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How Select Groups of Preservice Science Teachers with Inquiry Orientations View Teaching and Learning Science through Inquiry

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How Select Groups of Preservice Science Teachers with Inquiry Orientations View Teaching and Learning Science through Inquiry

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by

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Abstract

Although hailed as a powerful form of instruction, in most teaching and learning contexts, inquiry-based instruction is fraught with ambiguous and conflicting definitions and descriptions. Yet little has been written about the experiences preservice science teacher have regarding their learning to teach science through inquiry. This project sought to understand how select preservice secondary science teachers enrolled in three UTeach programs in Arkansas conceptualize inquiry instruction and how they rationalize its value in a teaching and learning context. The three teacher education programs investigated in this study are adoption sites aligned with the UTeach Program in Austin, TX that distinguishes itself in part by its inquiry emphasis.

Using a mixed method investigation design, this study utilized two sources of data to explore the preservice science teachers' thinking. In the first phase, a modified version of the Pedagogy of Science teaching Tests (POSTT) was used to identify select program participants who indicated preferences for inquiry instruction over other instructional strategies. Secondly, the study used an open-ended questionnaire to explore the selected subjects' beliefs and conceptions of teaching and learning science in an inquiry context. The study also focused on identifying particular junctures in the prospective science teachers' education preparation that might impact their understanding about inquiry.

Using a constant comparative approach, this study explored 19 preservice science teachers' conceptions about inquiry. The results indicate that across all levels of instruction, the prospective teachers tended to have strong student-centered teaching orientations. Except subjects in for the earliest courses, subjects' definitions and descriptions of inquiry tended toward a few of the science practices. More advanced subjects, however, expressed more in-depth descriptions. Excluding the subjects who have completed the program, multiple subjects tended to associate inquiry learning exclusively in terms of exploring before lecture, getting a single correct answer. Additionally, various subjects at multiple levels, described inquiry in terms of the 5E Model of Instruction, which is emphasized in the Arkansas UTeach lesson design. Implications of these findings and suggestions for program improvement at the course levels are suggested.

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CHAPTER 1: INTRODUCTION

How Select Groups of Preservice Science Teachers with Inquiry Orientations View Inquiry Instruction

Statement of the Problem

> *Science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge. Both elements-knowledge and practice-are essential."* (National Research Council [NRC], 2012, p.26).

In the history of science education, the teaching and learning of science has been fraught with ongoing discussions about *what* science content should be taught, and perhaps more prolific, are the discussions about *how* science should be taught (DeBoer, 1991). In both contexts, *inquiry* permeates discussions regarding science education reform (Crawford, 2014; NRC, 2012; Osborne, 2014) necessary to achieve the visionary expression about what students should know and do by the time they graduate from high school (NRC, 2012).

Scientific inquiry in the classroom is powerful. Not only does it reflect how scientists learn about the natural world, but also it is also at the heart of how students learn science (Donavon & Bransford, 2005). Although classroom teachers must develop the capacity to implement a *variety* of instructional approaches to meet the diverse needs of all learners (Bransford, Brown, & Cocking, 2000; NRC, 2000; NRC, 2010), teaching and learning science through inquiry is a desirable teaching practice that has long been recommended due to its potential for helping students learn science with understanding (NRC, 1996; NRC, 2000; NRC, 2010; Schwab, 1960). Founded on the principles of how people learn (Bransford et al., 2000; NRC, 2000), inquiry teaching makes cognitive demands on students that more traditional didactic classroom science instruction rarely does (Osborne, 2014). Perhaps, more importantly, however, inquiry learning parallels, to some degree, how scientists do science, and it provides a more fruitful context for students to learn about how science knowledge itself develops (Lederman, Lederman, Antink, 2013; NRC, 1996) even as they learn the underlying science concepts.

Contemporary references to inquiry in education are largely shaped by the *National Science Education Standards* (NSES) (NRC, 1996), which devoted considerable emphases to scientific inquiry:

> *Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.* (p. 23)

The definition of inquiry in the *NSES* identified multiple contexts that affect the teaching and learning of science. First, inquiry is what scientists do in pursuit of studying the natural world. Although having students do science like scientists is not a goal of education, having them participate in *science like* processes (doing inquiry) is intended by the *NSES*. Students should also learn about scientific inquiry because it is the foundation on which all science knowledge rests. Also, in conjunction with these inquiry goals, students are to develop knowledge and understanding of science concepts (the principles, theories, and ideas), otherwise known as *learning science* (Hodson, 2014) while engaging in the inquiry practices.

In any teaching or learning contexts, inquiry has some shared core components. The *NSES* (NRC, 1996) and its related publication, *Inquiry and the National Science Education Standards* (*INSES*) (NRC, 2000) described five *essential features of inquiry* that students should engage with as they learn to do inquiry. A more recent proposal for shared science teaching/learning standards *A Framework for K-12 Science* Education (*Framework*) (NRC, 2012) describes eight Science and Engineering Practices (SEP) that are similar to the essential features of inquiry in the *NSES*. Together these documents identify for teaching and learning purposes a level of student cognition and thinking involved in inquiry processes. See Table 1.1 for a list of the essential features and SEPs. For convenience, in this study context, future references to these essential features and science practices are termed *inquiry practices,* which include both procedural (e.g. making systematic observations and conducting investigations) *and* rational or logical aspects (e.g. explaining, arguing and defending, using evidence) of doing inquiry.

TABLE 1.1

A Comparision of the Essential Features of Inquiry (NRC, 1996; 2000) with the Science and Engineering Practices (NRC, 2012)

Essential Features of Inquiry (NSES)	Science and Engineering Practices (NGSS)
• Learner engages in scientifically oriented questions • Learner gives priority to evidence in responding to questions • Learner formulates explanations from evidence • Learner connects explanations to scientific knowledge • Learner communicates and justifies explanations	• Asking questions and defining problems • Developing and using models • Planning and carrying out investigations • Analyzing and interpreting data • Using mathematics and computational thinking • Constructing explanations and designing solutions • Engaging in argument from evidence • Obtaining, evaluating, and communicating information

The teaching and learning of science through inquiry may take many forms depending on the number of inquiry practices applied and expected and the degree of teacher guidance provided during any learning event. As such, all inquiry teaching and learning is not equal. *INSES* (NRC, 2000) published a matrix delineating an inquiry continuum that ranged from a teacher-centered structured inquiry to a more student-centered open form of inquiry. The matrix describes variations of inquiry based on the amount of teacher provided structure and subsequent student responsibility during an inquiry-based teaching and learning event. For example, on one end of the continuum, in a structured inquiry event, the teacher may provide students the guiding question, materials and other resources, perhaps even data, and ask students to develop their own conclusions about the topic. However, in a more open inquiry, the students may be expected to design an investigation from start to finish even posing their own question to investigate. As such the latter inquiry context gives students more responsibility for the learning event and will include more of the inquiry practices. (More information about the inquiry continuum is found in Chapter 2.) Although students are not expected to participate in all the inquiry practices during all learning opportunities (NGSS Lead States [Appendixes], 2013), components of inquiry should pervade all learning opportunities (Osborne, 2014) as students pursue knowing and understanding science content. Neither are the inquiry practices supposed to operate in isolation of one another; rather, they should overlap and interconnect at times.

Articulating the specific context for inquiry in any study is critical to understanding the premises. The *NSES* (NRC, 1996; 2000) describe inquiry in three learning contexts: (a) what students should be able to do (developing abilities to do inquiry), (b) what they should learn about (the nature of inquiry), and (c) a way for students to learn science through inquiry. Whereas the first two contexts are content goals, the latter focus implicates inquiry as a teaching strategy, which is the least understood context of all (Anderson, 2007). Whereas Crawford, 2014) defines *teaching science as inquiry* in terms of both the learning outcomes *and* the pedagogy of inquiry, I contend a simpler definition is warranted to effectively study what prospective science teachers understand about inquiry instruction. Expecting students to learn science concepts while doing inquiry and explicitly learn about inquiry at the same time is a complex task that even the most proficient of students will struggle, and the most experienced teachers will falter. Therefore, to avoid the mistake of too many goals in any single teaching and learning event (Hodson, 2014), in this study, I refer to the pedagogy of inquiry as what the teacher does to engage students in learning science through inquiry (which could include, but does not presume having students learn about inquiry). Furthermore, I used Minner, Levey, and Century's (2009) definition of inquiry instruction, which is broadly defined: Teaching science as inquiry means students are (a) engaged in learning content, (b) engaged in one or more of the inquiry practices, and (c) students have some measure of student responsibility for their own learning. In the study reported here, student responsibility means students have to make some measure of decisions related to their learning processes (e.g. what to explore and investigate, how to do it, how to interpret findings etc.) (Minner et al., 2009). Inquiry teaching and learning refers to a guided inquiry such that student responsibility and subsequent teacher guidance can fall anywhere on the inquiry continuum depending on the learning target. This study does not attempt to identify particular levels of inquiry as more meritorious over another; rather the purpose of the lesson should determine the level of inquiry. In any event, however, engaging students in the inquiry practices refer to the procedural and cognitive elements of inquiry - as described in Table 1.1.

Inquiry learning activities can take multiple forms (e.g. research on line, engaging in collaborative projects, reading the textbook, considering case studies, hypothesis testing, discussions etc.). Whatever the methods, inquiry teaching shifts the educational focus from memorizing and skill development to cognitive development (reasoning, evaluating, explaining and defending) in route to helping students develop understanding about targeted content specific outcomes (e.g. learning Newton's 2nd Law of motion, or learning about Newton, the man, in order to develop a greater understanding about the nature of science). Also, inquiry teaching and learning is "language intensive and requires students to participate in classroom science discourse" (NGSS Lead States [Appendixes], 2013, p. 3) while integrating both knowledge and practices (Bybee et al., 2010; NRC, 2012). Such approaches help students develop conceptual understanding of science concepts, develop their abilities to conduct investigative processes, and helps them develop their abilities to think logically and critically (NRC, 1996; 2000) (what I refer to as the rational aspects of doing inquiry).

The idea that all science subject matter should or even could be taught by inquiry methods is a myth (NRC, 2000) and is also impractical, impossible, and unwarranted (Osborne, 2014). Rather, teachers must be able to implement a range of instructional strategies to help students learn science with understanding (NRC, 2006; 2012). Inquiry-based science instruction is only *one* way of many to help meet the challenges for achieving a degree of science literacy (Chamberlain & Crane, 2008; NRC, 1996; 2000).

Despite decades of reform efforts to prioritize it as a valuable teaching strategy, "The evidence indicates that teaching science as inquiry is not now, and never has been, in any significant way, implemented" in classrooms in a widespread fashion (Bybee, 2010, p.138). The truth is that scientific inquiry even as a critical component of teaching and learning in the science classroom is a confounding, ambiguous concept that is often conspicuously absent from institutional settings (Bybee, 2000; 2010; Settlage, 2003).

There are many reasons for its absence. Inquiry has been repeatedly misconstrued to mean engaging students in hands-on learning activities, developing laboratory skills (e.g. using laboratory tools and following cookbook style procedures etc.), and confirming predetermined outcomes (e.g. verifying the existence of Newton's Laws of Motion) (Osborne, 2014). Such curricular emphases highlight a hands-on approach but at the expense of the minds-on component (Abd El-Khalick, et al., 2004). Focusing on these sorts of activities as inquiry precludes the rich and robust nature of true inquiry learning. Perhaps, most importantly, these misunderstandings about inquiry teaching and learning lead teachers to believe they are utilizing inquiry instruction, when in reality, they are not.

Clearly there is a continued need to know and understand more about inquiry instruction and how to help teachers develop their pedagogical practices using inquiry. What instructional opportunities are necessary to prepare teachers to successfully implement these inquiry standards? Is it even possible? Inquiry instruction is a complex and dynamic activity (Crawford, 2007), and helping preservice science teachers learn to plan for and utilize this engaging pedagogy is a daunting challenge that is not well understood (Anderson, 2007; Crawford, 2012; Keys & Bryan, 2001). Though the research is limited, some reports indicate teacher preparation should include some of the same elements recommended for K-12 instruction (NRC 1996; 2000; 2010). Prospective science teachers should have opportunities to (a) do science inquiry, (b) learn about science inquiry, and (c) learn science through inquiry.

The project discussed here is designed to explore and better understand how preservice secondary science teachers enrolled in three UTeach programs in Arkansas develop their knowledge of inquiry instruction and how they begin to value it as a worthwhile endeavor if, in fact, they do. The three undergraduate secondary science teacher education programs targeted for examination in this study were established to ostensibly replicate the UTeach science and mathematics teacher preparation plan created in 1997 at the University of Texas in Austin. The program has been cited as a model science teacher preparation program for its success at recruiting high quality math and science teachers into teaching careers. According to one well-known national report, *Rising Above the Gathering Storm: Energizing and Employing America* *for a Brighter Economic Future,* "Graduates [from the program] have deep disciplinary knowledge grounding, *they know how to engage students in scientific inquiry* [italicized emphasis mine]…" (Committee on Prospering in the Global Economy of the 21st Century, 2007, p. 117). As articulated on their website, the instructional focus in the UTeach Program is aligned with past and present reform efforts including inquiry and the NGSS. Among various other goals cited, the UTeach instructional focus also includes an inquiry focus:

> *The UTeach secondary STEM teacher preparation program has been preparing math and science teachers to design and implement inquiry - and project-based instruction that emphasizes application of mathematics and science concepts and practices since 1997. The new standards are in fact calling for the essential approaches to teaching and learning on which the UTeach instructional program was founded.* (UTeach Institute, 2013, p. 5)

As described, the UTeach Program prepares preservice science (and math) teachers to do inquiry *and* how to teach science using inquiry instructional strategies. Furthermore, the UTeach Program distinguishes itself in part by its inquiry emphasis and alignment to the recent NGSS Science and Engineering Practices:

> *One of the greatest strengths of the UTeach instructional model is the emphasis placed on developing teachers' abilities to 1) apply core scientific and mathematical practices to authentic, complex problems and 2) design instructional learning environments to engage K–12 learners in these same practices. The UTeach curriculum explicitly develops candidates' proficiency in the eight Mathematical Practices called for by the CCSS-M and the eight Scientific and Engineering Practices called for by the NGSS.* (UTeach Institute, 2013, p.8).

As such exploring the developmental understanding of prospective science teachers enrolled in these programs could provide insights and guidance to help science teacher education programs better prepare science teachers to more effectively utilize inquiry instruction in their teaching practices.

Purpose of the Study with Conceptual Framework

Constructivism is a common underlying paradigm about how people learn, and it provides the theoretical underpinning in this study. Although it has multiple meanings in the literature, perhaps in its most basic sense, a constructivist view of learning is that people construct new knowledge and understandings based on their existing belief structures and on what they already know. Students bring pre-instructional naïve and ill-conceived conceptions about science concepts to the classroom. These conceptions, which are often in stark contrast to contemporary views of science, prove to be formidable foes to the goal of learning science concepts with understanding (Duit & Treagust, 2003). Also inherent is the idea that students actively pursue knowledge and personally engage in their learning as opposed to being passively influenced by their environments (Bransford et al., 2000; McComas, 2014).

In concert with constructivist thinking, Bransford and colleagues (2000) assert, “that what is known about learning applies to teachers as well as to their students” (p. 190). This study presumes that preservice science teachers are students with underdeveloped and inadequate understandings about teaching science as inquiry. Their prior ideas, experiences, and beliefs about teaching and learning science are formidable foes to enacting reformed visions of teaching science as inquiry in the secondary classroom. In the spirit of a constructivist’s paradigm and a teacher education context, this research desired better understanding of a select group of preservice science teachers’ conceptions of inquiry instruction. As Ausubel (1968) said, "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach accordingly” (p.18). The underlying premise of this conceptual framework is that what these preservice science teachers know about inquiry provides a starting point for a new and more informed discussion about how to improve the teaching and learning of science through inquiry methods.

Significance of Study

“Whether in the science classroom or in the science teacher education program, how individuals learn from experience remains a poorly understood phenomenon” (Russell & Martin, 2014, p. 871). This “experience” includes, of course, the preservice learning environment. The NRC (2010) calls for more research about learning experiences in teacher preparation programs. Understanding typical learning trajectories for teachers require empirical evidence (NRC, 2012). Keys and Bryan (2001) advocate for more studies into teachers’ beliefs about inquiry and their knowledge base for implementing inquiry in the classroom. Van Driel, Beijaard, & Verloop (2001) recommend, “that teachers' practical knowledge be investigated at the start of a reform project, and that changes in this knowledge be monitored throughout the project” (p. 137). Likewise, because preservice and experienced science teachers alike have difficulty conceptualizing inquiry instruction, some scholars (Binns & Popps, 2013; Melville, Bartley, & Fazio, 2013) suggest that science teacher preparation programs explicitly promote the use of inquiry strategies *and* how to identify it by modeling appropriate instructional approaches and making explicit connections to the components of inquiry as well as explaining why it is inquiry (Binns & Popp, 2013).

Although inquiry instruction has been a national goal for decades, ‘‘We have little knowledge of teachers’ views about the goals and purposes of inquiry, the processes by which they carry it out, or their motivation for undertaking a more complex and often difficult to manage form of instruction’’ (Keys & Bryan, 2001, p. 636). Furthermore, more research is needed to unpack the discrepancy between teachers' knowledge of and preferences for inquiry instruction (Lakin & Wallace, 2015).

Much of the current teacher preparation research has focused on those entering K-8 educational service, but secondary science teacher preparation is equally important (NRC, 2010). Prospective science teachers' views about teaching and learning shape their instructional approaches, thus exploring their views and making them explicit in the context of teaching and learning is a vital undertaking (Crawford, 2007) for those interested in preparing secondary science teachers. This study will contribute to that knowledge base by sharing how prospective secondary science teachers, who indicate preferences for inquiry instruction, perceive and value teaching science as inquiry and how that knowledge base develops during their teacher preparation program (Eick & Reed, 2002), particularly in a program that emphasizes inquiry instruction as an important pedagogical technique. Studying a select group of prospective science teachers' conceptions of inquiry has a value for identifying areas of strengths and weaknesses that can be useful for improving science teacher education programs to better prepare prospective science teachers for utilizing inquiry-based instruction.

Research Questions

A compelling interest exists in understanding how preservice science teachers in a science teacher preparation program noted for its targeted emphasis on inquiry teaching and learning, perceive inquiry instruction. Specifically, the following three research questions and sub-research question guided this study:

1. How do preservice science teachers who indicate preferences for inquiry instruction describe their beliefs about teaching and learning science?
2. How do these preservice science teachers define and describe inquiry instruction?

3. What justifications do these preservice science teachers provide for utilizing (or not utilizing) inquiry instruction in the science classroom?

    - How do these preservices science teachers' beliefs, conceptions of inquiry instruction, and their subsequent justifications for using it compare at various stages of their teacher education program?

Overview of Methodology

The context of this study took place in an undergraduate secondary science teacher preparation program on three university campuses in Arkansas. All three institutions, which follow the UTeach organizational and program goals (featuring inquiry as a major instructional element and goal), were provided external funding to start their prospective secondary math and science teacher education programs. At the time this research study began, all of the study programs are currently in the fourth and final year of the adoption cycle.

Although the UTeach program is a mathematics and science teacher preparation program, this study focused specifically on prospective science teachers only. While pursuing a bachelor's degree in science (biology, chemistry, and physics), prospective teachers also complete eight specially designed courses in teaching and learning science that subsequently qualifies them to earn a secondary science teaching license in Arkansas. The courses of instruction emphasize and reinforce teaching science through inquiry, doing inquiry, and learning about inquiry while also preparing them to become science teachers. (See Appendix B for a curriculum matrix that identifies and describes each of the eight courses.)

This study employed a sequential explanatory mixed methods research design including two phases of data collection to explore subjects' conceptions of teaching science as inquiry at various stages in their program participation. The purpose for using a mixed methods approach was to identify select preservice science teachers who expressed preferences for inquiry teaching (Phase I) and later explore their rationales for and understandings about teaching science as inquiry during the second qualitative phase (Phase II). In sequential fashion, Phase I results informed purposeful selection of the second qualitative phase of data collection (Creswell & Clark, 2011).

To initiate the study, early in the fall (2015) and spring (2016) semesters, using Qualtrics™ (2015), email based survey system, I invited all accessible science majors in the three programs to participate in the study. Within two weeks of accepting their invitations to participate in the study, survey subjects completed a demographic survey and one of two possible modified versions (biology or physics) of the Pedagogy of Science Teaching Test (POSTT) (Cobern et al., 2014) designed to elicit prospective science teachers' preferred teaching strategies. (For convenience I refer to the modified versions of the POSTT as POSTT$_M$-Biology, and POSTT$_M$-Physics.) The POSTT is composed of teaching vignettes, prospective science teachers can envision themselves teaching, followed by four instructional methods each one corresponding to four particular pedagogical orientations: Didactic instruction, hands-on confirmatory instruction, guided inquiry, or open inquiry. Prospective science teachers selected one of the four pedagogical strategies they would most likely use if they were the teacher. (See Appendices C, D, and E for the survey instruments.)

Crawford (2007) asserts that prospective teachers should "make explicit connections between an inquiry process, their understanding of how people learn science, and their teaching practice…" (p. 638). Therefore, to elicit their rationales for their instructional choices, I modified the POSTT from its original form and added an open-ended response question for each vignette asking them to explain why they chose a particular method. This study assumed that to consistently prefer inquiry-based instruction, prospective science teachers' explanations should be consistent with constructivist and inquiry-based logic. Therefore, I used the subjects' open-ended responses to corroborate their inquiry instructional choices. I subsequently identified prospective science teachers who consistently indicated preferences for inquiry-based instruction.

