete metamorphosis

Table E4

Phase	Criteria	Grade	Comments
Engage	• Have a clear objective that students will learn after the lesson (4/5) • Interesting introduction (4/5)	8/10	Very interesting engagement and clear objective. Book reading could have been more creative to engage students.
Explore	• Clear instructions of the activities (4/5) • Organized way of recording data and analyzing it (4/5)	8/10	Instructions could have been better and could have asked students to make note of the Venn diagram in their journals. Estimated unrealistic time slot.
Explain	• Asking students CRITICAL questions that can lead them to the desired scientific explanation (4/5)	8.5/10	Did not have any critical questions but the activity was very

	• Mentioning how you will lead the discussion at different stages of the lesson and how you will relate the hands on (investigation) to the minds on (scientific explanation)(4.5/5)		interesting and helpful. .
Elaborate	• Mentioning one or two examples of how you will expand on what they have learned by mentioning other examples or relating it to real life	8.5/10	Good way to elaborate the lesson. Before asking students to do so, could have shown examples.
Evaluate	• Having an assessment question that is specific to the scientific content you taught. The question has to be clearly written for students to understand it (4/5) • Having an sample answer to your specific question and how you will grade if you were to give it to the students (4/5)	8/10	Very good assessment activity but did not mention the grading criteria.
Total		41/50	

Name: PSTW-28, PST-32 (Medium)

Title: Structure of the Earth

Objective: The student is expected to: build a model to illustrate the structural layers of Earth, including the inner core, outer core, mantle, crust, asthenosphere, and lithosphere.

Table E5

Phase	Criteria	Grade	Comments
Engage	• Have a clear objective that students will learn after the lesson (4/5) • Interesting introduction (4/5)	8/10	Clear objective and interesting engagement.
Explore	• Clear instructions of the activities (3/5) • Organized way of recording data and analyzing it (3/5)	7/10	Ask questions which push students to think and compare what they modelled and observed in the video/ slides.
Explain	• Asking students CRITICAL questions that can lead them to the desired scientific explanation (4.5/5)	9/10	Very good questions. T charts,

	• Mentioning how you will lead the discussion at different stages of the lesson and how you will relate the hands on (investigation) to the minds on (scientific explanation)(4.5/5)		discussions and making flip book altogether seems unrealistic with the time they mentioned but, good scientific explanation if implemented as planned.
Elaborate	• Mentioning one or two examples of how you will expand on what they have learned by mentioning other examples or relating it to real life	6/10	Good video to elaborate the lesson and good questions.
Evaluate	• Having an assessment question that is specific to the scientific content you taught. The question has to be clearly written for students to understand it (0/5) • Having an sample answer to your specific question and how you will grade if you were to give it to the students (5/5)	5/10	Did not mention questions but had grading criteria. That is too much information for one lesson.
Total		36/50	

Name: PSTM-23, PSTM-10 (Low)

Title: Plate Tectonics

Objective: The objective of this lesson is for students to understand how tectonic plates interact with each other at their boundaries.

Table E6

Phase	Criteria	Grade	Comments
Engage	• Have a clear objective that students will learn after the lesson (2.5/5) • Interesting introduction (2.5/5)	5/10	Good engagement and clear objective but have ways to assess students for their prior knowledge about the topic rather than jumping directly into the topic. Unrealistic

			time slot for this phase.
Explore	• Clear instructions of the activities (4/5) • Organized way of recording data and analyzing it (0/5)	4/10	Instructions could have been clearer. No organized way of recording data.
Explain	• Asking students CRITICAL questions that can lead them to the desired scientific explanation (_2.5/5) • Mentioning how you will lead the discussion at different stages of the lesson and how you will relate the hands on (investigation) to the minds on (scientific explanation)(_1.5/5)	4/10	Could have asked more questions which push students thinking about the plate movements. No ways mentioned to related hands-on and minds-on parts of the lesson. Failed to discuss the observations after experiments
Elaborate	• Mentioning one or two examples of how you will expand on what they have learned by mentioning other examples or relating it to real life (__/10)	4/10	Ask the students to give some examples rather than just showing them examples.
Evaluate	• Having an assessment question that is specific to the scientific content you taught. The question has to be clearly written for students to understand it (5/5) • Having an sample answer to your specific question and how you will grade if you were to give it to the students (_2/5)	7/10	Good way to assess, no grading criteria
Total		24/50	