Inquiry-based instruction is a demanding and difficult pedagogy even among experienced teachers. To express a preference for inquiry and intentionality to use it in instruction means a prospective teacher chooses a more difficult pedagogy over other methods. Realizing that intentions and preferences often fail to manifest in actual instruction (even with experienced teachers) I thought it more valuable to explore the thoughts and conceptions of preservice science teachers who indicated definite preferences for teaching science through inquiry. Therefore I utilized purposeful sampling to select research subjects for Phase II, which I believed provided a more fruitful understanding (Creswell, 2009). I also gave priority to Phase II, the qualitative phase of the study, which took place a few weeks to two months after Phase I. Phase II results were used to answer the research questions.

Phase II consisted of ten open-ended questions designed to elicit prospective science teachers beliefs about the purpose of science education, effective teaching and learning (e.g. What is the purpose of science education? Describe effective science instruction. Describe what it means to teach science as inquiry? What are the benefits and challenges to using inquiry approaches?). (See Appendix F for the questionnaire.)

Using a thematic analysis approach, I utilized a constant comparative approach of the open-ended responses to analyze preservice responses to the questions. By looking for specific instances of *inquiry practices* during data analysis, this research study used the five essential features of inquiry (NRC, 2000) and the science practices described in the *Framework* (NRC, 2012) as a conceptual framework for what students do when they engage in inquiry.

Research shows that consistently and effectively using research-based instructional models is known to improve instruction and help students learn content (Bransford et al., 2000; Bybee et al., 2006; Taylor, Scooter, & Coulson, 2007). For example, as it relates to this research context, program participants in the UTeach programs commonly use the BSCS 5E Instructional Model (Bybee et al., 2006), or 5Es, to help them design and teach their inquiry-based lessons. The 5E Instructional Model (Bybee, et al., 2006) is an example of a learning cycle model of instruction that utilizes a coherent sequence of learning activities that could be used to support inquiry teaching and learning (Bybee, 2009; Bybee et al., 2006; Duran & Duran, 2004; Goldston et al., 2013; Slykhus, 2009; Wilson, et al, 2010). The 5Es refer to five distinctive phases of teaching and learning events in sequence: Engagement, exploration, explanation, elaboration, and evaluation. (See Appendix A for a brief summary of the 5E Instructional Model.) When applied as intended, the 5Es provide learning sequences in stages, such that students take active role in their learning (Bybee et al., 2006). A teacher's job in this context shifts from presenting information to facilitating opportunities for students to learn to ask the right kinds of questions, how to look for evidence, evaluate findings (DeBoer, 1991; NRC, 2012; Schwab, 1960), and communicate their understanding using evidence rich explanations (NRC, 2012). Furthermore, the 5E is an instructional tool teachers can use to help them thoughtfully plan for inquiry-specific learning activities (Bybee, 2009; Bybee et al., 2006; Duran & Duran, 2004; Goldston et al., 2013; Slykhus, 2009; Wilson, Taylor, Kowalski, & Carlson, 2010). "Once internalized, it also can inform the many instantaneous decisions that science teachers must make in classroom situations" (Bybee et al., 2006, p. 1). Therefore, I also used the BSCS 5E Instructional Model (Bybee, et al., 2006) to describe what teachers and students do to create student-centered learning environments, many aspects of which are commonly associated with inquiry teaching and learning (DeBoer, 2002).

The research also employed a cross-sectional design to collect data on targeted prospective teachers at different stages of teacher preparation. Cross-sectional research has the benefit of allowing researchers to observe and compare subjects at different phases of the science teacher-training program simultaneously (Cohen, Manion, & Morrison, 2011). Data analysis allowed me to make developmental comparisons of the prospective science teachers in the program as well as to recognize potential critical junctures in the science teacher preparation program that promotes better understandings of inquiry instruction.

Assumptions

A substantial underlying assumption to this study is that all three UTeach programs on different university campuses have similar goals regarding the development of preservice science teachers and a similar instructional focus on inquiry teaching and learning. Such an assumption is based on the UTeach Model that attempts to ensure instructional fidelity during the first five years of program implementation. UTeach program developers collect evidence from a number of data sources including classroom observations, interviews with instructors and students, and a review of course materials (syllabi, samples of student work, course survey data) (Beth, Romero, Lummus-Robinson, & Perez, 2012). Perhaps now more than ever, there is an expectation of fidelity in terms of course descriptions and the integration of particular course design principles as designed by the program developers. In the future, however, this may not be the case.

I also assumed that course instructors emphasize relevant aspects of inquiry in the respective courses (e.g. modeling how to teach science using inquiry in the early courses as well as requiring program participants to develop inquiry-based lessons and implement them in real classroom environments, developing and implementing project-based units, doing inquiry in research class, and focusing on the history and/or the nature of science in the Perspectives course). Furthermore, specific program instructional faculty (i.e. Master Teachers, non-tenured clinical faculty with significant secondary teaching experiences) who teach various courses in the program and who are dedicated to ensuring program success received similar training from the UTeach Institute in Austin Texas.

The particular program of study that guides the three university programs investigated here not only promotes teaching science as inquiry, but also specific courses explicitly emphasize learning *about* science as inquiry and doing inquiry. An underlying assumption of this study is that successful completion of these courses is evidence the prospective teachers are provided these critical teaching and learning opportunities. Subsequently, much of the rationale behind this study assumes that prospective science teachers in the advanced stages of their programs have some significant background and understanding about the nature of science as inquiry.

Finally, this research assumes the survey participants will answer survey questions honestly based on what they actually think and not based on what they believe is the right answer. Survey instructions will explicitly state there are no right or wrong answers; rather the researcher seeks to explore prospective science teacher thinking.

Limitations

This study rigorously recognizes the primary focus of any reform effort is the effective implementation of the design strategies in real classrooms with real students. However, because evidence reveals a significant lack of inquiry-based approaches in science classroom environments even with experienced science teachers, this research sought instead to explore preservice science teachers thinking *before* they hit the realities of the classroom as classroom teachers. Some might assert that studying teachers' self-expressed conceptions and affinities toward inquiry instruction void of classroom observations could be construed as a limitation of the study. However, an underlying belief central to this study is that observing and studying the preservice science teachers during their practice teaching events would reveal no new findings. Knowing they were having inquiry-based teaching and learning experiences (or recently had these experiences) in at the same time they responded to the survey questions provided enough authenticity to elicit their thoughts and conceptions about inquiry teaching and learning.

This study was conducted on a small sample size of preservice science teachers in three undergraduate science and mathematics teacher preparation programs that promote the same inquiry focus through the same eight courses. However, because each of the programs have varying numbers of program participants at various stages, it was not possible to elicit equal participation from all three programs and equal subjects in all courses. As such I chose to combine all results and report them collectively (rather than by separate programs). Furthermore, because the sample population is small, the findings are generalizable only to these programs and to the participating subjects. Even still, the findings will be of use to a much wider audience by providing valuable information to the design and implementation of science teacher preservice programs, professional development providers, and to curriculum developers. Also, because the researcher was more involved in one of the three teacher preparation programs, she received a better response rate to her invitations to participate in the study from her home campus. As such, the generalizations could be skewed toward that program rather than to the three programs as a whole.

Delimitations

Although studying a program's *effectiveness* in terms of the preservice science teachers' in-depth understanding of inquiry instruction could have been a natural focus of this study, I intentionally purposed *not* to pursue this avenue of exploration. This study was not intended as an evaluation of any course, program or participant. Rather the study was explorative and designed to understand a select group of prospective science teachers' self-reported conceptions of inquiry-based instruction and to compare their understanding across program levels in a program designed to teach "inquiry" as an important skill for science instructors. Recognizing that even well informed teachers often express misconceptions about inquiry instruction, this study desired to explore the conceptions of inquiry of the most informed prospective science teachers at various levels of a science teacher education program that gives prominence to inquiry instruction. Knowing their thoughts, conceptions and rationales about inquiry instructions at various levels could provide valuable insights about how to target future improvements in science teacher preparation and improve opportunities for future teachers to more effectively implement inquiry instruction. Because making value judgments against some model of good teaching was not the intent (AAAS, 2012), the researcher utilized a broader definition of inquiry as a pedagogical strategy than might otherwise be used.

Additionally, although recent reform documents promote *Science and Engineering Practices* (SEPs) in lieu of *inquiry*, this study focus was primarily on prior reform documents descriptions of inquiry. Nonetheless, the frequent terminology used is *inquiry practices* to incorporate both past and current ideals of inquiry (NRC, 1996; 2000; 2012). The delimitation is that I excluded the *engineering* component of the SEPs during any discussion and analysis of data due to the already complex nature of inquiry. Adding additional criteria would serve to only complicate an already difficult understanding.

Finally, although this target program of study is an undergraduate math and science teacher preparation program, this study focused specifically on prospective *science* teachers' thinking about inquiry. The research did not attempt to explore prospective math teachers' perspectives, although that could have added an interesting and valuable contribution to the study.

CHAPTER 2: REVIEW OF LITERATURE

Introduction

Teaching science as inquiry has been recommended for decades due to its potential for helping students develop science literacy (Schwab, 1960; NRC, 1996; 2000; 2010). Helping students develop deeper understanding of the scientific enterprise (Crawford, 2012, p. 39), develop scientific habits of mind and related critical thinking skills are foundational to achieving even basic levels of scientific literacy (NRC, 2012; Windschitl, 2008). Whereas having students do inquiry in the classroom the same way scientists do inquiry is not a goal of science education (NRC, 1996), it is important to help them understand how science is conducted (Anderson, 2007; NRC, 1996), about the characteristics of science knowledge (Flick, 2004; McComas, Clough, & Almazroa, 1998), and to "understand a body of existing, consensually agreed and well-established *old* knowledge" (Osborne, 2014, p. 580).   To really know and understand science assumes students not only understand the facts, theories, and principles of science, but they also understand the epistemic and procedural knowledge that guides the development of such knowledge (Lederman et al., 2013; Duschl, Schweingruber, & Shouse, 2007; Osborne, 2010).

Unfortunately, there is a general lack of consensus in the literature about what constitutes an inquiry-based approach to teaching and learning science (Brown, Abell, Demir, & Schmidt, 2006; Lederman, Antink, & Bartos, 2014; Martin-Hanson, 2002; Settlage, 2003). Teachers (and researchers) conceptualize inquiry differently; yet their conceptions impact its implementation in the classroom (Kang, Orgill, & Crippen, 2008). Settlage (2003) describes inquiry as "one of the most confounding terms within science education" (p. 34). In this chapter I present the literature base that advocates for teaching science as inquiry. Also I present trends and gaps in the literature that pertain to preparing preservice science teachers learning to utilize this difficult pedagogy.

A Brief History of the Inquiry Standards

> "If a single word had to be chosen to describe the goals of science educators… it would have to be *inquiry"* (DeBoer, 1991, p. 206).

Many of the curriculum reform efforts from the Golden Age of Science Education more than 50 years ago placed an unprecedented emphasis on teaching science as inquiry. This was a new emphasis that changed a teacher's job from one of presenting information and telling students what they should know, to helping all students do science in ways similar to the ways scientists do science (DeBoer, 1991). Likewise, the goals changed further from learning just the facts and conclusions of science to also learning about how science knowledge comes to be known. As such secondary students were expected to "dissect textbooks and lectures to look for evidence for the validity of the claims of others, and to be active in a process of analysis" (DeBoer, 1991, p. 165). Engaging in the learning process meant asking questions, searching for answers, and participating in discussions. Learning shifted from rote memorization of facts to doing more activity-oriented processes to learn science content. However, this goal of teaching science the way scientists do science was not often successfully enacted in classrooms (Harms & Yager, 1980).

More than two decades later, the *National Science Education Standards (NSES)* (NRC, 1996) attempted to reinvigorate the inquiry movement. In the *NSES*, eight categories of science content standards explicated what students should be able to do and understand about by the time they graduate high school. One category included the *science as inquiry* standards, which had equal status with the more typical science content standards. According to the inquiry standards, students should develop (a) understandings about inquiry and (b) the abilities necessary to do inquiry (NRC, 1996). To clarify what this means practically speaking, the *NSES* recommended, for example, that students learn about Newton's Laws of Motion, biological evolution, energy transfer, and be able to *do* inquiry investigations (including both the procedural and rational aspects of inquiry) and *understand about* scientific inquiry (e.g. there are many methods of inquiry; science knowledge is evidence based, science knowledge advances through skeptical peer reviews etc.).

Additionally, however, not only did the *NSES* appoint inquiry as what students should know about and be able to do, but they also referenced inquiry as a teaching method, or a way for students to learn science concepts. Subsequently, the doing of science became conflated with the learning of science, "when in reality, the two are activities distinguished by their differing goals" (Osborne, 2014, p. 580). In an effort to translate what inquiry means in science classrooms, some researchers assert that learning science as inquiry can be perceived as (a) a set of skills (procedural and rational) students use to perform an investigation (*doing* inquiry), (b) what students should know *about* scientific inquiry, and (c) a means to learn science concepts (learning content *through* inquiry) (Abd-El-Khalick et al., 2004; Capps & Crawford, 2013; Lederman et al., 2014). Whereas the first two contexts are related to specific learning outcomes, the latter focus, learning science through inquiry, implies inquiry as a pedagogical strategy (Osborne, 2014). However, what teachers know about inquiry instruction is even less understood than inquiry learning (Anderson, 2007). Moreover, inquiry instruction is yet to be realized in many classrooms. Perhaps, as Hodson (2014) suggests, "It is all of these things because it is ill-conceived" (p. 2536). Due to its ambiguity and confounding conceptions, this section provides an overview of the three teaching and learning contexts that inquiry is commonly conceived and misconceived.

Developing Abilities to do Inquiry

Scientific inquiry, as scientists do it, involves a systematic approach in the pursuit of knowledge about the natural world and involves multiple approaches and contexts. Although inquiry is multifaceted and complex, there are certain rules of the game that scientists adhere to so their findings may be considered legitimate knowledge. For example, when scientists inquire about nature, they make observations and ask questions that lead to more in-depth questions. To build understanding, they read and research to see what is already known and eventually produce explanatory hypotheses that must be empirically tested. Subsequently, after investigating their ideas and developing defensible explanations using specific evidence, they explain and communicate their findings (NRC, 1996) to a potentially skeptical scientific community.

Although having students do science like scientists is not a goal of education, having them participate in *science like* processes (doing inquiry) is intended by the standards. Students should learn to engage in inquiry processes somewhat akin to how scientists do. When engaging in inquiry, students ask questions, develop and conduct investigations, analyze data, formulate explanations from evidence, and communicate findings. In other words, they engage in the essential features of inquiry practices. Doing inquiry, as intended by some reform documents (NRC, 1996; 2000), assumes that students use critical thinking during multiple and diverse inquiry contexts (laboratory, field studies, computer research etc.). Not only should students be able to conduct investigations to answer questions (NRC, 1996), but they should also be able to use scientific knowledge to evaluate their own findings as well as critique others' findings (NRC 1996; 2000; 2012). They also use the inquiry practices to make meaningful connections to scientific phenomena and perhaps even develop understanding about the nature of scientific inquiry (learning about inquiry). As such, having students engage in inquiry implies an investigative foray to figure out how some aspect of the world works and is based on the premise that learning science is an active process. It "is something students do, not something that is done to them" (NRC, 2000, p. 2), and it involves both a hands-on as well as a minds-on approach (NRC, 2000).

Today, in a new era of reform nearly twenty years since the *Standards* were introduced, the *Framework* (NRC, 2012), the forerunner of the Next Generation Science Standards (NGSS), issues a similar charge. However, in an attempt to rebrand the term inquiry, the *Framework* instituted the term *science practices* (in lieu of the term inquiry) "to stress that engaging in scientific inquiry requires coordination of both of knowledge and skill simultaneously" (NRC, 2012, p. 41). These new standards suggest students should learn science concepts (disciplinary core ideas and crosscutting concepts) and engage in *science practices*: Asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, engaging in argument from evidence, and obtaining, evaluating and communicating information (NGSS Lead States, 2013, p. 1). The curriculum reform movement of the 1960s, the *Standards* (1996), and the NGSS (NGSS Lead States, 2013), as such, are intended to ensure students have opportunities to develop their abilities to engage in inquiry practices.

Learning *about* Inquiry

Joseph Schwab (1960), chair of the Biological Sciences Curriculum Studies (BSCS), promulgated the idea that students need to understand that the knowledge base science rests upon is tentative and subject to change. According to Schwab, to teach science facts as literal truths or "rhetoric of conclusions" (p. 185) is to present a false image of science. Rather, according to Schwab, science should be taught as inquiry:

> *He* [the student] *needs to see the readiness with which the inquirer moves to challenge the soundness of his own work and to start afresh. Most of all, he needs to understand the conditional truth of scientific knowledge. Wherever possible, he needs to know the specific, concrete conditions which limit the truth and the application of the bodies of knowledge he is taught.* (p. 186)

As evidenced by his explanation, Schwab promotes the idea of students doing and learning about inquiry in science class. In his elaboration about how the teaching of science might attend to these practical matters, he proposed that science class should be taught as "an inquiry into inquiries" (1960, p. 188). By his descriptions, Schwab promoted the idea that students should know and understand subject matter disciplinary knowledge in context and as a product of inquiry investigative processes. Therefore, students should learn science concepts, not as a "rhetoric of conclusions" (Schwab, 1960, p. 25) but rather as "conclusions of evidence" (Rudolph, 2003, p. 270) embedded within a conceptual framework that both defines and limits it validity (Schwab, 1960). In the context of learning science, Schwab emphasized the idea that students should know *about* inquiry.

The "Nature of Science (NOS) is that element of the science curriculum in which students learn how science functions, how scientific knowledge is generated and tested, and how scientists do their work" (McComas, 2014, p. 67). Scientific inquiry and the nature of science (NOS) in educational settings are closely related concepts with overlapping elements (Capps & Crawford, 2013) but they are distinct types of knowledge. Because it is important to know about the nature of science and the nature of scientific inquiry, some scholars recently started making a distinction between them making references to to NOS and the Nature of Scientific Inquiry (NOSI) (Lederman et al., 2013; Schwartz, Lederman & Lederman, 2008) distinctively.

According to this distinction, NOS refers to the characterization of scientific knowledge as a *product* of scientific inquiry (Schwartz et al., 2008) that is based on “values and beliefs inherent to the development of scientific knowledge” (Lederman et al., 2013, p. 140). For example, the notions that scientific knowledge has important human elements and that observations and conclusions are not entirely objective (as many believe) is a NOS concept (McComas, 2014). These ideas and much more are what students need to know *about* the nature of scientific knowledge. The *NSES* have a separate content standard that attend to NOS and, as such, are not the focus of this study.

NOSI, the primary emphasis in this research, refers to the *processes* of scientific inquiry and how knowledge comes to be known and accepted (Lederman et al., 2013; Schwartz, Lederman & Lederman, 2008). For example, understanding that scientific questions guide investigations and that “scientists use different kinds of investigations depending on the questions they are trying to answer ” (NRC, 2000, pg. 20) are NOSI concepts. Furthermore, because science operates in communities of practice (Schwartz et al., 2013), “scientists review and ask questions about the results of others ’work,” such that science advances through legitimate skepticism ” (NRC, 2000, pg. 20). Another NOSI idea is that all scientific explanations must adhere to certain criteria such as being logically consistent, abide by rules of evidence, be open to questions and possible modifications, and they must be based on historical and current scientific knowledge (NRC, 2000). As such, when students engage in inquiry, not only do they learn to perform science like processes, but also they should also explicitly recognize these processes are representative of how science is conducted in real life. Although, students can learn about inquiry by engaging in inquiry processes, one does no presuppose the other. In fact, it is in error to assume students will learn about inquiry by doing inquiry (an implicit approach) (Llewellen, 2002). To teach about inquiry via inquiry processes requires that teachers provide explicit opportunities for students to reflect on the nature of scientific inquiry (Lederman, 2004; Schwartz et al., 2002; 2004). Learning about inquiry by doing inquiry requires an intentional reflective framework so students can make these connections (Lederman, 2004; Schwartz et al., 2002; 2004). As such, there needs to be an explicit intention to recognize that when scientists do science there are the same sorts of "cultural" negotiations that students engage in as they develop their personal understanding of science concepts.

However, learning about inquiry can take multiple forms (lecture, readings etc.) including investigative forays. In fact, what students need to know about science inquiry is much more extensive than what they can learn about science inquiry by engaging in the science practices. According to Hodson (2014), learning about inquiry by doing inquiry is a complex undertaking that when done in the classroom doesn't accurately portray the nature of scientific inquiry. Therefore, learning about inquiry may be best taught using a wide range of teaching and learning activities (lecture, videos, case studies, simulations, role playing etc.) rather than learning about it through inquiry methods per se (Hodson, 2014). Learning about inquiry *is not* something that happens just because students engage in inquiry (Lederman, 2004; Schwartz et al., 2002; 2004).

Inquiry for Learning and Teaching

Whereas *engaging in* inquiry references what students do as they engage in the inquiry practices to learn to do science, likewise, *learning through inquiry* implies a similar idea. However, learning through inquiry specifically implicates teachers as designers of the learning environment. As such, *inquiry instruction* is a specific reference to how teachers structure learning activities to target the goals of having students do inquiry to learn science concepts (which could but does not presuppose the goal of learning about inquiry).

Learning to do inquiry, learning about inquiry, and learning through inquiry are three different contexts (Hodson, 2014; Osborne, 2014); yet, historically this distinction has been obscured with unfortunate consequences on the teaching and learning of science (DeBoer, 1991; Hodson, 2014; Osborne, 2014). Because inquiry is so central to science, a misinterpretation of the science as inquiry standards has led to a preeminent focus on inquiry as a teaching technique (Bybee, 2004; Osborne, 2014) and a best way to learn science content (Hodson, 2014). Yet "the importance of inquiry does not imply that all teachers should pursue a single approach to teaching science" (NRC, 1996, p. 2).

The compelling idea of having students do science like scientists do science is a flawed argument (Osborne, 2014). Whereas scientists engage in inquiry to create new knowledge, engaging students in inquiry "refers to the activities of students in which they develop knowledge and understanding of scientific ideas" (NRC, 1996, p. 23) that are already known. Therefore, how students should engage in learning science concepts (e.g. about Newton's laws) should be determined based on what works best in a particular environment and context. The teaching and learning of science should be based on principles and theories of learning (Bransford, et al., 2000). How students learn is rooted in an impressive foundation of research grounded in educational psychology and neuroscience about how people learn (Bransford et al., 2000). As such, teachers should utilize the most engaging and applicable pedagogies to engage students in learning science. Although engaging students in learning through inquiry is grounded in these learning principles, students can also effectively learn science principles through multiple other methods that are not inquiry per se. For example, students can develop conceptual understanding of Newton's laws of motion by exploring phenomena (e.g. carts, ramps, and masses) and conducting investigations specifically designed to develop their understanding of these concepts (through an inquiry approach). Also, however, students can develop an understanding of Newton's Law of Motion by reading about them, listening to a lecture, watching a demonstration, etc. (events that are not typically thought of as inquiry-based). The *NSES* (NRC, 1996; 2000) do not indicate that students have to learn about Newton's laws by doing inquiry.

Recommended for decades as a best practice in the science classroom, the goals and purposes for inquiry-based instruction are often conflated. As such, there is a need to clarify the goals and aims of inquiry instruction in ways that are understandable and usable to classroom teachers (Abd-El-Khalick, et al., 2004; Bybee, 2004; Osborne, 2014). Borrowing from Osborne (2014), constructivist learning theory, and cognitive sciences, learning science by doing inquiry is most valuable because it is embedded in how people learn, and how students learn science (Bransford et al., 2000; Donavan & Bransford, 2005). As such, having student engage in inquiry has value only "if (a) it helps students to develop a deeper and broader understanding of what we know, how we know, and the epistemic and procedural constructs that guide its practice; (b) if it is a more effective means of developing such knowledge; and (c) if it presents a more authentic picture of the endeavor that is science" (Osborne, 2014, p.587).

In an effort to provide teachers a better understanding of how to incorporate inquiry instruction into classroom instructional practices, *Inquiry and the National Science Education Standards* (*INSES*) (NRC, 2000), written four years after the *NSES,* expanded on the inquiry recommendations and provided a list of five essential features of inquiry linked to particular cognitive behaviors that students should engage with during inquiry learning events. For instance, students should engage in scientifically oriented questions, give priority to evidence, construct explanations using evidence, connect these explanations to science knowledge, and communicate and justify their explanations. However, there are multiple variations of what this might consist of in any teaching and learning event. Therefore the *INSES* (NRC, 2000) provided a matrix that delineates an inquiry continuum that ranges from a structured or highly guided inquiry to an open inquiry depending on the degree of teacher structure and guidance provided during a learning experience (Bell, Smetana, & Binns, 2005; Cobern, et al., 2013; Martin-Hansen, 2002, McComas, 2014; NRC, 2000). (See Table 2.1 for the inquiry continuum depicting the essential features of inquiry and the varying levels of student engagement.)

Not all teaching and learning events will utilize all five features and may be described as full or partial inquiries depending on the number of essential features present (NRC, 2000). Rather, the level of inquiry is dependent in part on the context (e.g. students, topic, previous experiences with inquiry, time and resources available, etc.) and in part on the goals of the lesson and the skills of the teacher. Although students are not expected to participate in all the practices during any given learning event (NGSS Lead States, 2013), components of these practices should pervade all inquiry-based teaching and learning events (Osborne, 2014).

As evidenced by the inquiry continuum, there are varying levels of teacher guidance and, subsequently, varying levels of student responsibility necessary during an inquiry-learning event. Although some may incorrectly qualify one level as better than another, ultimately striving for students to participate in open inquiry in the science classroom was not the intent of *NSES* movement (NRC, 2000). Rather the level of inquiry is dependent on the teaching and learning goals as well as on a multiplicity of other factors (grade, discipline, student and teacher experiences, intended learning outcomes, resource availability etc.). For example, if the goal of instruction is purposed to help students develop their abilities to do inquiry, then varying levels of openness is desired. However, if concept development is the goal, then the inquiry experiences should be more teacher-guided. The more autonomy students have in their investigations and subsequent justification and communication of their findings, the more features that will likely be present. Students should have multiple opportunities to engage in all the inquiry practices at various times in their learning careers (NRC, 2000).

TABLE 2.1

Essential Features of Classroom Inquiry and their Variations on the Inquiry Continuum (NRC, 2000)

Open Inquiry	More---------------Amount of Learner Self-Direction----------------Less Less-------Amount of Direction from Teacher or Material-------More			Guided Inquiry
Essential Features	**Variations**			
Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other sources
Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
Learner formulate explanations from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence and how to use evidence to formulate explanation
Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to use sharpen communication	Learner given steps and procedures for communication

Adapted from *Inquiry and the National Science Education Standards* (NRC, 2000, p. 29).

Inquiry-based instruction can be a powerful way to help students learn both the content and the processes of science in a way that research agrees students learn best (Bransford, et al., 2000). However what this means is not clear. Although the science content standards (NGSS Lead States, 2013; NRC, 1996) outline what students should know and be able to do in science by the time they graduate high school, they are not a curriculum. Neither are they prescriptive regarding particular instructional choices teachers should make (NGSS Lead State, 2013; NRC, 1996) about how to teach science as inquiry. The assumption, however, is that to engage in inquiry activities to learn content also engages students in "a range of inquiry related activities" (Abd-El-Khalick et al., 2004, p. 415) and scientific practices (Osborne, 2014) (e.g. asking questions, developing and using models, abilities to perform an investigation, constructing explanations, engaging in argument from evidence, analyzing and interpreting data, using mathematics, and obtaining, evaluating, and communicating information) (NRC, 2012). To choose an inquiry-based strategy should assume a teaching goal targeting these specific outcomes. Also, it bears repeating, although teaching science through inquiry deemphasizes traditional and didactic instructional approaches (Eick, 2000), it does not preclude them.

Trends and Gaps in the Research on Inquiry Instruction

Knowing inquiry doesn't happen in actual practice as frequently as teachers say they utilize it (Abd-El-Khalick et al., 2004; Lakin & Wallace, 2015), it is pertinent to examine what the literature says might be the reasons for the discrepancy. In this section, I present the trends in the literature specific to preparing teachers to implement inquiry instruction in their own practice. More specifically, I focus on the research base regarding the meanings teachers make of inquiry teaching and learning.

Science Teachers' Beliefs about Teaching and Learning Science

Researchers have studied for a number of years the role that teachers' personal beliefs play in their instructional decisions (Anderson, 1996; Luft & Roehrig, 2007; Pajores, 1992; Prawat, 1992) and the role that teacher education has in impacting those beliefs (Crawford, 2007; Keys & Bryan, 2001; Luft & Roehrig, 2007; Pajores, 1992; Tatto, 1998; Tillitson & Young, 2013; Tsai, 2002). Multiple researchers assert that teacher' beliefs about teaching and learning science are likely forecasters of their intentions to teach science through inquiry (Crawford, 2007; Luft & Roehrig, 2007; Tillitson & Young, 2013; Wallace & Kang, 2004). In one study, Crawford (2007) followed five intern teachers over the course one year to explore their beliefs about teaching, understanding of inquiry, and how they attempted to carry it out in actual practice. Using multiple data sources (semi-structured interviews, inquiry-based unit plans, classroom observations, and journal entries documenting informal conversations) as evidence, she suggested that "prospective teacher's personal view of teaching science as inquiry, comprised of his or her knowledge of scientific inquiry and of inquiry-based pedagogy and his or her beliefs of teaching and learning, is a strong predictor of a prospective teacher's actual practice of teaching science" (p. 636). In Crawford's study, the interns who espoused informed views of inquiry were able to carry it out in practice. Subsequently, the author suggests that prospective science teachers need to clearly articulate to themselves and to potential critics why an inquiry approach is valuable pedagogy. They should be able to articulate personal learning philosophies supported with evidence that make connections between inquiry instruction and how students learn. This study adds to this line of research by exploring how a group of prospective science teachers who espouse inquiry instruction, and who have had multiple experiences implementing it in actual practice (an assumption based on program descriptions and program protocols designed to ensure course fidelity) articulate and describe it.

Teachers' beliefs about teaching and learning science are sometimes subsumed under the umbrella of *orientations to teaching science* (Cobern et al., 2014; Magnusson, Krajcik, & Borko, 1999; Friedrichsen, Van Driel, & Abell, 2010). Friedrichsen and colleagues (2010) proposed that science-teaching orientations have three dimensions: "beliefs about the goals or purposes of science teaching, beliefs about the nature of science, and beliefs about science teaching and learning" (p. 373). This research intends to use Friedrichsen and colleagues description of inquiry orientation and probe prospective science teachers "conceptions of science teaching and learning, including beliefs about the role of the teacher, the learner, how students learn science, and how to teach it in ways that make science attractive and comprehensible" (p. 371).

Some researchers assert that changing teachers' beliefs during their teacher preparation does not necessarily translate into their actual teaching practice (Tsai, 2002; Haney & McArthur, 2002; Mellado, 1998). Therefore, studying teachers' beliefs in conjunction with their practice provides essential insights needed to evaluate the connection between teachers' beliefs and practice. However, more information is needed to understand why teachers have the particular beliefs and conceptions they have. As such, "detangling beliefs from practice is important" (Luft & Roerig, 2007, p. 49), and conducting observations to study beliefs could complicate the researchers' understanding of the meaning the prospective science teachers make of inquiry instruction. This study adds to this area of research by exploring preservice science teachers' beliefs about teaching and learning science as well as their conceptions of inquiry independently of their practices.

Teaching scenarios are useful and efficient methods for capturing teachers' beliefs and conceptions about inquiry teaching and learning (Cobern et al., 2013; Kang et al., 2008). Furthermore, they offer opportunities for researchers to explore the underlying reasons guiding teachers' conceptions and beliefs. Cobern and colleagues (2013) constructed an assessment instrument to capture teachers' knowledge of and predispositions toward teaching science across various disciplines and specific topics. They created the Pedagogy of Science Teaching Tests (POSTT) primarily as formative assessment tools to elicit opportunities for K-8 preservice science teachers to share and discuss their responses to context specific vignettes in science method's class environments. Believing science teaching orientations are context specific, the creators of the POSTT constructed various multiple-choice items reflecting real instructional scenarios that teachers could relate to. Each item on the POSTT begins with an introductory vignette that specifies a topic, an aim, and a grade level followed by a lead in sentence to direct the teachers' attention to the four instructional methods that teachers could choose from. Each instructional method represents one of four teaching orientations that range on a scale from direct instruction (receptive learning) to inquiry instruction (discovery learning) (Cobern et al., 2014).

During the original instrument development process, the developers collected assessment items and alternative responses from science education faculty, research associates, and experienced K-8 teachers. Assessment items came directly from teachers' experiences or from the thoughts and insights from experienced and knowledgeable others using state and national standards and other research documents. Once sample item were collected and refined according to the developers' criteria, sample items were discussed in detail within focus groups composed of 3-15 pre or inservice teachers. Additionally, science education professors from other universities were also asked to comment on samples of items. Subsequently, the items were refined and revised until the instrument developers reached a consensus that each item aligned consistently with the intended pedagogical approaches.

Three versions of the POSTT are currently available for researchers and science teacher educators to use in their courses. Each version consists of 16 multiple choice assessment items that range in topics across the life, physical, and Earth science, grade ranges, and facets of instruction. The instrument developers have made these assessment items available online for instructional and research purposes. For more information, go to the Mallinson Institute for Science Education (www.wmich.edu/science/inquiry-items). As such, the instruments can be administered as formative assessments in the form they are presented, or the assessment items can be compiled from the various versions into customized Pedagogy of Science Teaching Tests (POSTT) to build science-teaching orientation profiles, which can be compared across reference points (Mallinson Institute for Science Education, 2016).

Although scenario assessments, such as the POSTT, provide researchers an efficient means to assess prospective science teachers beliefs and conceptions of inquiry instruction, more studies are needed to explore the meanings teachers make of their beliefs and knowledge of inquiry instruction (Keys & Bryan, 2001). This research intends to add to this line of research. In addition to using the POSTT to elicit the prospective teachers orientations to teaching particular science topics, this study will include an open-ended question asking subjects to explain their rationales for why they believe one particular method is preferable over another. After identifying those who demonstrate inquiry orientations, this research will explore their conceptions of inquiry at a deeper level using an open-ended survey instrument.

Teachers' Understandings of Inquiry Instruction

The history of reform in science education reveals that envisioned conceptions of science education reform are mostly incongruent with classroom practices (Abd-El-Khalick, et al., 2004; Duit & Treagust, 2003; Lakin & Wallace, 2015; Osborne, 2014). Many teachers are unfamiliar with the contemporary views of science education reform (e.g. constructivists theories of learning, conceptual change theory, the learning cycle) and have limited views of teaching and learning (Duit & Treagust , 2003; Young, 2013). Furthermore, even experienced teachers lack knowledge of reform documents related to inquiry-based teaching and learning (Kang et al., 2008; Young, 2013). Young (2013) conducted a national survey with highly motivated science teachers and found that most have not read any of the key reform documents, and their conceptions of inquiry were incongruent with descriptions of inquiry in those documents. Kang and colleagues (2008) conducted a study with 45 experienced teachers using a teaching scenario instrument and found these teachers emphasized certain components of inquiry over others. The teachers consistently conceptualized inquiry in terms of giving priority to evidence and formulating evidence based explanations more than of engaging students in scientifically oriented questions. Moreover, these same teachers rarely mentioned using scientific knowledge to evaluate their explanations.

Researchers have found that these inaccurate and naive conceptions of inquiry are significant barriers to its effective implementation in classrooms (Anderson, 1996; 2002; Brown et al., 2006; Kang et al., 2008; Young, 2013). As such, future research should target learning more about teachers' knowledge of inquiry (Keys & Bryan, 2001; Saad & BouJaoude, 2012), how they conceive their roles in teaching the inquiry process (Keys & Bryan, 2001). Although there have been studies regarding experienced teachers conceptions of inquiry, there is limited research about the conceptions preservice science teachers have about inquiry instruction (Ozel & Luft, 2013; Yager & Simmons, 2013) and how they learn to incorporate it into their teaching experiences (Binns & Popp, 2013; Crawford, 2007). Researchers assert that science teacher preparation programs must continue to promote inquiry instruction and explicitly target helping preservice teachers develop accurate conceptions and how identify it (Binns & Popp, 2013; Melville et al., 2008; Minner et al., 2010; Ozel & Luft, 2013; Saad & BouJaoude, 2012). This study seeks to add to this knowledge base by describing what preservices science teachers' conceptions of inquiry are in a teacher preparation program that emphasizes inquiry. Although this study focuses on the prospective science teachers who demonstrate the most intentionality toward inquiry instruction, there is an expectation based on literature base, they will also have naive and inaccurate conceptions of inquiry. As such exploring their views and conceptions of inquiry will add to the teacher preparation literature base that can be used to target these misconceptions.

Reasons for an Inquiry Focus

The reasons for an inquiry focus are multifaceted and embedded in research about learning (Bransford et al., 2000) and, more specifically, how students learn science in the classroom (Donavan & Bransford, 2005). Inquiry instruction is premised on the belief that it is an engaging pedagogy grounded in the research about how people learn. Children are naturally curious and inquisitive about their surroundings. Engaging students in scientific questions that capture their interest capitalizes on their natural instincts to know and understand more about the world. Thus inquiry learning is associated with students' motivation to engage in science class student enjoyment (Gibson & Chase, 2002). Gibson and Chase (2002) conducted a controlled longitudinal study over the effects of a 2-week inquiry-based science camp on students' long-term interests in science careers. Their findings suggested that inquiry learning positively affects students' interests in science over the long term compared to students who do not receive inquiry-based instruction.

The Cornell Science Inquiry Program (CSIP), an NSF funded project, placed graduate fellows in middle and high school classrooms to work with teachers to successfully develop and implement inquiry-based lessons and units. Trautman, MaKinster and Avery (2004) conducted a study to explore how 21 of these science teachers perceived the benefits and challenges of inquiry successfully enacted in their classrooms. Data evidence in the form of interviews, classroom observations, and an Inquiry Teaching Belief instrument suggested that teachers recognized student benefitted from inquiry learning due to being more interested and motivated to engage in the learning events, and by developing their higher-order thinking skills. Likewise, in another study with preservice science teachers during their internship, Reaume (2011) found preservice science teachers initially unfamiliar with inquiry instruction grew to view the teaching style positively due to its effectiveness to engages student's interests, increase their responsibility for learning, and helps students make connections to their learning. Thus in both studies, the motivational and engaging aspects of inquiry instruction provided the primary reasons why the preservice and inservice teachers attested to engaging students in inquiry. However, as reflected in Reaume's study, some of the preservice teachers' perceptions, the obstacles surmounted these benefits.

Furthermore, inquiry learning shifts the educational focus to developing students' cognitive skills (e.g. reasoning, analyzing and critiquing information, defending one's understanding by making coherent and logical arguments) (Abdi, 2014; Bybee, 2010; Schroeder et al., 2007) necessary to becoming "autonomous, independent, thinkers" (DeBoer, 2004, p. 19). At the same time, students also have opportunities to develop an understanding about the nature of science inquiry (Lederman et al., 2013; NRC, 1996).

Multiple purposes can be served by having students learn through inquiry. Yet these reported benefits are not enough to promote the teaching of science as inquiry in classrooms. Only a few studies have been conducted to elicit teachers' perceptions about the benefits and challenges of inquiry instruction (Trautman et al., 2004; Reaume, 2011). Understanding how preservice science teachers view the benefits of inquiry instruction is necessary to support them in learning to value it as a worthwhile endeavor. "We do not ask our novice teachers to embrace reform methods on faith alone or because their science educator recommends them. … Theirs should be a conscious choice, knowing the difficulties, but valuing the rewards" (Crawford, 2012, p. 638). More studies are needed to explore ways to enhance teachers valuing a curricular emphasis on inquiry (Abd-El-Khalick et al., 2004) and explore teachers' goals and purposes for enacting inquiry and their knowledge base for implementing it (Keys and Bryon, 2001). "It has been recommended that teachers' practical knowledge be investigated at the start of a reform program and be monitored throughout the project…." (Van Driel, et al., 2001 p. 137) as clearly there exist a need for more information about why/how teachers adopt the particular conceptions of inquiry the way they do (Kang et al., 2008).

"Teaching science as inquiry must be both feasible and viable in the mind of the teacher. Teachers need to see that things can work, that it is possible to carry out inquiry-based instruction in actual classrooms; and be able to evaluate their current beliefs for effectiveness " (Crawford, 2012, p. 638). This study continues to pursue this line of research by exploring how preservice science teachers who report intentions and preferences for using inquiry instruction explain why they prefer it over other strategies. Moreover, perhaps their rationales will provide insights into why some teachers who express intentions and beliefs aligned with inquiry instruction do not manifest in actual practice.

Misconceptions about Inquiry Instruction

The majority of teachers hold limited and distorted views about NOSI (Capps & Crawford, 2013; Llewellyn, 2002; Wilcox, Kruse, & Clough, 2015; Young, 2013). For example, doing inquiry is often conflated with anything that is hands-on or activity-based. Also, empirical investigations (i.e. experiments and laboratory exercises) are often identified as inquiry at the expense of other equally valid inquiry related activities in science (conducting field observations, doing research, finding patterns, constructing models etc.) (Llewellyn, 2002; McComas, 1998; Wilcox et al., 2015). Other misinterpretations about inquiry involve students performing verification labs to confirm what they already learned in the classroom as they follow cookbook style procedures to replicate particular phenomena (McComas, 2005). Unfortunately, many individuals view scientific inquiry as a sequence of steps, an algorithm per se that scientists follow when conducting investigations. This myth (McComas, 1998) is often perpetuated in science textbooks as "The Scientific Method." The idea of using some single scientific method is a gross misrepresentation of scientific inquiry and the nature of science at the same time (McComas, 2005). Some requires students to memorize the steps of the scientific method and follow these steps in their investigative processes. Furthermore, because many believe the *science as inquiry* standards are "soft" and not as valuable as anything related to content (Llewellyn, 2002) so such standards may not receive equal status as the content standards.

Some researchers assert that inquiry-based instruction and learning is equivalent to "minimally guided instruction" (Clark, Kirschner, & Sweller, 2012; Kirschner, Sweller, & Clark, 2006) such that students are supposed to *discover* key concepts on their own. As such, these opponents of inquiry-based instruction assert that unguided inquiry doesn't work. However this idea of minimally guided instruction also referred to as *discovery learning*, negates the significant role the teacher plays in carefully designing and scaffolding the learning activities to ensure the targeted goals are achieved (Hmelo-Silver, Duncan, & Chinn, 2007; Llewellyn, 2002; Wendel, 1973; Wilcox et al., 2015).