Appendix F

PSTs	Field Lesson Plans	Peer Teaching Lesson Plans	Peer Teaching Sessions
PSTM-1	33(M)	32(M)	31(M)
PSTM-2	41(H)	38(M)	37(M)
PSTM-3	32(M)	40(H)	42(H)
PSTM-4	31(M)	36(M)	37(M)
PSTM-5	40(H)	30(M)	29(M)
PSTM-6	36(M)	40(H)	44(H)
PSTM-7	24(L)	21(L)	23(L)
PSTM-8	36(M)	40(H)	44(H)
PSTM-9	40(H)	30(M)	29(M)
PSTM-10	34(M)	24(L)	24(L)
PSTM-11	41(H)	38(M)	37(M)
PSTM-12	35(M)	34(M)	40(H)
PSTM-13	36(M)	37(M)	38(M)
PSTM-14	36(M)	37(M)	38(M)
PSTM-15	41(H)	38(M)	37(M)
PSTM-16	25(L)	29(M)	32(M)
PSTM-17	31(M)	36(M)	37(M)
PSTM-18	34(M)	41(H)	43(H)
PSTM-19	24(L)	21(L)	23(L)
PSTM-20	41(H)	36(M)	37(M)
PSTM-21	30(M)	37(M)	38(M)
PSTM-22	41(H)	36(M)	37(M)
PSTM-23	34(M)	24(L)	24(L)
PSTM-24	35(M)	29(M)	32(M)
PSTM-25	34(M)	41(H)	43(H)
PSTM-26	25(L)	34(M)	40(H)
PSTW-27	44(H)	32(M)	39(M)
PSTW-28	25(L)	34(M)	37(M)
PSTW-29	34(M)	38(M)	41(H)
PSTW-30	24(L)	29(M)	35(M)
PSTW-31	40(H)	42(H)	46(H)
PSTW-32	30(M)	34(M)	37(M)
PSTW-33	23(L)	24(L)	23(L)
PSTW-34	24(L)	27(L)	33(M)
PSTW-35	32(M)	34(M)	30(M)
PSTW-36	34(M)	24(L)	23(L)
PSTW-37	34(M)	34(M)	35(M)
PSTW-38	32(M)	41(H)	45(H)
PSTW-39	40(H)	31(M)	34(M)
PSTW-40	23(L)	36(M)	39(M)
PSTW-41	44(H)	34(M)	35(M)

PSTW-42	34(M)	34(M)	37(M)
PSTW-43	25(L)	36(M)	39(M)
PSTW-44	40(H)	40(H)	46(H)
PSTW-45	34(M)	36(M)	36(M)
PSTW-46	29(M)	31(M)	32(M)
PSTW-47	32(M)	27(L)	39(M)
PSTW-48	34(M)	34(M)	30(M)
PSTW-49	32(M)	41(H)	45(H)
PSTW-50	34(M)	38(M)	41(H)
PSTW-51	32(M)	32(M)	39(M)
PSTW-52	34(M)	36(M)	33(M)
PSTW-53	29(M)	29(M)	35(M)
PSTW-54	34(M)	35(M)	36(M)
PSTW-55	40(H)	36(M)	33(M)
H%M%L%	23.64%H, 58.18%M, 18.18%L	16.36%H, 69.09%M, 14.55%L	23.64%H, 65.45%M, 10.91%L

VITA

Personal Background	Ramya Krishna Enugu Fort Worth, Texas
Education	Bachelor of Pharmacy, Jawaharlal Nehru Technological University, Hyderabad, India, 2009 Masters of Education, Texas Christian University, Fort Worth, Texas, 2016
Experience	Teaching Assistantship, Texas Christian University, 2014-2016