Another misconception about inquiry instruction is the idealized notion that an *open inquiry* is the preferred form of inquiry that teachers should strive for in their classrooms. Brown and colleagues (2006) conducted a study with 19 college professors across the life and physical sciences and found they also viewed inquiry as “totally student driven, with students asking questions, designing investigations, and collecting data” (p. 798). This view perpetuated the idea that inquiry “is unstructured, time consuming, and difficult to enact,” and only for upper level students (Brown et al., 2006, p. 798). Such notions are not only inaccurate, but they are problematic and need to be extinguished (Brown et al., 2006; Settlage, 2007) because these beliefs constrain teachers from even trying to incorporate inquiry in their classrooms.

The more we know about the developing thoughts and conceptions preservice science teachers have about inquiry instruction, the more prepared science teacher education programs will be to support science teacher learning. In this light, as Wilcox and colleagues (2015) suggests, this study intends to make prospective science teachers’ thinking visible. This study presumes to add to this literature base by uncovering inaccurate conceptions and notions about inquiry instruction held by prospective science teachers who indicated inquiry-based beliefs about teaching and learning. Such information can be used to target needed improvements in science teacher learning.

Presumed Challenges and Barriers of Inquiry Instruction

Research studies and discussions with science teachers reveal many multifaceted and complex barriers that hinder successful implementation of teaching science as inquiry at all levels of teachers’ expertise. At the most practical level, teachers report time constraints, state-mandated testing, and adherence to curricular expectations at the local level (Brown, et al., 2006; Garritz, Labastida-Piña, Espinosa-Bueno, & Padilla, 2010; Marshall, et al., 2009; Reaume, 2011; Trautman et al., 2004) as prohibitive to inquiry approaches. Inquiry approaches are time consuming and appear to conflict with the need to cover science content to prepare students for mandated standardized tests (Marshall, et al., 2009; Reaume, 2011; Trautman et al., 2004). Inquiry approaches often seem chaotic in the classroom, and teachers may not have adequate science content knowledge and pedagogical expertise to support students during inquiry instruction (McComas, 2014).

Teachers' beliefs about students, teaching and learning, and the role of the teacher impact their teaching preferences (Crawford, 2007; Keys and Bryan, 2001; Wallace & Kang, 2004). Teachers question whether students (on both ends of the achievement scale) have the ability to perform inquiry abilities (Brown, et al., 2006; Trautman et al, 2004). In these studies, teachers express beliefs that students with lower abilities need step-by-step instructions in order to be successful in the classroom, and even the most structured forms of inquiry are beyond their reach. On the other hand, high achieving students who are successful in more traditional and transmissive styles of instruction may become frustrated and annoyed when the answers are not clearly available to them as may be case with inquiry. Lotter (2004) conducted a study to explore the challenges preservice teachers face in conjunction with their teaching science as inquiry practice. She found six categories of concerns preservice teachers commonly reported. Most all of their concerns were related to their own self-efficacy beliefs about their abilities to teach science as inquiry. Some reported concerns about students' abilities.

Teachers may also hold competing beliefs about teaching science as inquiry (Crawford, 2007; Eick, 2002; Keys & Bryan, 2001). Whereas, on one hand, they may express having core beliefs that favor inquiry because it promotes independent and critical thinking, problem solving, and immerses students into scientific thinking practice, the reality is their competing beliefs about students, about learning science, and the efficiency of teaching inhibit teaching science as inquiry (Crawford, 2007; Keys & Bryan, 2001; Trautman, et al., 2004; Wallace & Kang, 2004). Though they hail the ideals of inquiry science and the benefits students receive, teachers' classroom practice often does not reflect an equivalent focus on teaching science as inquiry.

Preservice science teachers will have seen a limited number of inquiry-oriented lessons in their teaching and learning careers. This is unfortunate because cognitive studies (Bransford et al., 2000) reveal that knowledge development and subsequent transfer requires repeated opportunities to learn concepts and in various contexts. A lack of understandings about science and the nature of science and scientific inquiry (Crawford, 2007; Keys and Bryan, 2001; Rutherford, 1964; Wallace & Kang, 2004) are also barriers to inquiry-based instruction.

> *Until science teachers acquire a rather thorough grounding in the history and philosophy of the sciences they teach, this kind of understanding will elude them, in which event not much progress toward the teaching of science as inquiry can be expected.* (Rutherford, 1964, p. 84)

Contemporary research about the lack of inquiry-based approaches in the classroom is often based on the underlying assumption that "teachers do not change their current practice of teaching science as *rhetoric of facts* to teaching *science as inquiry* without having a deep understanding of the nature of scientific inquiry" (Crawford, 2014, p. 527) and the value of inquiry within the sciences.

Preparing Preservice Science Teachers for Inquiry Instruction

Teaching is a dynamic and complex endeavor, and utilizing inquiry instructional approaches adds even more challenges (Crawford, 2007). There is no recipe for how to incorporate inquiry instruction effectively. Therefore “support, guidance, and leadership are vital if teachers are to make major shifts from a traditional didactic style of teaching to one that emphasizes inquiry” (NRC, 2000, p. 143). In light of the lack of inquiry-based teaching models (Crawford, 2007; Fazio, Melville, & Bartley, 2010) in the schools and, especially in higher education, the science teacher education community must continue its efforts to promote accurate conceptions of inquiry teaching and learning (Saad & BouJaoude, 2012).

Though research in the field of preservice science teacher preparation is growing (NRC, 2012) and may suggest what effective programs might consist of, there is a dearth of empirical evidence that can be used systematically prescribe what successful science teacher programs should look like (NRC, 2010). There continue to be pertinent questions that need focused attention. For example, “What instructional opportunities are necessary to prepare successful science teachers” (NRC, 2012, p. 143)? “How can we support teachers in their learning of science through inquiry?” and “How can we support them in developing a stance and a practice of science teaching as inquiry” (Abell, Smith & Volkman, 2004, p. 196)? There is little empirical evidence available that addresses these questions (Crawford, 2012).

Some have proposed that teacher education programs be reorganized around a central set of core practices to help preservice teachers develop their knowledge, skill, and professional identity (Grossman, Hammerness, & McDonald, 2009; Windschitl et al., 2012). According to Windschitl and colleagues (2012), “We then argue for the development of a set of research-based core practices for beginning educators that are limited in number and represent broadly applicable instructional strategies known to foster important kinds of student engagement and learning” (p. 879). Furthermore, the task for preparing science teachers to implement inquiry-based pedagogies will likely require explicit inquiry-based instruction and modeling (Akerson &

Hanuschin, 2007), opportunities to engage in learning through inquiry as science learners themselves, and explicit reflective exercises that help them make connections to their beliefs, experiences, and to how this relates to their teaching practices (Windschitl et al., 2012).

In order to support teachers in their development to teach science through inquiry, preservice teachers need opportunities beginning early in their teacher education programs to engage in authentic science inquiries, practice teaching science as inquiry, and explicit teaching about science as inquiry (Capps & Crawford, 2013). Eick & Reed (2002) found that preservice science teachers who regularly practiced inquiry approaches tended to develop inquiry-oriented identities. Kang (2008) argues that teachers reflecting on their teaching practices during teacher education programs serve to facilitate the integration of more sophisticated pedagogies such as those espoused by inquiry instruction. Because preservice and experienced science teachers alike have difficulty conceptualizing inquiry instruction, some scholars (Binns & Popps, 2013; Mellville et al., 2013) suggest that science teacher preparation programs explicitly promote the use of inquiry strategies *and* how to identify it by modeling appropriate instructional approaches and making explicit connections to the components of inquiry as well as explaining why it is inquiry (Binns & Popp, 2013).

Research shows that K-12 teachers most frequently teach as they have been taught (Davis, Petish, & Smithey, 2006; Duschl et al, 2007; NRC, 2010). Therefore, teachers need multiple opportunities to experience any new technique such as inquiry-based teaching before they will be able to incorporate it into their own practices. Preservice science teachers need multiple opportunities to experience inquiry instruction *before* they start their student teaching (Eick & Reed, 2002; Yager & Simmons, 2013). The *Framework* (NRC, 2012) on which the

NGSS are based asserts that to prepare science teachers, prospective teachers need exposure to and experiences conducting scientific investigations in the classroom.

In a review of the literature seeking to identify effective learning opportunities for prospective science teachers, Davis and colleagues (2006) found in part that effective teacher preparation programs use the same general approaches to teaching science teachers as those advocated for in K-12 education (such as fostering inquiry). If students are to learn about science inquiry and do science, it is necessary that teachers learn about science inquiry and practice doing it in their own academic endeavors in the same way their students develop understandings (NRC, 1996; 2000; 2010). Further, they need experiences planning for student-designed investigations including how to guide their students during inquiry investigations from start to finish (NRC, 2000). Novice teachers who have limited pedagogical content knowledge and a limited repertoire of teaching strategies may rely on rote teaching science strategies they learn in their programs or what they have experienced as students in science courses (Eick & Reed, 2002). Importantly, explicit teaching in these high priority areas of science teacher education are needed to overcome the current status quo of teaching science in the classroom (Eick, 2000; Schwartz et al., 2002).

Instructional Design Supports for Inquiry Instruction

Helping prospective science teachers develop accurate conceptions of inquiry, beliefs aligned with the inquiry reform efforts, and learn to implement inquiry into practice is not enough. Preservice science teachers need significant encouragement and support during their learning to teach experiences (Crawford, 2007; Lotter, 2004). Novice teachers also need significant instructional guidance to support their learning to implement new strategies (Bryk, 2010; Teachers' Advisory Council, 2015). According to the Teachers' Advisory Council (TAC)

(2015), to be most effective instructional materials need to be aligned with the NGSS and support inquiry-based learning. “They need to be coherent and driven by learning goals, provide opportunities for students’ investigations and support discourse and elicitation of students’ ideas” (p. 190).

To this end, the learning cycle approach supports inquiry-based student learning and achievement in science (Duran & Duran, 2004; Lawson, Abraham, & Renner, 1989) by alleviating some of the uncertainty teachers experience when first learning to design inquiry-based lessons (Duran & Duran, 2004). Although the learning cycle and its multiple versions (e.g. 3E, 5E, & 7E) have been around since the Science Curriculum Study (SCIS) (Atkins & Karplus, 1962), the BSCS 5E Instructional Model (Bybee, 2009) is of particular significance to this study.

The 5E Instructional Model is designed with constructivist learning principles that emphasize investigation and constructing evidence based explanations. According to Bybee and colleagues (2006), “Individuals redefine, reorganize, elaborate, and change their initial concepts through interaction with their environment, other individuals, or both. The learner ‘interprets’ objects and phenomena and internalizes the interpretation in terms of the current experience encountered” (p. 11). The 5E is based on an instructional sequence of learning activities that incorporates best practices about how people learn (Bransford et al., 2000). Although it was not originally intended as a way to incorporate inquiry-based strategies, from a constructivist-learning perspective, inquiry connections are evident (Bybee, 2002). See Table 2.2 for a brief comparison of the 5Es and the Essential Features of Inquiry (NRC, 2000). There is evidence that using the 5E Instructional Model (and other learning cycle approaches) may be beneficial to helping teachers design and implement inquiry-based learning activities that are congruent with the *Standards* description of learning science as inquiry (Bybee, 2009; Bybee et al., 2006; Duran & Duran, 2004; Goldston et al., 2013; Slykhus, 2009; Wilson, et al, 2010), as well as support science teacher efficacy (Bybee, 2009; Lawson et al., 1989). Also, according to Bybee (2009), "The model has been used to help frame the sequence and organization of programs, units, and lessons. Once internalized, it also can inform the many instantaneous decisions science teachers must make in classroom situations" (p. 4).

TABLE 2.2

Comparing Essential Features of Inquiry (NRC, 1996; 2000*) with the 5E Instructional Model of Instruction* (Bybee et al., 2006)

	5E Stages What Students do	Essential Features of Inquiry What Learners do
Engage	Show interest and ask questions about phenomenon.	Engages in scientifically oriented questions
Explore	"Mess around" with materials, testing predictions, recording observations.	Gives priority to evidence in responding to questions
Explain	Explain concepts and ideas in their own words using recorded observations to in their explanations, listen to and debate ideas with other	Formulates explanations from evidence
Elaborate	Make conceptual connections between new and past experiences using scientific terms and descriptions.	Connects explanations to scientific knowledge
Evaluate	Demonstrate understanding and answer open-ended questions using evidence to support their explanations	Communicates and justifies explanations

UTeach: Science (& Mathematics) Teacher Preparation

Much research has been conducted on how to prepare quality science teachers (Allen, 2003; NRC, 2010; Tytler, 2007; Yager & Simmons, 2013): yet much remains to be known. There is no clear consensus about what works and what is currently being done (NRC, 2007; 2010). The fact remains, however, that "quality teaching is critical to successful outcomes for students" (Tytler, 2007, p. 57), and teacher preparation is known to impact teaching practice

(NRC, 2010). In a study conducted by Darling-Hammond, Chung, and Frelow (2002) who investigated variation in teacher preparation programs found “the extent to which teachers felt well prepared when they entered teaching was significantly correlated with their sense of teaching efficacy, their sense of responsibility for student learning, and their plans to remain in teaching” (p. 286). On that note, it is a worthwhile endeavor to explore how one particular science teacher program that emphasizes inquiry instruction prepares its preservice teachers to utilize inquiry instruction. Exploring the participants’ thoughts and conceptions concerning their own sense of preparedness to utilize inquiry instruction is essential to accepting the premises promoting the program’s effectiveness.

The UTeach science and mathematics teacher education program was developed in 1997 and enjoys high acclaim regarding the number of high quality math and science teachers prepared using their model who will teach in the STEM fields (Committee on Prospering in the Global Economy of the 21st Century, 2007). The program is designed to allow preservice secondary science and math teachers to major in a STEM field of interest (although our focus in this study is on science, specifically) and simultaneously earn teaching credentials within a four-year period. The UTeach Program identifies nine *Elements of Success* that “outline aspects and features of the program that contribute to its effectiveness” (UTeach Institute, 2015). Among these unique and identifying features is a commitment to “rigorous and research-based instruction” (p. 9).

In addition to their major requirements, preservice science teachers take eight specially designed courses specific to teaching math and science. The courses of instructions were designed around two main goals: (a) Integrate content and pedagogy and (b) connect theory and practice (UTeach, 2014). According to Abraham (2007-2010), “In the place of general education courses we created new pedagogy courses with a focus on how to teach math and science with modern theories of learning. UTeach students learn to design and teach inquiry-based lessons that develop critical thinking skills" (n.p). Table 2.3 provides a typical course sequence for freshmen entering into the program. Further elaboration and course descriptions will follow.

TABLE 2.3

A Flow Chart of Typical Course Sequence in the Uteach Model Science Teacher Education Program

	Freshmen	**Sophomore**	**Junior**	**Senior**
Fall	*Step 1	Knowing and Learning	*Project Based Instruction	[a] Perspectives
Spring	*Step 2	*Classroom Interactions	[b] Research Methods	[c] Apprentice Teaching

Notes. [1] This typical course sequence is an option, not descriptive or prescriptive of what any programs do. Rather, each program is unique, and courses sequences are determined programmatically. [2] Courses with an asterisk include a field-based practicum consisting of 5-8 hours of observing and teaching experiences.
[a] Perspectives teaches prospective science teachers about history and nature of science. [b] Research Methods provides prospective teachers with opportunities do inquiry. [c] Apprentice Teaching is a semester long full immersion teaching internship experience.

Course Descriptions and Instructional Emphases

To help understand the background and rationale for this study, this section presents a brief description of the inquiry emphasis found in each of the courses of instruction as described in the UTeach Operations Manual (UTeach Institute, 2014). Because the intent is to capture how specific course emphasize inquiry-relevant details, the course descriptions that follow do not attempt to describe any of the courses in significant details except as they pertain to inquiry instruction. See Table 2.4 for the brief descriptions of each course.

Four of the eight courses include carefully structured practicums to ensure the participants have opportunities to teach science through inquiry. Typically, the instructional focus is on inquiry-based lesson preparation and teaching experiences using the 5E Instructional Model. These courses involve a number of observations in local science classrooms, the design and implementation of three to four inquiry-based lessons at local schools, thorough guided written lesson reflections following each observation and teaching event, and multiple discussion opportunities. Master teachers, clinical faculty with successful secondary math or science teaching experiences, provide intensive coaching and support including written and oral feedback regarding the lesson plans and practice teaching sessions. Both explicit instruction and practical experiences teaching science through inquiry are embedded throughout the coursework. For data collecting purposes, the following section breaks the eight courses down into four categories of program progression: Early, middle, advanced, and program completers.

TABLE 2.4

UTeach Course Descriptions and Inquiry Instructional Emphases (UTeach Institute, 2014)

Early Level Participation (Recruitment Courses) • *Step I: Inquiry Approaches to Teaching and Step II: Inquiry-based Lesson Design,* the first two courses in the UTeach series, are *tryout* teaching recruitment courses that offer prospective science teachers opportunities to explore teaching science through inquiry. “The master teachers introduce students to the theory and practice behind excellent inquiry-based science and mathematics instruction” (p. 10). Other “key instructional approaches include classroom discussion, lesson demonstration, student reflection, collaboration, and peer coaching” (p.13). One of the multiple course objectives in both introductory courses is for participants to “design and teach inquiry-based lessons using the 5E Instructional Model” (p. 11). *Field Experiences:* Participants observe twice and teach three inquiry-based science lessons in local elementary and middle school classrooms.
Middle Level Participation • *Knowing and Learning* is three-hour courses designed with the goal of helping participants construct a model of knowing and learning specific to mathematics and science domains. Course participants explore various theories of knowing and learning including the cognitive, social, as well as “nature vs. nurture” perspectives. They examine their own preconceptions and assumptions about learning. “Key instructional practices include modeling effective direct-teaching and questioning strategies, interactive discussion, collaborative group tasks, and formative and/or summative assessment of student learning of skills, knowledge, and understanding” (p.18). *Knowing and Learning* is typically the gateway course into the teacher education program. *Field Experiences:* Participants to conduct clinical interviews of various learners (children, peers, experts) in a problem solving contexts.

TABLE 2.4 (Cont.)

UTeach Course Descriptions and Inquiry Instructional Emphases (UTeach Institute, 2014)

Middle Level Participation (Cont.)

- Classroom Interactions (CI) is a three-hour class that revolves around practicum experiences and an iterative three-step cycle of developing and implementing three inquiry lessons and subsequent critical reflections. “Students continually explore and compare various models of teaching (direct instruction, inquiry, cooperative grouping, etc.).” (p. 22). According to one of the course objectives, students “observe, analyze, and discuss how students’ knowledge and skills can be built using a variety of instructional strategies (including direct instruction, inquiry teaching, and use of small groups), focusing on what each model requires of teachers” (p. 5-23). *Field Experiences:* “Students interview and observe classroom teachers and teach twice in high school classrooms. The first teaching experience is a 1-day event; the second lasts 2 days. Both teaching experiences are videotaped. Students spend significant time preparing, practicing, and revising lessons for the teaching events” (p. 24).

- *Research Methods (RM)* is a 3-hour lab course (cross-listed with multiple science content courses, biology, chemistry, and physics), primarily, designed to meet the needs of science (and math) majors who are also going to be teachers. RM provides prospective science teachers opportunities to do a number of inquiry investigations to answer questions they are interested in exploring, and simultaneously they learn how to support student learning through inquiry. In part, the goals of the course are (a) to provide program participants (i.e. prospective science and math teachers) with the tools scientists use to solve problems and use these tools in a laboratory setting, (b) to make participants aware of how scientists communicate through peer-reviewed literature, and (c) how they develop new knowledge, which eventually makes its way to textbooks and is taught in science class. *Field Experiences*: None

Advanced Level Participation

- *Project-based instruction (PBI)* is designed on the “premise that project-based instruction engages learners in exploring authentic, important, and meaningful questions of real concern to high school students” (p. 26). Despite its name, PBI “incorporates a variety of instructional approaches, distinguishing among project-based and other examples of inquiry-based instruction” (p. 27). Two of the stated objectives are that course participants will “distinguish between project-based instruction and other instructional approaches and decide which approach best fits instructional goals based on the benefits and limitations of each,” and “use inquiry methods with secondary students in a problem-based setting.” (p. 28). Participants develop a three-four week project-based unit. *Field Experiences:* During their field-based experience, participants observe in project-based classrooms twice, and they develop and teach four inquiry-based lessons in local middle and high school classrooms.

TABLE 2.4 (Cont.)

UTeach Course Descriptions and Inquiry Instructional Emphases (UTeach Institute, 2014)

Advanced Level Participation (Cont.)
• *Perspectives* addresses the nature and history of the scientific enterprise. Designed to make course participants to think critically, it "illustrates how knowledge has often emerged through torturous struggles, against obstinate resistance, and within cultural, religious, and social structures. Students are brought to understand that science is not merely a body of facts, theories, and techniques; it involves diverse processes by which it is continually generated and reformulated" (p. 39). The course portrays the rich and robust nature of science and its character as a human endeavor. Students come to understand that historical inaccuracies and myths are often perpetuated in textbooks. Additionally, students develop an understanding that science knowledge is dynamic and subject to the cultural and social factors within the science community. Subsequently, students gain insights about the critical thinking and creative processes of science. Participants design and teach a 5E lesson incorporating historical content to their peers: *Owing to the nature of the material itself, there is a greater share of investigation and discussion of historical and conceptual topics than the sort of hands-on activities promoted by the 5E model that UTeach students use for their own lesson plan assignments. Nevertheless, the intent of the Perspectives curriculum overall is to model an inquiry-based approach, and instructors should strive to increase the quantity and quality of whatever activities they may deem appropriate. In all cases, there should be a conscientious attempt to model instructional best practices through use of Socratic questioning, facilitation of student explorations, and inquiry-based activities*. (p. 41). *Field Experiences:* None
Program Completion Level Participation *Apprentice Teaching (AT)* is the culminating experience preservice teachers have in preparation for becoming full time science and math teachers. In AT preservice teachers immerse in teaching practice their final semester in the program for a minimum of twelve weeks under the mentorship of experienced science teachers in the public school setting. They also attend a weekly seminar class taught by a master teacher. *Field Experiences:* Full immersion teaching experiences

Note. The course descriptions above are intended to provide the reader a brief overview of the inquiry emphasis in each course. There is absolutely no intent by the author to provide in-depth course descriptions.

Conclusion

It likely that all of those invested in helping students learn science will agree that teaching and learning science should be more than rote memorization, the teaching of facts, and a regurgitation of the same. Intuitively we will all likely agree that students need to be critical thinkers, problem solvers, and they need the skills to be able to inquire and investigate phenomena. Such ideas are congruent with the use of inquiry methodologies in the science classroom. However, as already stated, inquiry approaches to teaching and learning are not happening in most classrooms despite decades of research documents that urgently demand a scientifically literate society (NRC, 1996; 2000; 2012) and despite that inquiry based approaches are the central tenet in the NSES (NRC, 1996).

There has been little written about how preservice science teachers conceptualize inquiry instruction or how they learn to incorporate it into their teaching practice. This research study is different from others like it because the program makes a concerted effort to emphasize elements of inquiry instruction through modeling, lesson plan development, and teaching in three courses (Step I, II, and Project Based Instruction), helps preservice science teachers learn to do inquiry (in Research Methods), and help them understand about inquiry (in Research Methods and Perspectives classes). Preservice science teachers have multiple opportunities to experience successful inquiry-based instruction over an extended time before they begin teaching full time in the Apprentice Teaching experience.

Preservice science teachers' experiences and beliefs are central to this study. Even though this study does not follow a single group of teachers through their learning to teach program, it does explore how groups of prospective science teachers conceptualize inquiry at various stages in a teacher education program. The premise behind this cross-sectional study is that preservice science teachers who are more advanced in this program have had more explicit learning about inquiry and doing inquiry experiences - specifically in a teaching science context. As such, the study makes preservice science teachers thinking visible at the beginning of a program and at various stages throughout it. This study pursues the line of research that explores teachers' beliefs and knowledge base about how and why preservice science teachers adopt the particular conceptions of inquiry they way they do (Kang et al., 2008). Research on developing teachers' understandings of and intentions for teaching science as inquiry require a clearly defined pedagogy of inquiry grounded in the practical aspects classrooms (Crawford, 2014). Although, this research is conducted devoid of classroom observations, all of the preservice science teachers have had experiences developing inquiry-based lessons and teaching them in real classroom contexts. The questions remain, so how do these preservice teachers conceptualize inquiry at various stages in their teacher preparation, and why do they value it as a pedagogical practice? It is in this context this study was conducted.

CHAPTER 3: METHODOLOGY

Background and Study Context

The UTeach Program, created in 1997 at the University of Texas in Austin, has been cited as a model science teacher preparation program by the National Academy of Sciences (Committee on Prospering in the Global Economy of the 21st Century, 2007) for its success at recruiting high quality math and science teachers into teaching careers who know how to engage students in scientific inquiry. As stated by the Committee, "Graduates [from the program] have deep disciplinary knowledge grounding, they know how to engage students in scientific inquiry…" (p. 117). Participants in the program can complete their undergraduate degree, earning a bachelor's degree in a science or mathematics and also complete their respective state mandated secondary teacher licensure requirements in four years. The teacher education program is typically offered as a collaborative effort between the College of Education and colleges that provide the content in science and mathematics. Although the science component is implemented in traditional lecture and laboratory courses offered in the college(s) responsible for offering STEM degrees, certain of the UTeach courses of instruction emphasize critical aspects of inquiry-based instruction. For example, the courses of instruction provide early and frequent supervised teaching experiences that emphasize elements of guided inquiry. Furthermore, program participants have opportunities to conduct guided and open inquiry investigations in a learning to teach science (and mathematics) environment, and they also learn *about* inquiry. (See Chapter 2 of this document for descriptions of each of the UTeach courses specifically as they pertain to teaching and learning science through inquiry.) Beginning in 2008, 13 universities in nine states (Cohort I) adopted the program UTeach program. Now there are 44 universities implementing it in 21 states (https://institute.uteach.utexas.edu).

Beginning in 2012, three University sites in Arkansas adopted the UTeach program on their respective campuses: University of Central Arkansas (UCA), University of Arkansas at Little Rock (UALR), and University of Arkansas- Fayetteville (UA). At the time of this study, the three adoption sites are all in their fourth year of program implementation. Because these programs were implemented according to the same UTeach Model, and they are all new and within the same program adoption cycle, this research is based on an assumption that the three programs prepare science teachers in much the same way. They operate under the same *Elements of Success* (e.g. active student recruitment and support, clinical faculty with exemplary secondary teaching records, early and intensive field experiences, flexible and compact degree plans and more). They offer the same courses of instruction that program developers reviewed for course fidelity the first time they were implemented. (See the UTeach Institute for more information about the UTeach Model: https://institute.uteach.utexas.edu/uteach-model). As such, these circumstances provided an interesting opportunity to explore how the preservice science teachers in these three programs construct their conceptions of inquiry during their teacher education programs. Although the three programs operate independently from each other, the number of subjects enrolled in each course on the respective campuses was too small to study them separately. Therefore, I treated the three programs as a single science teacher preparation program, and I report the results collectively.

During the spring semesters of 2015 I obtained Institutional Review Broad (IRB) permission to conduct this study on the two of the three University Campuses. (See Appendix G for the approval letter.) I began collecting data on these two campuses during the subsequent fall semester. Because I was unable to obtain IRB approval (See Appendix H) for the third campus until the following spring semester, data collection was not completed until the spring 2016.

In this chapter I describe the research approach and methods used to explore how select prospective science teachers at various stages in their teacher education programs conceptualize inquiry instruction. By *select prospective science teachers,* I specify those who have consistently expressed an intentionality to utilize inquiry instruction in the classroom. In the following sections I will describe my research methodology in two discrete phases, which are distinguished from each other based on selected subjects, data collection and analysis, and the interpretation of results. The following three research questions and related sub-research question guided the study:

Research Questions

1. How do preservice science teachers who indicate preferences for inquiry instruction

describe their beliefs about teaching and learning science?

2. How do these preservice science teachers define and describe inquiry instruction?
3. What justifications do these preservice science teachers provide for utilizing (or not utilizing) inquiry instruction in the science classroom?
    - How do these preservices science teachers' beliefs, conceptions of inquiry instruction, and their subsequent justifications for using it compare at various stages of their teacher education program?

Research Design

This research employed a sequential explanatory mixed methods research design involving both quantitative and qualitative data collected at two distinct phases (Creswell, 2009). Typically, in sequential explanatory studies, the second qualitative strand is used to explain the initial quantitative results (*follow-up explanations variant)*. However, this research chose to use the quantitative strand to identify select participants to participate in the qualitative phase. Therefore, unlike a typical sequential explanatory design that prioritizes the quantitative results, this study employed the "less common *participant selection variant* " (Creswell & Clark, 2011, p. 86) and emphasized the qualitative data in Phase II. Participant selection variant is desired when quantitative results are needed to purposefully select participants for a more in-depth, follow up, qualitative study. See Table 3.1 for a visual description of this research design.

In the first phase numeric data were collected using a modified version of the Pedagogy of Science Teaching Test (POSTT) (Cobern et al., 2013) to collect summary indicators of preservice science teachers' teaching orientations and subsequent preferences for utilizing inquiry instruction. However, inquiry instruction is a complex and dynamic teaching endeavor even among experienced inservice teachers (Crawford, 2007). Recognizing that even experienced teachers often express incomplete and inadequate understanding about inquiry instruction, this research sought to explore how the most informed prospective science teachers at various levels of these three programs characterize inquiry instruction. Knowing their thoughts, conceptions, and rationales about inquiry instruction at various levels could provide valuable insights about how to target future improvements in science teacher preparation to more effectively implement this pedagogy. Because I was not intending to evaluate their knowledge of inquiry, per se, but instead desired to understand these preservice science teachers conceptions and misconceptions of inquiry, Phase I informed participant selection for the follow-up study in Phase II.

Table 3.1

An Overview of the Sequential Explanatory Study Design

PHASE I							
Quantitative Data Collection (POSTT_M)	→	Quantitative Data Analysis (POSTT_M)	→	Quantitative Results (POSTT_M)	→	Interpretation of Quantitative Results (Subject Selection Based on POSTT_M Results)	→
PHASE II							
Qualitative Data Collection (Beliefs and Inquiry Survey)	→	Qualitative Data Analysis (Beliefs and Inquiry Survey	→	Qualitative Results (Based on Beliefs and Inquiry Survey	→	□□□□□□□□□□ □□ on of Qualitative Results	

Purposeful sampling in Phase II allowed the researcher to pursue a more in-depth understanding about how a select group of prospective science teachers conceptualize inquiry instruction. As such, this study gave preference to Phase II of the study and explored the thinking of those who indicated a definite preference for teaching particular science topics using inquiry-based instructional strategies. The sections that follow describe the research methods in both phases of the study.

Data Collection Methods and Analysis (Phase I)

In Phase I of the study, the researcher employed two data sources to explore and understand more about preservice science teachers' developing conceptions about teaching science as inquiry. Both instruments were administered at the same time:

- A demographic Survey (See Appendix C.)
- POSTT_M (Pedagogy of Science Teaching Test-modified versions) (modified from Cobern et al., 2016) (See Appendices D and E.)

The demographic survey captured the subjects' personal and professional contexts, including their historical and current status in teacher education and their teacher preparation experiences. Because the researcher also sought to capture developmental differences, demographic information was especially pertinent to recognize subjects' levels of progression, disciplinary focus, and future plans regarding intentions to teach science. Therefore, I sought representative research participants from various levels in their teacher education programs.

I used modified versions of the Pedagogy of Science Teaching Test (POSTT) (Cobern et al., 2014) to develop a preliminary overview of subjects' preferences for inquiry at all levels of their program development. (In future references, I use the label POSTT_M to distinguish between the original and modified versions of the POSTT.) The following sections describe these data sources more fully.

Subject Selection and Demographics: Phase I

To initiate Phase I of the study, I gained permission to visit individual classes during the instructional periods on all three campuses to solicit subjects. After spending about ten minutes in each class to share the research plan with students, I requested their email information and permission to contact them concerning their participation in the study. Following the class visits, a total of 87 identified preservice science teachers enrolled in any of the eight UTeach courses were invited, via Qualtrics™, to participate in the study. Follow-up reminders were sent twice, encouraging members to complete the surveys. Fifty-three potential subjects (61%) completed the surveys, but for reasons elaborated upon later, analysis was conducted on 46 subjects' (53%) responses. See Table 3.2 for the survey subjects' demographic characteristics in Phase I of the study.

All of the subjects in the study are science majors (biology, chemistry, physics) enrolled in the Arkansas UTeach programs during the fall and spring semester of 2015-2016. Relative to the number of courses they have completed, the subjects have experienced the same program elements that emphasize teaching science as inquiry. Although they have all declared an interest in teaching science, for some of them, the teaching pursuit is a "back-up plan" in case their preferred choice of careers becomes unavailable at some point in time (e.g. don't get accepted into medical school). For others, the pursuit of a teaching licensure is based on some future plan to teach ("such as when I decide to have kids," or "after I retire and want to do something else"). For others, teaching is what they wanted to do all along, or is what they have decided to do since experiencing teaching during the early-on recruitment courses.

Data Collection: Phase I

To identify select preservice science teachers who indicated inquiry-based teaching orientations, the researcher employed a teaching scenario tool, modified from the Pedagogy of Science Teaching Test (POSTT) (Cobern et al., 2016). Teaching scenario data are particularly useful for probing teachers' beliefs and knowledge about teaching and learning (Cobern et al., 2014; Kang et al., 2008). Working from the belief that teaching is context specific,

TABLE 3.2

Phase I: Survey Subjects' Demographic Characteristics per Program (Percentages in Parentheses)

Characteristics	UALR (n = 11)	UCA (n = 9)	UA (n = 26)	**Total (n = 46)**
Gender				
Female	7	4	13	24 **(52)**
Male	4	5	13	22 **(48)**
Courses Completed				
Level I: 1 to 2	2	6	9	17 **(40)**
Level II: 3 to 5	5	2	4	11 **(24)**
Level III: 6 to 7	4	1	5	10 **(23)**
Level IV: 8[a]	-	-	8	8 **(19)**
Major				
Biology	9	3	12	24 **(52)**
Physics	1	1	11	13 **(30)**
Other Science[b]	1	5	3	9 **(20)**
Degree				
BA	-	-	12	12 **(28)**
BS	11	9	14	34 **(74)**
Academic Level				
Freshman	1	-	4	5 **(12)**
Sophomore	4	1	1	6 **(13)**
Junior	1	4	6	11 **(26)**
Senior	5	4	7	16 **(35)**
Program Completer	-	-	8	8 **(19)**
Post Graduation Plans				
Teaching job[c]	7	4	19	30 **(65)**
Graduate School[d]	4	4	7	15 **(33)**
Undecided	-	1	-	1 **(02)**

Note. University of Arkansas - Little Rock (UALR), UCA (University of Central Arkansas, Conway), UA (University of Arkansas- Fayetteville)

[a] Subjects in this category have recently graduated from the program. One subject is currently in his first year teaching. At the time of this survey, there were no Level IV subjects at UALR or UCA. [b] The *other* science category consists of chemistry (4), horticulture (1) , environmental science (1), and engineering (1) majors. [c] Most of the survey subjects (65%) indicated an intention to teach immediately post graduation. [d] Other subjects plan to attend graduate school and possibly teach science eventually.

the POSTT is a collection of vignettes, or cases, of teaching scenarios that specifies an instructional goal and a particular grade level across the life and physical domains of science. An example scenario follows: "Ms. Adams's ninth grade students have learned that light travels in a straight path and that shadows form when an object blocks light. Ms. Adams wants her students to be able to apply these ideas to make predictions about shadows." After providing more contextual information, the each vignette is followed by a lead-in sentence, "Thinking about how you would teach this lesson, of the following" [and some iteration of] which is the most similar to what you would do next? Subjects selected one of the four pedagogical choices that followed. The choices ranged on a scale from very teacher oriented to greater levels of student-centered instruction: Active Direct (AD), Guided Inquiry (GI), and Open Inquiry (OI). See Table 3.3 for specific explanations of the teacher orientations used in this study.

TABLE 3.3

Teaching Orientations (Modified from Cobern et al., 2013)

Teaching Orientation		Description
Traditional Orientation	Didactic Direct (DD)	Teacher presents and explains science content directly; illustrates concepts using examples or demonstrations, excluding student activities.
	Active Direct (AD)	Teacher presents and explains science content directly; students actively engage in verification/confirmation labs.
Inquiry Orientation	Guided Inquiry (GI)	Students actively explore a phenomenon; the teacher provides some level of student guidance and direction toward a desired outcome.
	Open Inquiry (OI)	Students actively explore phenomenon or ideas of their choosing; the teacher facilitates processes but does not prescribe.

Since the original POSTT survey was designed to assess K-8 preservice science teachers' orientations to teaching science, the vignettes are not tightly connected to a particular grade level. Because I wanted the subjects to envision themselves "in the particular teaching situation, play the role of decision-maker, and respond accordingly" (Cobern, et al., 2014, p. 2272), I selected only those scenarios reflecting middle school and higher science topics. For convenience purposes, I refer to this modified version of the POSTT as POSTT_M (modified). Next I compiled the relevant assessment items into two separate versions, which I refer to as POSTT_M-B (biology) and POSTT_M-P (physics). The POSTT_M-B consisted of four biology specific teaching scenarios, and the POSTT_M-P consisted of four physics specific topics. Further, I changed the grade level wording to reflect upper levels of instruction. For example, instead of saying, “Mr. Montgomery was teaching his 5th graders about inheritance….”, the question was realistically restated to say, “Mr. Montgomery was teaching his *10th* grade biology students about inheritance” Rewording some of the scenarios in this fashion to reflect a range of 7-12th grades was purposed to help the respondents envision themselves in the particular situation better.

In order to validate these instruments for this study specifically, I administered samples of assessment items on the POSTT_M to five science teacher educators (three professors and two doctoral students) who are actively involved in science teacher education. They were tasked to read each scenario and then assign each response to the most appropriate instructional orientation: Didactic direct, active direct, guided inquiry, and open inquiry using the operational definitions and descriptions provided by Cobern and colleagues (2013). Subsequently, I removed any assessment items that had less than an 80% agreement among the science teacher educators. Six out of the final eight items used had 90-100% agreement. One item had 80% and the other had 85% agreement.

Although the instrument developers did not include an open response type question with each scenario, in concert with inquiry thinking and constructivist philosophy, I wanted to know more about the subjects’ responses and why they chose one method over another. Subsequently, each vignette on the revised POSTT_M was followed by an open-ended question: “Please explain WHY you chose this particular instructional strategy over the other three options (i.e. Why is inquiry better than another approach?). Please include any clarifying information you think will help the researcher understand your response better."

To identify preliminary summary indicators of subjects' inquiry thinking at each level of the science teacher education program, I administered either the $\mathrm{POSTT_M}$-B or the $\mathrm{POSTT_M}$-P to 53 prospective science teachers, all science majors who had completed at least one course in the program. The subjects chose which $\mathrm{POSTT_M}$ version (biology or physics) they wanted to take based on their own science major. They were asked to read the four teaching scenarios specific to their disciplinary area, and choose one of four responses that best reflected their own teaching preferences. Each response correlated to one of four basic descriptions of teaching orientations as described by Cobern and colleagues (2013): Open inquiry (OI), guided inquiry (GI), active direct (AD), or didactic direct (DD). Additionally, each selection was followed by an open-ended question asking the subjects to explain their pedagogical choice.

Data Analysis ($\mathrm{POSTT_M}$): Phase I

Data analysis involves organizing the data and creating categories that cut across all data sources (Creswell, 2009). To start making sense of subjects' responses, I transferred them to an Excel spreadsheet for initial analysis. Next I categorized the responses into counts for each pedagogical choice. Then due to the challenges identified with reliability of survey data (AAAS, 2012), I used the prospective teachers' open-ended responses to validate their self-selected teaching preferences. Reading vignettes and choosing an inquiry-based strategy because it is "what I would do if I were teaching that topic" is one thing. Defending that strategy using a rationale that encompasses some aspect of instructional effectiveness as measured by potential student learning outcomes (Colbern et al, 2014) adds a layer of validity to that choice. Using Crawford's (2007) assertion that prospective teachers should make explicit connections between their teaching practice and how students learn, I iteratively read all of the open-ended response looking specifically for consistency among subjects' pedagogical choices and the corresponding rationales.

Subsequently, s*tudent benefits* emerged as a single reoccurring theme in most subjects' responses. There were also four sub-themes that emerged: Affective benefits (AB), learning outcomes (LO), student responsibility (SR), and active thinking (AT). As a reminder, the purpose of using the POSTT$_M$ in Phase I was primarily to identify potential preservice science teachers in the program who were most likely to consistently prefer inquiry-based instructional strategies. Once these individuals were identified, I planned to invite them to continue into another phase of the study so I could explore their thinking further. Therefore, I considered the subjects' rationales valid only if they included at least one potential student benefit from that instructional choice. For example, in response to "Explain why you prefer this approach over the other options listed," one inquiry oriented response said, "I like this one better because it's the most inquiry based. It gives the students responsibility, and it also prepares them for college." Because her rationale included the statement that "it gives the students responsibility," I counted her inquiry selection as valid. The idea of student responsibility is consistent with inquiry-based rationales in literature (Minner et al., 2009). However, "because it is inquiry-based," and "because it prepares students for college" did not count as student benefits directly related to inquiry processes.

Subsequently, I eliminated any survey questions that lacked a rationale and any responses that did not corroborate appropriately. For example, if a subject said, "I chose this method because it is inquiry-based," I did not include that response in the final tally. For example, if a student selected an inquiry teaching strategy, but the corresponding rationale was because "students learn better when the teacher tells the students what they need to know before they investigate," that response was removed from the data analysis because it didn't correspond with the inquiry-based approach selected. Another participant who selected an inquiry based approach stated in his rationale, "Because it is a 5E method." Although his statement might be accurate, the rationale was not congruent with using inquiry due to its potential to positively impact student achievement, so I did not count his response as valid for purposes of this project.

Likewise, I validated each non-inquiry response as long as it had a corresponding rationale for why students will benefit. For example, one Level II subject who preferred an *active direct strategy* for a particular topic said, "This approach gives students a hands on opportunity while also showing them what they should be looking for." As such, the pedagogical selection and the rationale were consistent, so I counted that response as valid. As long as each selection included at least one reason how students might benefit from that instructional strategy, I counted that response as valid. Ultimately, based on these guidelines, I eliminated a total of six complete surveys and 18 survey questions, and I focused further analysis only on the remaining 46 surveys and the corresponding validated rationales (inquiry and non-inquiry).

After validating the preservice teachers' pedagogical selections with congruent rationales, I organized their numerical responses into counts for each of the four pedagogical choices (DD, AD, GI, and OI). Subsequently, I reported the tallied responses combined into inquiry (GI and OI) or non-inquiry (DD and AD) responses. Next I assigned the data into categories depending on the number of courses the subjects had completed. Lastly, I constructed a frequency table to organize the results, and the calculated the percent rankings.

The number of UTeach courses program participants have completed defines each category level: Levels I, II, III, and IV. (See Table 3.4 for a description of program level categories and the instructional emphasis.) Subjects in the Level I category have completed one or two of the "*try out teaching*" (Step I and II) courses. These courses emphasize *guided* inquiry lesson development and implementation at the elementary and middle school levels. Students also learn to use the 5E Instructional Model of instruction to help incorporate inquiry principles into their instruction. Level II subjects have completed three to five of the courses, including another practicum-based course that emphasizes theory and science specific teaching methods. Subjects in Level III have completed six to seven of the eight courses including Research Methods, Project-based Instruction, and Perspectives. All of these courses emphasize either doing inquiry, teaching science as inquiry, or learning about inquiry. Lastly, the Level IV subjects have completed all the course work including the Apprentice Teaching (the full immersion student-teaching experience in a local high school).

TABLE 3.4

Levels of Participant Progression and Corresponding UTeach Courses and Instructional Emphases

Program Level	Courses Completed	Course Names	Inquiry Instructional Emphasis
[a]I	1-2	Step I & Step II	Inquiry Instruction & 5E Instructional Model
II	3-5	Knowing and Learning Classroom Interactions Research Methods	Teaching and learning methodologies Various models of teaching Doing & learning about inquiry
III	6-7	Project Based Instruction Perspectives	Inquiry teaching in a problem-based setting Learning about the nature of science inquiry
IV	8	Apprentice Teaching	Intern teaching (full immersion)

[a]Participants in Level I have are enrolled in one of the two *recruitment* courses. These students are *trying out teaching.* Participants enrolled in courses beyond the recruitment courses have made a commitment to complete the program and obtain a teaching minor.

At this point, my primary goal was to identify select subjects in the three Arkansas

UTeach programs who expressed definite preference for and intentionality toward inquiry instruction. It was their thinking I wanted to know more about. Therefore, I needed to evaluate their inquiry rationales more rigorously in order to find subjects most likely to provide in-depth information I needed to explore their understanding. As such, I established a point value system I could use to identify subjects who were most likely to consistently prefer inquiry instruction using student-centered rationales. By student-centered, I refer to rationales that connected the instructional choice with one or more student specific benefits.

Believing that subjects who value inquiry instruction for multiple reasons rather than "because it is more engaging than other forms of learning," are more likely to utilize inquiry in the actual classroom, I expressly valued diversity of reasons (rather than multiple reasons of the same type). Once more I returned to the subjects' open-ended responses and reread all of their explanations and evaluated them in terms of diversity of rationales. Subsequently, I decided each question could receive a maximum of 4 points (one point per benefit). Therefore, even if a student responded with more than one example of the same type of benefit in any given problem, only one point per benefit type was allotted. Because there were only four questions, 16 was the maximum number of points possible for any one person. To illustrate, the following open-ended response (an actual example) about why one individual chose inquiry instruction over other methods   received 3 points: "It [a specific inquiry-based instructional strategy] allows the students to come up with their *own ways* (SR) to *classify the wheat* (LO) causing them to think critically (AT). I would go farther though and *have them argue* (AT) if the diagram or the way they sorted them makes more sense and why (AT)." (See Table 3.5 for a sample from the code table.) Next I tallied the results and recorded the average number of student benefits described per subject for each category of respondents.

After summing all their points, I established a cut-off score of five, which was the average score from the baseline groups (Step I and II) of survey responses. This cut-off score allowed me to invite the majority of subjects in each category but also filtered out those who provided the least robust inquiry rationales for their instructional choices. I chose not to follow up with all subjects because I sought to explore the thinking of those who had the most in-depth inquiry rich responses.

TABLE 3.5

Sample Code Table for Participant' Open-ended Responses on the POSTT$_M$ *(Coburn et al., 2013)*

	Q1	Q2	Q3	Q4	Total
[1]Student A	SR_LO_AT	AT_AB_SR_LO	AT_LO_AB	SR_LO_AT	13
Student B	LO_AB	AT_SR	-	AB	5

Note. SR- Student responsibility, LO-Learning outcome, AB-Affective benefit, AT-active thinking

[1]Student A was invited to participate in Phase II with 13 points, but student B was not because he had only 5 points.

Participant responses and explanations on the POSTT$_M$ survey items provided data I could use to begin building a profile for how prospective science teachers at varying stages of their teacher education programs conceptualize teaching science in the classroom. Furthermore I used the results from the revised POSTT$_M$ to identify a sub population of subjects who exhibited a tendency to prefer inquiry instructional approaches and use that information to delve deeper and explore their conceptions during the qualitative phase of the study.

Data Collection Methods and Analysis (Phase II)

Subject Selection: Phase II

According to Creswell (2009) the idea behind purposeful selection of subjects is to identify subjects who can best provide information to help the researcher understand the phenomenon, more specifically, inquiry instruction. According to Debour (1991), there is "no one best science program for all. Students differ, teachers differ, and local communities differ… The most important thing is that we understand why we do what we do and the likely consequences of that particular approach" (p. 240). Although data analysis in Phase I allowed me to compare groups' of subjects' teaching orientations, a more in-depth exploration was needed to better understand how they conceptualized inquiry instruction. Purposeful selection of the subjects is necessary when the researcher seeks specific cases that are "information rich" in regard to the research questions (Teddlie & Tashakkori, 2009, p. 173).

Purposeful sampling strategies informed selection of the best subjects to participate in the follow-up study. Jones, Torres, and Arminio (2006) assert that in qualitative studies, sample size is negotiable depending on the purpose of the study and the rationale behind the sampling techniques including but not limited to judgment and negotiation. Because the three university programs have a relatively small number of students in their programs, the number of survey subjects is also small. Also since the three programs are relatively new teacher education programs, the number of preservice science teachers enrolled drops significantly in the upper level courses in each program. Upper level courses may have as few as three preservice science teachers enrolled. Therefore, achieving saturation, the concept of maximizing data and sample size to the point of redundancy of ideas (Jones et al., 2006) among the subjects at different levels of the program is unlikely and unwarranted given the constraints of time and the limited number of subjects available to the researcher here.

Based on their responses to the original survey, using Qualtrics™ I sent 24 subjects an invitation to participate in Phase II of the study. Once invitations to participate in the second follow-up study were sent to the select subjects, convenience sampling, based on their willingness to participate, determined what subjects provided the subsequent data used to explore the preservice science teachers' conceptions and perceptions of inquiry instruction. Nineteen (.79) subjects responded, and there were at least four subjects at each program level who participated in the follow-up study. See Table 3.6 for Phase II participant demographics.

Data Collection: Phase II

Creswell (2009) suggests that phenomenological research focuses on developing, describing, and understanding participants' views of phenomena. Consistent with Creswell, this research sought to explore and understand a select group of preservice science teachers' conceptions of teaching science as inquiry as well as their conceptions of why it is important. By select group, I refer to preservice science teachers who expressed some measure of intentionality toward inquiry instruction (based on Phase I results). Phase II of this research utilized a qualitative research design.

To explore the prospective science teachers' rationales for and conceptions about teaching science as inquiry, the study utilized a ten question open-ended survey to explore and probe their thinking about teaching science as inquiry. (See Appendix F for the survey.) The open-ended survey was developed by the researcher as informed by contemporary research in science education based on the ideas that teachers should make explicit connections between their teaching preferences and how students learn (Crawford, 2007; Eick & Reed, 2002). As

TABLE 3.6

Phase II: Survey Subjects' Demographic Characteristics per Program (Percentages in Parentheses)

Characteristics	UALR	UCA	UA	**Total Population**
	n = 5	n = 2	n =12	**n = 19**
Gender				
Female	3		8	**11 (.61)**
Male	2	2	4	**8 (.42)**
Courses Completed				
1 to 2	1	1	2	**4 (.22)**
3 to 5	2	1	4	**7 (.37)**
6 to 7	2	-	2	**4 (.22)**
8+	-	-	4	**4 (.22)**
Major				
Biology	4	2	6	**12 (.63)**
Physics	1	-	5	**6 (.33)**
Other Science	-	-	1	**1 (.06)**
Degree				
BA			6	**6 (.33)**
BS	5	2	6	**13 (.68)**
Academic Level				
Freshman	1	-	-	**1 (.06)**
Sophomore	1	1	3	**5 (.28)**
Junior	-	1	1	**2 (.11)**
Senior	3	-	4	**7 (.39)**
Graduate			4	**4 (.22)**
Post Graduation Plans				
Teaching	4		8	**12 (.67)**
Graduate School	1	2	4	**7 (.37)**

Note. University of Arkansas - Little Rock (UALR), UCA (University of Central Arkansas, Conway), UA (University of Arkansas- Fayetteville)

such, subjects were asked about their beliefs about teaching and learning science as well as inquiry-specific questions. Qualitative data consisted of verbatim participant responses to these questions that asked them to describe and elaborate upon their beliefs and about the components of inquiry instruction.

To minimize bias in subjects' responses due to what they might perceive is the *right answer*, I asked the same questions but from different perspectives (AAAS, 2012). For example, the open-ended ten-question survey was divided into two parts. The first part consisted of three questions designed to elicit the subjects' beliefs about teaching and learning science. The questions were purposefully general and did not include the term *inquiry*. However, I still looked for descriptions of inquiry and inquiry-based rationales in the responses. Once the first three questions were answered, the design of Qualtrics™ prevented the subjects from returning to their answers as they proceeded through the survey. As such, subjects' beliefs about teaching and learning and science added a level of validity to their responses about inquiry instruction and could be used to triangulate their inquiry specific responses later in the survey.

The second part of the survey consisted of seven open-response questions explicitly targeting the subjects' explanations about inquiry instruction. They were asked to define and describe inquiry, explain the benefits and challenges of using inquiry instruction in the classroom, place a value on how much time it should be used as well as describe occasions why inquiry should *not* be used. (See Appendix F for the survey instrument.)

Methods of Data Analysis: Phase II

Jones and colleagues (2006) assert that "the process of finding, naming, and elaborating a theme" is what enhances understanding the phenomenon (p. 89). After reading through the responses multiple times, I reduced the data into categories of occurrence to establish the first round of emerging themes. Multiple iterations revealed significant statements (Creswell, 2009) used to construct a description of the subjects' views. Subsequent readings uncovered other hidden or embedded themes that reoccurred within the participant' narratives that elaborated upon their perspectives. A final list of reoccurring themes was compiled and subsequent readings for all the subjects' responses to all ten questions allowed me to organize the data into categories.

To respond to the subjects' conceptions of inquiry instruction at different at different phases in the program, the research used a cross-section comparison strategy. I disaggregated the collected data according to levels of program progression and compared participant responses at various stages of program progression: Levels I, II, III, and IV. Although the sampling numbers were small, I was able to explore the subjects' conceptions of inquiry at each of these junctures using thematic analysis to analyze their open-ended responses.

Reliability and Validity of Methods and Instruments

Although surveys are efficient methods of collecting information about prospective teacher characteristics (AAAS, 2012), they typically offer respondents opportunities to make *forced choices*, which may or may not align with their preferences. To offset this validity issue, this research included an open-ended response with each of the forced choice selections. The open-ended question asked the subjects to "Please explain why you chose this particular instructional strategy over the other three options (i.e. Why is it better than another approach?). Please include any clarifying information you think will help the researcher understand your response better." As such, the respondents could provide clarification to their preferred teaching choices if any of the four methods presented were not representative of their teaching preference. Furthermore, as previously mentioned, the researcher used the open-ended response to validate the subjects' responses.

Another issue related to item interpretation is that respondents often misinterpret named instructional approaches (AAAS, 2012). Presuming components of inquiry instruction would permeate the subjects' descriptions of effective instruction and student learning if they truly indicated intentionality toward utilizing inquiry instruction, I asked *non-inquiry* related questions early and then targeted inquiry specific terminologies later. For example, instead of saying, “Describe inquiry instruction in the science classroom,” the survey question was (a) Please describe what "good (effective) science teaching" looks like to you; (b) if you could give specific advice to one of your science instructors (past or present) about how to improve their teaching so you could learn better, what would you say; and (c) as a prospective (or practicing) science teacher, how do you recognize when students are learning in your classroom? I used the effective teaching responses to triangulate the subjects’ responses to inquiry specific responses later in the survey. Although many will agree that inquiry “is more fun than other ways of learning science” there is an expectation that those who understand the importance of inquiry will recognize this reason is much less importance than the one requiring students to defend their explanations using evidence. As such, there was some degree of expectation that the subjects reflecting more advanced rationales would defend their responses using conceptions that are more in line with the features of inquiry as delineated in the *Standards* (NRC, 1996; 2000) and more recently the *Framework* (NRC, 2012).

One of the challenges to the reliability of survey data, especially if data collection is administered electronically, is the limited response rate. To increase response rates, I traveled to each research site and made face-to-face visits to provide potential subjects a description and corresponding explanation of the study and to solicit their participation. To engage their participation, I marketed my study in a way that participants would find relevant and useful to their teaching careers as well as interesting and engaging (AAAS, 2012). I also collaborated with the individual instructors who helped facilitate my efforts and encouraged their students to participate. Utilizing Qualtrics™ allowed me to customize the invitation to select the subjects and follow up with reminder emails to increase the response rate.

Qualtrics™ was also useful because survey participants could take the survey when it was convenient for them, and they could move at their own pace. Furthermore, if the prospective science teachers started the survey and could not finish it in a set amount of time, they could log out of Qualtrics™ and return later to the survey without losing their place. I also offered opportunities for the prospective teachers to win various e-gift cards ($25-$50) if they completed the survey within an allotted amount of time (typically a week that also spanned a week-end). I sent two reminder emails to follow up with the prospective science teachers who failed to respond within that time.

A challenge to survey analysis validity is that self-reported data can be biased based on the desire of the prospective teachers to provide the ‘right’ answer to the question. Especially since the researcher was also an instructor at one of the three institutions, there is a potential for some prospective teachers to unknowingly try to answer the questions the way they *think* she wants them to answer. Survey instructions emphasized there are no right or wrong answers to the questions and that each response should reflect individual experiences.

Self-reported data reports what the subjects think about phenomena, and does not necessarily reflect, “what is.” To increase validity of the quantitative results, the researcher analyzed the objective portions of the survey in concert with the open-ended questions that asked the subjects to provide a rationale for their particular pedagogical selections. The open-ended responses were used to corroborate the objective responses to ensure that inquiry preferences were consistent with student centered and conceptual building instructional practices.

To ensure data analysis reliability and validity of qualitative data, the researcher relied heavily on coding protocols to reduce opportunities for researcher bias during data analysis. Anonymity of responses during the analysis process also decreased chances for researcher bias.

Pilot Study

Another challenge and limitation to survey data reliability is that different participants may interpret the survey questions differently (AAAS, 2012). To identify potential areas of confusion and misinterpretation of the questions, I administered a small pilot survey to a group of nine graduate level preservice science teachers and three veteran inservice teachers. Using the results of the pilot, I modified and refined specific questions to reduce ambiguity of survey questions and added some grade level clarifications to increase reliability of data. Pilot study feedback also indicated the survey was too long, included some redundancy in questions, and participation requirements were too arduous. Subsequently, I reduced the number of survey questions from six to four, eliminating the questions that elicited the least differences among survey respondents.

CHAPTER 4: RESULTS

The purpose of this research was to explore a select group of secondary preservice science teachers' explanations and descriptions of inquiry instruction relative to their progression in an undergraduate science teacher preparation program that emphasizes inquiry instruction. Through this study, individual participants were examined to see if they indicated preferences for inquiry-based instruction. Once I identified select subjects, subsequently, I explored their thoughts and conceptions of inquiry instruction. This chapter presents the findings obtained from the collected data. The following research questions and sub-research question that guided my data analysis follow:

1. How do preservice science teachers who indicate preferences for inquiry instruction describe their beliefs about teaching and learning science?
2. How do these preservice science teachers define and describe inquiry instruction?
3. What justifications do these preservice science teachers provide for utilizing (or not utilizing) inquiry instruction in the science classroom?
    - How do these preservices science teachers' beliefs, conceptions of inquiry instruction, and their subsequent justifications for using it compare at various stages of their teacher education program?

To address the research questions, I analyzed prospective science teachers' responses with respect to two different data sources collected at two separate times, which I refer to as Phase I and Phase II. In Phase I, I utilized two versions of the Pedagogy of Science Teaching Test (POSTT) (modified from Cobern et al., 2013), which I refer to as POSTT_M- B (biology) and POSTT_M-P (physics), to elicit the subjects' particular orientations toward teaching science: Didactic direct, active direct, guided inquiry, and open inquiry. The didactic direct and active direct orientations refer to the more traditional teacher-centered orientations such that the teacher directs all the learning activities. They are different in the sense that the didactic direct orientation is entirely teacher oriented exclusive of student interactions. The active direct orientation consists of students engaging in hands-on activities and confirmatory type laboratories. In this study, those who indicated these teaching orientations were categorized as having non-inquiry orientations, and they were *not* the focus of this study.

Because the intent of this research was to identify particular individuals who indicated preferences for inquiry and explore their understanding more in-depth, I was most interested in identifying those with inquiry teaching orientations. The inquiry orientations (guided and open) are student centered teaching methodologies that allow students to explore phenomena in a hands-on minds-on fashion. Students have significant autonomy and responsibility for their own learning. These two orientations differ according to the level of guidance the teacher provides. During a guided inquiry, the teacher provides some measure of guidance as students engage in inquiry learning. For example, the teacher may provide the guiding question or data to be analyzed. The students, then, make other decisions about how to explore and how to interpret the data. In an open inquiry, the students are entirely responsible for initiating and conducting their own investigation that begins with a question of their own choosing. Therefore, in an open inquiry, students investigate or explore phenomena they want to know more about.

Each question on the POSTT involved a teaching scenario such that the prospective science teachers could envision themselves teaching a particular topic. For example**,** “Ms. Adams’s ninth grade students have learned that light travels in a straight path and that shadows form when an object blocks light. Ms. Adams wants her students to be able to apply these ideas to make predictions about shadows.” After providing more contextual information, each scenario is followed by a lead-in sentence, “Thinking about how you would teach this lesson, of the following which is the most similar to what you would do next?” Subjects selected one of the four pedagogical choices that followed. Each pedagogical choice corresponded to one of the four teaching orientations: Didactic direct (DD), active direct (AD), guided Inquiry (GI), and open inquiry (OI). Additionally, each question was accompanied by an open-ended response asking subjects to explain their reasoning for why they preferred one methodology to another.

Subsequently, I analyzed the subjects' responses quantitatively and qualitatively. I used the findings to invite a select group of subjects to participate in the second phase of the study. By select group, I refer to the preservice science teachers who consistently chose inquiry instructional strategies and justified them using student-centered rationales.

The premise of inviting only a limited number of preservice science teachers to participate in Phase II of the study is founded on a constructivist principle as ascribed by Ausubel (1968**),** "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach accordingly" (p. 18). As such, recognizing that inquiry instruction is a complex and daunting challenge (Crawford, 2007), I desired to delve into the thinking of those who *most* demonstrated an intentionality to teach using inquiry methodologies. Understanding their particular thoughts and motivations could shed valuable light on why inquiry instruction is lacking in many science classrooms even among experienced science teachers. Therefore, in Phase II I administered a ten-question questionnaire to explore this select group of prospective science teachers' beliefs about science instruction and student learning and their conceptions about inquiry. (See Appendix F for the questionnaire.)

First, I present the prospective science teachers' self-selected preferred strategies for teaching particular science topics along with their corresponding rationales. Then from Phase II, I present the selected preservice science teachers' beliefs about science teaching and learning, definitions and descriptions of inquiry instruction along with its benefits and challenges. I present these findings according to levels of participant progression (based on the number of courses completed) in the teacher preparation program. It is the second phase of the study that answers the research questions.

Phase I: Teaching Preferences and Participant Selection

After administering the POSTT_M to all science majors in the three Arkansas UTeach programs who agreed to participate in the study, I compiled the results and tallied them into frequencies of teaching orientations (DD, AD, GI, and OI). Next I categorized them into two groups, inquiry or non-inquiry. Although the POSTT_M survey asked participants to respond to each vignette by selecting one of four teaching preferences, I present only the combined inquiry responses (guided and open) since this was the response required to remain in the study for the next phase. Finally, I disaggregated the results according to each subject's progression in the program and by science major. (See Table 4.1for a tally of the subjects' inquiry responses). By progression in the program, I refer to the number of UTeach courses the subjects have completed: Level I (1-2 courses), Level II (3-5) courses, Level III (6-7 courses), and Level IV (8 courses). Based on the POSTT_M scores alone, at all levels of program participation, subjects tended to choose inquiry-based instruction over non-inquiry strategies.

The primary purpose in Phase I was to identify a select group of prospective science teachers, at each level of the program who consistently preferred inquiry instruction. As such, I analyzed their open-ended responses to validate their pedagogical choices. Each vignette on the POSTT_M was followed by a single open-ended question that asked subjects to explain their rationale for their pedagogical selection. To consistently prefer inquiry-based instruction, I expected subjects' responses to defend their choices using student-centered rationales. As such, using an iterative coding process, the theme *student benefits* emerged as a reoccurring theme for why participants preferred inquiry to other strategies. In subsequent readings, I looked for common subthemes related to this idea and identified four types of students benefits commonly used to justify the subjects' inquiry choices: Affective benefits (AB), content specific learning outcomes (LO), student responsibility (SR), and active thinking (AT). I returned to the data and identified specific instances of each subtheme in all subjects' inquiry responses. Although broadly defined for purposes in this study, I describe what I mean by these subthemes next.

TABLE 4.1

Subjects' who Self-Selected Inquiry-based Teaching Preferences at Different Stages of Program Development (% in Parentheses)

Program Category	Subjects ([a]N)	Questions ([b]n)	Inquiry Responses	
			Total	(%)
Level I (Early)	16	52[d]	40	(77)
Level II (Middle)	11	40[c]	35	(88)
Level III (Advanced)	11	42[d]	38	(90)
Level IV (Completers)	8	32	32	(100)
Combined Tests	46	166	145	(87)
Biology	27	102[d]	82	(80)
Physics	19	64[d]	62	(97)

[a]N refers to the number of subjects in each category. [b]n refers to the number of questions per category of subject. [c]The odd number of questions is due to the removal of inconclusive responses or the failure of participants to answer all four questions.

A*ffective benefits* related to students' interests or enjoyment in the learning process. For example, one subject said he chose a particular strategy because "I love it when the students can test what they are curious about. It gives them a sense of freedom. This also motivates them to do the project" (Sydney, L-III). Other subjects' responses related to affect included student curiosity, excitement, interests etc.

Multiple subjects stated that inquiry is beneficial due to some specified learning benefits. For example, students remember better when they figure things out, or inquiry learning is more meaningful to students so the understand it better. Also as David (L-II) said, "This is a great way for the students to apply their knowledge to a novel situation." As such, I looked for specific rationales related to how inquiry learning promotes better recall or more in-depth understanding and categorized these responses as *learning outcomes* (LO).

Inquiry learning was frequently characterized in terms of *student responsibility* (SR). Charles (L-II) said, " This choice is the least authoritarian and allows students to take charge in their education." Therefore, statements about students having to make decisions and be accountable were included in this category.

Lastly, subjects also frequently described students involved in *active* thinking (AT) as the reason for their inquiry choices. For example, Evan (L-II) said, "This method allows students to test out their ideas and draw their own conclusions." Therefore, I looked for terms descriptions that related to students actively constructing knowledge. (See Table 4.2 for these categories of student benefits and representative terms and phrases subjects used to explain their inquiry choices.)

TABLE 4.2

Categories of Student Benefits with Representative Terms and Phrases

Affective Benefits (AB)	**Learning outcome (LO)**	**Student Responsibility (SR)**	**Active Thinking (AT)**
Curious	Remember better	Responsible	Compare findings
Excited	More meaningful	Make decisions	Ask questions
Freedom	Making connections	Collaborate	Draw conclusions
Student Pride	Specific objectives	Accountable	Debate and argue
Interested	Identify differences		Explain

Note. The identifying code used for each category of benefits is in parenthesis in the column headings.

Next, to filter through all subjects' responses and find those select subjects most likely to provide robust descriptions of inquiry-based teaching and learning, I established a point system. To keep coding simple, I allowed for only one type of benefit per question. Since there were four types of benefits identified, four was the maximum number of points a person could receive for any given question. Also for illustrative purposes, since there were four questions, 16 would be a “perfect” score. Next, I summed all participants’ points, tallied the results and calculated the average number of student benefits identified per question and per person at each level in the program. See Table 4.3 for the results.

Although the tallied results indicate that subjects in Levels II-IV provided more student-related benefits for inquiry instruction than those in the early levels of the program (Level-I), the average number of benefits per question were more closely aligned. However, more in-depth understanding was needed. Therefore, to identify select individuals indicating the most definite preferences for inquiry at each level of the program, I established five as a participant cut-off point. A score of five, the average score from the baseline group (early level subjects), allowed me to invite the majority of subjects in each category to participate in the follow up study. Furthermore, it allowed me to filter through the subjects’ responses to find those most likely to provide more robust responses.

Phase II: Discussion of Survey Subjects

Subsequently, I invited 24 participants to participate in Phase II of the study; 19 (79%) participants responded and completed a ten-question survey designed to elicit their perceptions of effective teaching, student learning and inquiry instruction. To report these findings, I divided all the subjects into categories based on their levels of program progression (just as I did in Phase 1): Levels I, II, III, and IV. Brief descriptions of subjects in each level follow.

Four subjects who share the Level I category have completed the Step I class and are currently enrolled in Step II. Because the survey was administered late in the semester, in reality, the subjects had almost completed both recruitment courses. Since the nature of these courses is to provide program participants early field-based experiences, the subjects have all had opportunities to teach six inquiry-based 5E lesson at the time they completed this survey. Instructors in these courses also modeled inquiry-based instruction at various times, so the subjects had multiple experiences with inquiry teaching and learning as students and as practicing teachers.

TABLE 4.3

Student Benefits as a Rationale for Choosing Inquiry-based Instruction on the POSTT$_M$-*B and* POSTT$_M$-*P as described by Preservice Science Teachers at Different Stages of Program Development*

Program Level	Subjects (^{a}N)	Questions (^{b}n)	Student Benefits		
			Total	Average per Person	Average per Question
I (Early)	17	68	96	5.3	1.9
II (Middle)	8	32	58	7.5	2.0
III (Advanced)	10	40	77	7.7	2.2
IV (Completers)	8	32	64	8.0	2.0
Combined Tests^a	43	172	295	7.1	1.8
Biology	24	96	185	7.7	2.2
Physics	19	76	110	5.8	1.8

Note. Each program level corresponds to the number of UTeach courses preservice teachers have completed: Level I = 1-2 courses; Level II = 3-5 courses; Level III = 6-7 courses, and Level IV = 8 courses.
^{a}N refers to the number of subjects in each category. ^{b}n refers to the number of questions per category of subject.

There were six Level II preservice science teachers who took the survey. Four of these prospective teachers have completed three courses. One participant has completed four courses including an additional practicum course, and another subject has completed five courses. These subjects have had both educational theory and practicum courses. Like the subjects in the early level courses, most of them have taught only six lessons at the elementary and middle school levels.

Of the five Level III subjects, the advanced category of participants, four of them have completed seven courses (all of the UTeach courses except for Apprentice Teaching (or teaching internship) including those courses that explicitly involve teaching science through inquiry, doing inquiry and learning about inquiry (project-based instruction, perspectives, and research methods). One subject, Kylah, has completed six courses. Based on their progression in the program, these subjects should have the most theoretical understanding of all the prospective teachers second to the group who has completed the program. This groups of participants has recently taken Research Methods, Problem-based Instruction, and Perspectives, three courses that specifically attend to helping them engage in inquiry as students, learn how to develop and implement sustained inquiry in the secondary science classroom, and learn about the nature of inquiry (as a human endeavor).

Finally, four Level IV preservice science teachers also completed the survey. Three of them were in their final weeks of the semester before graduation. One subject had graduated a semester prior and was in her first year teaching science. As such they are all categorized as program completers. All four subjects are planning to be full time career science teachers. See Table 4.4 for a list of the subjects' pseudonyms and their program categories.

Phase II: Qualitative Analysis

This section presents the findings from the qualitative data collected in Phase II of the research study. To analyze the narrative data, I iteratively read each subject's responses to the open-ended questions and looked for reoccurring themes among participants in each category. I define a recurring theme as one that the majority of subjects in a particular category reported. To illustrate each theme that emerged during the data analysis, where possible, I present selected participants' responses based on how well they articulated the corresponding theme, how well they typified other subjects' ideas, and where possible, based on the number of themes represented in a single response. Because sample sizes are small (minimum of four, maximum of six), typical responses may not be available for each category of responses. I report these findings categorically, by program levels, and topically based on the three research questions: (a) beliefs about science education, effective teaching, and learning, (b) definitions and descriptions of inquiry with an emphasis on the students and teachers respective roles during the teaching and learning events, and (c) the subjects' rationales for and against an inquiry approach to teaching and learning.

TABLE 4.4

Participant's Pseudonyms and their Relative Levels of Progression in the Program based on the Number of Courses Completed

Level I	Level II	Level III	Level IV
Early Level	Middle Level	Advanced Level	Program Completers
Hector Morgan Melinda Derrell	Donald Brielle Evan Deanna Marion Charles	Camryn Addison Andrea Sydney Kylah	Stefani Beverly Sophia Warren

Note. Each category level corresponds to the number of UTeach courses preservice teachers have completed: Level I = 1-2 courses; Level II = 3-5 courses; Level III = 6-7 courses, and Level IV = 8 courses (all).

RQ1: The Preservice Teachers Beliefs about Teaching and Learning Science

Haney and McArthur (2002) assert that to exclude teachers' beliefs from any of their learning experiences is akin to ignoring their prior knowledge. Therefore, this study sought to explore and describe the prospective science teachers' beliefs about teaching and learning science. Furthermore, "Many of the attitudes and dispositions we associate with student-centered teaching and learning are also the attitudes and dispositions we associate with scientific inquiry" (DeBoer, 2002, p. 407). As such, a premise of this research study is that teachers who espouse and identify with student-centered learning environments are more likely to espouse inquiry-based instruction. As such, it was especially relevant to explore their beliefs during data collection without mentioning the word inquiry. To this end, survey subjects responded to four questions about their beliefs regarding the teaching and learning of science. (See Appendix F for the survey.) Strategically, the term inquiry was not used in the questions designed to elicit their beliefs. The survey questions included the following:

1. What is the purpose of science education (asked in the first survey but analyzed here).
2. What does effective teaching look like to you?
3. What advice might your give a past science instructor about making instruction more relevant to your learning needs.
4. How do you recognize when students are learning in your classroom?

To describe teaching and learning science in terms of inquiry practices without being prompted is an indicator of the prospective science teachers' commitment to its ideals. Therefore, to analyze their beliefs, I coded their responses looking for constructivist learning notions and student-centered teaching and learning practices as elaborated upon in the 5E Instructional Model (BSCS, 2003) and for reoccurring descriptions of the inquiry practices found in contemporary reform documents (NRC, 1996; 2000; 2012). This section presents the prospective teachers beliefs about teaching and learning science.

Level I: Early Program Subjects' Beliefs

Thematic coding of subjects responses to the question about the purpose of teaching and learning science revealed similar responses among three of the four early program subjects. Hector's response reflects the majority of his peers thinking: "The main purpose for teaching science in high school should not be to memorize facts about different topics, but to give the students an understanding of how to learn these facts for themselves through research." Like

Hector, his peers agreed the facts are important, but science teachers should do more than lecture in order to engage students in their learning. Likewise, according to Megan, “They [teachers] could improve their teaching by spending more time letting us experience science and less time lecturing us about it.” As such, descriptions of student active engagement as evidence of learning were also a common thread among their responses. Accordingly, the subjects believe when students are learning they are actively engaged, asking questions, and applying their understanding. Darrell’s response illustrates: “I know students are learning they ask questions that take a concept from the current lesson and apply it to a situation of their own imagination.” Lastly, another common response among all four subjects was the idea that science should prepare students for some future goal (science careers, decision making, and how to learn and problem solve).

Level II: Middle Level Subjects’ Beliefs

Regarding the purposes for learning science, five of the six preservice teachers made specific references to science education being primarily to help students develop their critical thinking skills, become problem solvers, or critical consumers of information. Four subjects also suggested that content knowledge was the goal, and three subjects added that science education should prepare students for future careers in science. Donald’s response illustrates all three of these ideas:

> *Science education should provide students with a perspective of how the world works. Also it should prepare students for a science career. But even if that was not the goal of a student than to provide them with the tools to formulate educational decisions and to reason out an understanding of what is being said or done around them. There are many times when misinformation or erroneous facts are given that could impede a person as an adult. Science skills go beyond just a career.* (Donald)

The majority also described effective teaching in terms of teachers not just telling students information and requiring them to do more than just memorize concepts. They also described student learning in terms of actively figuring things out and interactively talking in the classroom. Donald and Brielle’s responses illustrate these ideas:

> *Good teaching is not just passing along information that students will be able to recite from memory. Set up more group activities to search for an answer to a question before it is given. Use guided discussion rather than lecture- not for every lesson but as often as possible. This will help students invest in their own learning.* (Donald)
>
> *When I think of "good science teaching, I see an image of students engaged in hands on activities, research, group work, presentations, exploring, discovering, making connections between other topics in science and even in other subjects. If we can show students how to explore and figure out problems on their own without weighing them down with memorization and placing concepts out of their reach, we have done good.* (Brielle)

Including Brielle and Donald’s response above, the most prevalent response among all six subjects was in reference to descriptions of students communicating their understanding in various ways: Discussions, asking questions, explaining their understanding. According to Charles, “When students ask questions beyond the class material it shows they understand the current material and want to know more.” Evan said student learning is evident when students can “explain concepts in their own words.”

Level-III: Advanced Subjects’ Beliefs

Regarding the purpose of science education, five of the advanced subjects agree that content knowledge is the goal. Four subjects also include the idea that science should promote the development of critical thinking and decision-making skills. Additionally, three of them believe that science class should prepare students for future educational endeavors. Camryn and Kylah’s responses illustrate these ideas:

> *The main purpose for teaching science in high school should be to provide students’ opportunities to engage in learning experiences to help them understand the world they live in and make decisions. Teaching science content knowledge is also important so that students who go on to college have a base level to build from. More importantly, though, is the former, providing students with the critical thinking skills they need.* (Camryn)

> *With a general understanding of science concepts, students are more likely to understand and dissect the world around them. Simultaneously, it is important for teachers in high school to prepare students for the rigors of college.* (Kylah)

Another common theme running through all five responses had to do with the teachers' roles in teaching science. Most significant was the idea that teachers should make science class enjoyable and interesting so students will want to engage in learning science. According to Camryn, "Effective science teaching should be centered around a question that creates a 'need to know in students. Fostering an environment that creates intrinsic motivation creates good opportunities for teaching." In another example, Andrea advised science instructors to "please don't lecture every class period for 1.5 hours! Not only is it beyond boring, but it is also disengaging and extremely frustrating for those that are not pure visual and auditory learners."

Level-IV: Program Completers' Beliefs

There was a lot of overlap among the four program completers' beliefs. They all reported that gaining content knowledge is a primary goal for what students should learn in science class, that science class should prepare students to further their education, and that science should help students develop particular skills they need to survive in the world. Two subjects responses illustrate these three ideas:

> *The primary purpose of teaching science in high school should just get students excited about science. If students aren't excited about the subject, they will not put in the effort to actually learn the content. Once students are excited about science, though, the next purpose would be to teach them content knowledge that will benefit them as they further their education. Students also need to learn to work with their peers. In almost any job that the students may have one day, they will have to work with others whether they like them or agree with them or not. Science classrooms are great ways to teach students this life skill.* (Beverly)

> *The purpose of science class is to teach students to be scientific learners. Although understanding the material in the subject taught is an unquestionable goal for teachers, one of my main purposes in teaching science is that students can think and learn like scientists by using critical thinking skills, non-biased judgment, and can understand and*

> *interpret data. Coming out of the classroom with these skills will equip students for life even the students not entering a future in science.* (Stefani)

As illustrated in both responses above, another theme common among their responses was the idea of student motivation and active engagement in the learning activities. According to Stefani, "If students are asking questions, you know that they have a classroom environment where the nature of science as an investigation of the world around them is being fostered. It's also indicative of students finding internal incentive. Warren also described effective teaching in terms of student engagement: "If the students are engaging with the material then the lesson will be more successful. Demonstrations and inquiry labs are some of the best learning experiences we can provide." Additionally, to keep students interested and engaged they all agree that teachers should use diverse teaching methods. For example, while referencing a previous science teacher, Beverly said, "Science is such an exciting field and science teachers need to be getting students excited about doing and learning science. So my suggestion would be to do more appropriate activities and hands-on lessons and less just lecturing and note taking."

Also common among all Level IV responses were descriptions of what students do in the classroom when they are engaged in their learning. In all six responses, students are asking and answering questions that consist of more than just regurgitating the facts.

> *When students ask questions, I can see they have used the information and applied it to something else. Not only have they learned the information I have given them, but also they have thought about it in depth. I also see learning when they are able respond to questions without just regurgitating an answer someone else said two seconds beforehand.* (Sophia)

According to three subjects' responses, students should have opportunities to actively engage in hands-on learning activities (inquiry labs, conducting investigations, or working in cooperative learning groups) as they build understanding and make real world connections to what they are learning. Beverly and Stefani explain:

> *Most of the class should be devoted to students talking to their peers in some type of group or even writing what they are thinking down. Cooperative learning allows students to see the perspective(s) of their peers. Sometimes a different perspective from the one a student has can make the difference between listening and understanding what the topic is, and actually learning the topic.* (Beverly)

> *Good science teaching" has the students behaving like scientists: questioning the value of statements, looking for empirical evidence, having rationale behind their own conclusions, testing hypotheses before making assumptions.* (Stefani)

As illustrated in the responses above, the majority of subjects also described inquiry specific ideals about teaching and learning. For example as Beverly stated, students should see perspectives of their peers (alternative conceptions). Likewise Stefani, described inquiry activities such as questioning value of statements and looking for evidence to support their conclusions.

Finally, three of the four subjects described common roles for what good teachers do in the classroom. In addition to engaging students in the learning activities, and using diverse teaching strategies, teachers should emphasize understanding rather than memorization, actively assess students learning, and create classroom cultures that encourage students to think critically.

To summarize their beliefs about teaching and learning, much overlap existed across all four categories of subjects' responses. The majority of responses in all categories believe teaching and learning science should involve active student participation and engagement, should teach students the facts of science, prepare students for future endeavors including how to think and problem solve. The more advanced groups provided more in-depth descriptions of teachers and students roles in the learning process. The program completers provided the most in depth inquiry-specific descriptions of teaching and learning.

RQ2: The Preservice Science Teachers' Descriptions of Inquiry Instruction

Although hailed as a powerful form of instruction, in most teaching and learning contexts, inquiry-based instruction is fraught with ambiguous and conflicting definitions and descriptions. Therefore, I sought to discover how a select group of preservice science teachers who ostensibly favor inquiry instruction define and describe inquiry instruction. This section presents the findings of the preservice science teachers' responses to three open-ended survey questions designed to elicit their conceptions of inquiry instruction explicitly:

1. Define and describe inquiry instruction in the science classroom.
2. Identify and describe any specific teaching strategies that account for inquiry instruction.
3. How much instructional and learning time should be dedicated to inquiry teaching and learning?

Unless otherwise stated, the findings are reported in terms of reoccurring themes common among the majority of subjects' responses. By majority, I mean more than 50% expressed similar ideas. As before, I present the analysis of their responses in categories according to their level of progression in the program. As a reminder, each program level consists of four to six subjects.

Level I: Early Program Subjects' Descriptions of Inquiry Teaching and Learning

Level I subjects had little congruence among their descriptions of inquiry. However, three of the four subjects' descriptions of inquiry revolved around students exploring to figure something out. With the exception of one response, their descriptions were vague and ambiguous. For example, according to Hector, "inquiry means the teacher presents concepts first and encourages students to ask questions and explore without limitation." Except for Morgan, the other subjects' responses were equally ambiguous and confusing. Morgan, however, said "Inquiry instruction in the science classroom means leading a student toward learning a concept by posing questions they can muscle through." Moreover, "students play with different ways to answer the question without having much background on the topic, which lets them consider for themselves what a logical path would be to answer the original question." Common to three subjects' responses was the idea that teachers ask a question to facilitate student exploration.

Level II: Middle Level Subjects' Descriptions of Inquiry Teaching and Learning

To describe inquiry teaching and learning, there was considerable overlap in most of the six middle level subjects' responses. First, like the early level subjects, all Level II subjects also described inquiry in terms of students figuring something out. However, they provided more in-depth explanations about what they mean. Five subjects described a guided inquiry such that the teacher poses a question or a problem, and the students figure out the answer. Brielle and Evan's responses illustrate this idea and more:

> *The teacher presents class with a question…and students using resources, information, and the materials provided will work toward a solution to the question. Students (for the most part) come up with their own procedures and do not follow a checklist. They may use trial and error and reach dead ends. Students may come up with different answers to the question, which the teacher can use to discuss the variety of the answers or even error. The teacher doesn't actually present the students with the "textbook information" until after the students have done their own investigation. "Textbook information" is the goal topic or main take away from the lesson*. (Brielle)

> *Inquiry instruction is teaching by allowing students to explore concepts and come to conclusions about the topic. The teacher would likely engage their students on the topic with some related content or something else that may get them thinking, hypothesizing, and building models. Then instead of telling the students the answers as a lecture would do, inquiry instruction guides students through a process that challenges their views and conceptions on a topic, giving them opportunity to modify them and explain how and why their previous model was not the best one, and how the new one describes reality.* (Evan)

Including Brielle and Evan's responses, the ideas that students have some degree of autonomy and decision-making responsibility during their learning activities was a common characterization of inquiry teaching and learning. Four of the six subjects agree that students should choose their methods of exploration and define their own parameters for how they plan to figure out the solution. Also, common among most of their responses was the idea that multiple outcomes were expected even though there was a single correct answer intended, or as Brielle said, “textbook information is the goal.” Although they do not reflect the majority of subjects in this category, also congruent with Brielle and Evan’s responses is a description of inquiry that aligns nicely with the 5E Instructional Model. In essence, according to their descriptions, the teacher *engages* the students; students *explore* and develop conclusions; they share, then the teacher tells or *explains* the right answer.

Charles provided a unique description of inquiry such that the students have more autonomy, responsibility for decision-making and less teacher guidance than his colleagues described. However, he consistently referred to a single method (i.e. an experiment or laboratory investigation), as the context for inquiry teaching and learning. His response follows:

> *Inquiry instruction is a type of instruction where you (as a teacher) or the students come up with a question, you want answered. Because of this, you do not know what the results of the experiment will be nor do you know how to do the experiment. You work like scientists trying to solve a problem to get a result. Scientists don't have instructions telling them step-by-step what to do and neither should you.*

Charles’ description of inquiry aligns closely with the NSES descriptions of an *open inquiry* lesson However, although Charles was explicit that neither the students nor the teacher knows the outcome ahead of time, in a separate response when describing an inquiry teaching strategy, he said, “The teacher shouldn't tell the student the correct answer directly, but instead guide them with a line of questioning so the student comes to their own conclusion.” As such, Charles also has the conception that inquiry should lead to a single answer.

Although they do not represent a majority of thinking, two subjects described inquiry in terms of particularly robust student cognitive engagement. Donald and Evan’s responses follow:

> *Depending on the activity, the teacher will have students in some arrangement of groups, allowing students to collaborate, review each other’s' ideas, explain those ideas, and test them. They also will have the opportunity to explain their ideas, reasons, and hypothesis, allowing them to not just list rote facts, but instead must use critical thinking in order to see if their ideas are logical, communicable, and applicable to the situation. (*Evan*)*

> *During inquiry, the students create or research answers or explanations as individuals or in groups, which are challenged or agreed upon by fellow students and the teacher. The students may then adjust or change their responses. If done well enough not only do the students learn the topic they also learn how to question scientific ideas and respectfully interact in discussions. They have to reason out the understanding for themselves and not just take the teacher or textbook at their word.* (*Donald*)

Furthermore, both of their responses have student participating in several science practices (NRC, 2012).

According to five of the six subjects, teachers clearly play a prominent role in inquiry-based teaching and learning. Although there were diverse descriptions, a few themes were particular prominent among the majority of responses. First, teachers engage students in inquiry by asking questions that provide a reason for students to explore and figure out the answer. The focus, however, is an *a* priori investigation so that students figure something out before the teacher lectures about it. In fact, four Level II subjects made explicit references to the *teacher not telling* students information, but rather to put the responsibility for leaning on the students. Three subjects said the teacher could tell *after* the students investigate. Also, subjects stated that teachers should guide students' thinking by asking probing question but not giving them the answers. According to Evan, "The teacher would be open to questions, but not answer them as to give the student a direct answer but instead use questions to guide the student to the path the leads to the answer."

Level III: Advanced Subjects' Descriptions of Inquiry Teaching and Learning

Like the early and middle level subjects, the majority of Level III preservice science teachers agree that inquiry instruction means that students work to figure something out. Student autonomy for choosing their methods and responsibility for making decision emerged as a common theme in four of the five subjects responses. Two subjects described an *a priori* exploration such that students had to research to find a particular answer to a teacher provided question. Addison's response illustrates these ideas:

> *As an example* [of inquiry instruction]*, the teacher can give the students an open-ended question such as "Are heart rate and blood pressure related?" Then it is up to the students to find a connection. Students can conduct their own research. Some students may do actual research in the library or online about the topic. Other students may do an actual experiment, changing their heart through physical activity to see if it changes their blood pressure as well. Hopefully, all the students will arrive at the same answer that heart rate and blood pressure are in fact related no matter which avenue they took to find their answer. At the end of the project, the teacher could lead a class discussion about the methods used to find their answers.*

Two participants, however, provided more authentic descriptions of inquiry such that the outcomes are unknown ahead of time. Kylah's response follows:

> *With inquiry instruction, teachers need to provide a clear problem for the students to solve. Throughout the unit, it is the teacher's role to guide the students without controlling their project. As there are endless possibilities for solutions, the teacher is viewed as a resource, but not a solution-source. Students, on the other hand, can be viewed as investigators, detectives, and designers. As inquiry based teaching is highly autonomous, the students are expected to use critical thinking skills and work together to create what they believe to be the best approach.* (Kylah)

Regarding the teachers' roles in inquiry, clearly, all responses presumed significant teacher guidance. More specifically, the teacher facilitated the initial exploration by asking a question that students had to find the answer to. Also, as described above, the teacher typically provides instruction *after* the students spend time exploring solutions first.

Finally, the majority subjects described inquiry in terms of the two or more of the 5Es (engage, explore, explain, elaborate, and evaluate) on the 5E Instructional Model. Camryn's response illustrates:

> *The teacher engages the students in the topic through a demonstration, video, activity, game, etc that is someone related to the topic that is being taught. The student here participates and this is hopefully giving a platform to build off of. The teacher provides an opportunity for the students to investigate or explore an idea. The teacher provides the instruction that is needed. I don't think there is one "right" way to do inquiry. But generally, I believe here the teacher has given some end goal, broad, questions, or*

> *parameters for the students to work under. The students work with the concepts whether that is through a lab, an investigation, or activity. The teacher should have students recall their prior knowledge to maybe show what they know from their experience, maybe what they think will happen in certain situations, or how they perceive something. This allows for something to refer back to after inquiry is completed. Students should have the opportunity to explain. Maybe students are asked a questions and the teacher has each student think individually and then partner with someone else. Defending answers and giving explanations is an important part to inquiry so students should make sure to do this when talking with a partner. Then I think students should also have the opportunity sometimes to present to their class. The teacher should create an environment that has open communication where students can disagree and present their "arguments." I think one final piece that brings it all together is having students have the opportunity to transfer their knowledge to a new situation. I'm not really exactly sure how to do this always, but the teacher can provide opportunities for the students to put their knowledge in another context, another scenario, etc.* (Camryn)

Although she used the 5E to describe inquiry, clearly she emphasized critical of inquiry teaching and learning. She recognizes that inquiry teaching and learning involves students constructing explanations and defending them. Furthermore, she describes a classroom climate that values the nature of inquiry, as students are free to question ideas, collaborate with one another, and to critically evaluate information. In a prior response, she also emphasized the idea good teaching creates “an environment that allows ‘failure" and mistakes’ and wrong thoughts and embraces these things as learning experiences.”

Level IV: Program Completers’ Descriptions of Inquiry Instruction

When asked to define and describe inquiry instruction, all Level IV subjects described a teacher-guided inquiry such that students explore possible answers to a question. Unlike her colleagues, Sophia is the only subject who described a more teacher-centered perspective. Her detailed description of inquiry follows:

> *For instance, in a lesson teaching homeostasis, the teacher COULD [subject emphasis] tell the students a definition, a few examples, and move on. However, with inquiry instruction, the teacher might start off the lesson by asking students to make a prediction on what they think their body temperature would be inside the building versus outside, (assuming the inside is colder and the outside is summertime heat). After students write down their predictions, students would be allowed to test their predictions using*

> *thermometers. After measuring temperatures inside and outside and finding them basically the same in both environments, a classroom discussion could be held about why they think that happened. If the teacher said Jimmy's temperature was 32 degrees Fahrenheit, students could agree or disagree and discuss with the teacher what they thought. This discussion could lead to the definition of homeostasis. The students would use the example of body temperature to define homeostasis without ever hearing the word. The teacher would then introduce the term. Following the teacher's instruction, students could think of other examples of homeostasis (besides body temperature). Thus, a lesson is completed that involved student activity, interaction and their own questions and answers.*

Although her description describes an engaging lesson that allows students to agree or disagree with the teacher, her response indicates a strong teacher centered perception of inquiry such that the teacher directs most of the learning activities. In a separate response, Sophia also describes a teacher-centered perspective in the context of assessing students' learning. Her response follows, but the bolded emphasis is mine:

> *I am able to clearly see learning when students ask questions they have used the information and applied it to something else. That to me means that not only have they learned the information I have given them, but also they have thought about it in-depth. I also see learning when they are able to answer my questions after being called on during review time.*

In Sophia's characterization of inquiry the teacher is central to the teaching and learning activities. Beverly's response, however, illustrates a more robust description of a guided inquiry. Like Sophia, she describes elements of student engagement that involves hands-on experiences, discussions, and asking questions, but unlike Sophia, she allows for multiple methods for students to explore and multiple outcomes, and less teacher direction. Her response follows:

> *Inquiry based instruction to me is students looking to answer a question that has more than one correct answer. Practices that fall into inquiry-based learning is beginning the class with a question or hands on experience and then letting students explore that experience or question. Students should ask questions, do research, and have discussions with their partners, groups, even the teacher if need be. Students are asking more questions than the teacher in order to deepen their understanding of a topic. There should be minimal lecture time.* (Beverly)

In another response, Beverly said "There are many possibilities of inquiry based instruction, but they all have a basis of avoiding students just regurgitating information." As such, both Sophia and Beverly seem to agree the primary goal of inquiry is student engagement to learn more than the facts that could be easily memorized. Another common idea between them is that the teacher doesn't lecture as much.

Stefani and Warren both provide in-depth descriptions of inquiry teaching and learning that are closely aligned with the *Standards* descriptions of students doing inquiry. Stefani even explicitly distinguishes between guided and open inquiry:

> *Inquiry instruction is a student-focused teaching practice where the activity, lab, project, or lesson is planned around the use of high-order thinking skills usually to either investigate a scientific query or problem-solve. In the classroom it is often seen in the form of guided inquiry, where for example, a teacher may pose a question and students must design and perform an experiment to investigate. True inquiry, where the process of developing the inquiry and carrying out the investigation are entirely the responsibility of the student, is a teaching practice obtained by introducing the necessary expectation over time and developing a classroom climate of student intrinsic motivation.*

According to Stefani's characterization, students have significant responsibility and autonomy for making decisions about developing and implementing an investigation. Similar to Stefani, Warren's also emphasizes open inquiry: "My understanding of inquiry instruction is that it is instruction centered on the students exploring their own ideas and interpretations of evidence." Warren's response follows:

> *To facilitate inquiry instruction, you [the teacher] provide the opportunity for and allow students to investigate questions and problems with as little teacher influence as possible. This does not necessarily mean throwing the students into the deep water and letting them sink or swim. Inquiry instruction can include modifications such as having the initial investigation set up by the instructor.*

As evidenced in Warren and Stefani's responses, the idea of teachers scaffolding inquiry and building classroom climates conducive to inquiry teaching and learning was a common theme among the majority of the Level IV subjects. Like her peers, Beverly said, " Furthermore, students need to be *trained* and have an understanding of what they are doing in an inquiry classroom in order for it to be effective."

In summary, the prospective teachers' descriptions of inquiry seem to divide them into three categories instead of four. Level I had the least robust descriptions of inquiry. Their responses were mostly based on the teacher asking a question and students figuring out the answer. Levels II and III had similar views of inquiry, which consisted of significant student autonomy and responsibility for developing procedures, working together in groups, making explanations, but ultimately with a correct answer in mind. Level IV had the most robust and complete descriptions of inquiry that involved students in elaborate cognitive demands. Furthermore, the students were learning to research like scientists do science. Except for one subject, the prospective teachers agreed inquiry learning means multiple outcomes. Their focus was more on the process and less on a specified outcome.

RQ3: Subjects Stated Rationales for and against Inquiry Instruction

Level I: Early Program Subjects' Rationales for and against Inquiry Instruction

There was only one common theme found in three of the four early level subjects' responses regarding the purposes for using inquiry instruction in the classroom. As Melinda said, "The students remember what they learned better because they actually have to go through all the thought processes in their head to get to the conclusion. It isn't given to them. That's what really makes it stick." However, regarding the challenges of inquiry, all four subjects described students struggling to understand. For example, according to Morgan, "If a concept is difficult to grasp, some lecture is in order for the question approach to be effective. Otherwise, if there are too many new concepts for the student to absorb at once, they just became frustrated."

No common themes emerged in the subjects' responses about why inquiry should *not* be used in the classroom. However, even though no one response represented the majority's thinking, there were several blatant misconceptions represented. For example according to Melinda, "inquiry instruction should always be used. Students just learn better when it's inquiry based." Hector said, "When a lesson is math-based, inquiry should not be used." Additionally, he added that "Inquiry based instruction should be approximately 30% of class time. This leaves plenty of time for explanation and assessment." Morgan referred to inquiry as "the question approach," and Darrell said that when he has his own classroom, he will "use inquiry in all labs and experiments and during the *Explore*," the second phase of the 5E Instructional Model.

Level II: Middle Program Subjects' Rationales for and against Inquiry Instruction

There was only one theme common among the majority of the middle level subjects' responses regarding the purpose for implementing inquiry instruction in the science classroom. According to four of the subjects, inquiry instruction is most beneficial because students learn content knowledge better and can remember it longer. Brielle and Marion's responses illustrate this idea:

> *Inquiry instruction increases student engagement, which leads to an increase in student learning. It is harder for the student to zone out when they are doing an experiment versus listening to a lecture. Also students are more likely to remember a conclusion they came to themselves, rather than a conclusion they were given on a PowerPoint*. (Brielle)
>
> *More connections are made when students find the answers on their own, and they retain the knowledge longer when they can tie it to an experience where they had to find it out on their own (*Marion)

Five of these preservice teachers reported limited classroom time as the primary challenge to implementing inquiry in the classroom. Additionally, although they don't represent the majority of responses, the idea of teacher efficacy, or confidence in their abilities to utilize inquiry, was represented in three subjects' responses. Three subjects' responses illustrate:

> *There are expectations and timelines that must be meet as a teacher. My greatest concern is in my own ability to create the excitement needed for the students to participate in meaningful exploration. It takes a lot of time to complete a topic thoroughly and not create more confusion than understanding.* (Donald)

> *First, it takes a lot longer to come up with a good inquiry based lesson, than it does to make a worksheet. It is also more tedious and stressful. Inquiry lessons really should be worked out ahead of time because, honestly, sometimes they just flat out don't work.* (Brielle)

> *The challenge with inquiry instruction is keeping students involved and on task. Since there is more discussion, collaboration, and coordination, there is more opportunity for "distraction" compared to a lecture.* (Evan)

Regarding reasons why teachers should *not* use inquiry instruction, four subjects made references to topics that can be successfully taught without inquiry. To illustrate, consider Donald’s explanation below:

> *Basically I feel that you don't use inquiry when you don't have time and the subject could be successfully taught without it. Things like the anatomy of the body has to be taught; yet investigating whether or not we accurately understand the purpose of teeth may not be very helpful. Though if there is time, having the students put together a presentation of what they found most interesting in whatever media they want would be a quick way to include inquiry learning.* (Donald)

Closely akin, other subjects said to not use inquiry to teach easy to learn concepts (e.g. vocabulary) or when it just makes sense to tell it. See Marion’s response that follows:

> *We should not use inquiry strategies when it just makes more sense to show it, or on little pieces of information that are easy enough to learn. For example, I could teach phagocytosis and pinocytosis in a hands-on or inquiry based style, but that would take an entire class; it would be easier to spend 10 minutes explaining it, as most students will pick it up on the first run anyway.* (Marion)

Three subjects said that choosing to use inquiry should depend on the students. “Teachers should also not use inquiry strategies when those strategies oppose student learning. As teachers, our role is to make sure that the students are learning” (Evan). Although Marion also suggests that inquiry instruction should depend on the students, his response reveals some misconceptions. Consider his explanation below:

> *While several concepts can and should be "discovered" by the students, there are some concepts where the activity may be more confusing when we try to shove it into an activity. My main concern is that the students might not reach the "right" answer and draw the wrong conclusions and remember that instead of the textbook response.* (Marion)

As evidenced in his response, not only does he refer to inquiry learning as *student discovery* and inquiry instruction as "shoving concepts into an activity," but also the ultimate goal is for students to reach the *right answer*, or the textbook response. Both Marion and Brielle make references to this intention. There were other responses from this group that target misconceptions as well. Charles specifies, "All labs should be inquiry-based." Marion suggested that "Some students tend to get disgruntled at the thought that they will be *teaching themselves*, and we will be grading them on it."

Level III: Advanced Program Subjects' Rationales for and against Inquiry Instruction

The majority of the advanced subjects agreed on three reasons why inquiry instruction is most beneficial to students: Students build deeper understanding of content; inquiry is more engaging and fun than other ways of learning, and students develop important life skills when they engage in inquiry learning. Camryn's response illustrates all three of these ideas:

> *Inquiry gives students a greater conceptual understanding of concepts rather than memorizing and regurgitating facts. My hope (and I think to be true) is that inquiry fosters an environment that allows students to be more engaged in their own learning, maybe more interested. Inquiry allows for a lot more collaborative opportunities between students, which can greatly benefit their "soft skills" of working together, solving problems. Inquiry gets students asking questions that they want to answer.* (Camryn)

Regarding the challenges that come with inquiry instruction, there were two areas the majority of prospective teachers found problematic. First, three subjects cited issues related to their teaching efficacy as the biggest challenge. Andrea and Kylah explain:

> *Preparing the lesson itself can be a doosey, but I imagine that will get easier with experience. Differentiating between what is an appropriate "explore" or "elaboration",*

> *what's an awesome "engagement"? These are things that can make you want to pull your hair out but once all the pieces start to come together it's worth it.* (Andrea)
>
> *The largest challenge I foresee teaching inquiry instruction involved my own preparedness. When a teacher allows such freedom in a classroom, there are endless possibilities as to what the students will come up with. Even with a solid background in science, I am sure there will be questions that I am unable to answer. However, with that said, a teacher that doesn't know an answer has the opportunity to unite with students in the learning experience. Ultimately, I believe that a teacher researching with students can aid the student's learning.*

Another challenge cited among a majority of advanced prospective science teachers was the idea that sometimes students just don't respond well to inquiry or they develop misconceptions. According to Addison, "If you are teaching students through inquiry, some may develop misconceptions about a topic. Misconceptions are very hard to *unlearn*." In similar fashion, Kylah said, "To some extent, not all students respond well to inquiry instruction. Additionally, students with a strict inquiry instruction learning background may experience a shock when taking strict lecture based college courses."

When asked to state reasons that teachers should not use inquiry instruction, three subjects referenced the idea that sometimes students just need lecture to help them understand the concepts. According to Camryn, "Direct instruction is sometimes needed to pull the concepts together and re-enforce understanding." Otherwise, two subjects believe advanced topics and complex material should be taught through traditional methods. According to Addison, "Teachers should avoid inquiry learning when introducing new, complex material. Some material, the Krebs's Cycle for instance, is difficult to begin with, and it is easy to form misconceptions."

Level IV: Program Completers' Rationales for and against Inquiry Instruction

According to the majority of subjects in the Level IV category, there are three reasons inquiry instruction is beneficial to students. First is the idea that inquiry is more motivating (than lecture) and students are more likely to engage if they are interested. Three subjects also referenced the idea that inquiry helps students develop deeper understanding and remember the content better. Lastly, three subjects said that inquiry helps students develop important life skills. Sophia and Stefani's responses illustrate two or more these ideas:

> *With inquiry instruction, the students are more engaged in the learning experience. They are more involved in the discussions and development of the lessons and the interactions are more memorable for students in the long run. Furthermore, inquiry is more conducive to critical thinking than a lecture format.* (Sophia)

> *Inquiry instruction creates a unique incentive for students where even if there is not a specific authenticity to the real world, there is a motivation lended to the inquiry by autonomy given to the students. Inquiry instruction also trains high-order thinking and critical thinking skills*. (Stefani)

In addition to students developing critical thinking skills, the subjects also listed using laboratory tools, working in cooperative learning groups, and learning how to research information as needed life skills.

Level four participants also noted three particular challenges to inquiry teaching and learning. For example, Sophia said, "Sometimes inquiry instruction is time-consuming. Following a strict calendar may result in a decrease in inquiry-based lessons, and sometimes needs to be replaced with a more time-friendly method." In addition to the lack of classroom time available for inquiry instruction, all four subjects cited the teacher's preparation time as prohibitive. Warren's response illustrates: "It takes a lot of time in the classroom and outside the classroom. It can be difficult to contrive lessons that allow the students to learn on their own." Like Warren's response suggests, two other subjects also said inquiry is a difficult pedagogy, and teachers and students need training to effectively participate in inquiry teaching and learning. Stefani's response illustrates these ideas:

> *My early experiences with inquiry either had more scaffolding than I was hoping to use or the lesson was chaotic. It is a teaching style I would only recommend to teachers*

> *willing to spend the time to get their students accustomed to the expectations and skillsets required for inquiry based learning. Students who haven't been eased into the process usually with either take the freedom afforded by inquiry instruction's student autonomy to do anything but the task at hand or become paralyzed by indecision or confusion. Inquiry is not a one and done; it's something that takes quite a lot of time and effort on the teacher's part.* (Stefani)

When asked to describe when inquiry instruction should *not* be used in the classroom, their reasons were minimal. Three subjects agree that to choose or not choose inquiry as an instructional methodology just depends on the topic and on the students. Beverly and Stefani explain:

> *Every lesson is different and some lessons can be tailored to more inquiry time than others. Some topics are more difficult than others, and when it is apparent that students aren't getting a topic, time should be taken to sit down and talk about the issues and misconceptions rather than try to have students figure it out.* (Beverly)

> *There are so many styles of teaching, and inquiry is a great style among them, but certain material may be better suited using alternate teaching practices. Ideally, with suitable material, close to 100% of instructional time could utilize inquiry-based instruction if there were, say, a unit on optics that could be discussed and investigated using labs and projects and the like. However, inquiry instruction should be avoided if it is evident students require more scaffolding first. If a teacher notices students struggling with foundational knowledge while preparing them for an inquiry activity, the teacher may have to redirect to review the material they have to understand before performing the activity.* (Stefani)

Two subjects also cited the ideas that inquiry should not be used to teach science facts and vocabulary. According to Sophia, “I would avoid inquiry and use a traditional notes method to teach facts that are necessary for standards but not necessarily a big scientific concept.” Likewise, Warren said, “If what you really need is just memorization of vocab, then run those sort of drills. Inquiry based instruction is most efficiently utilized for gaining fluency over concepts and skills.”

Conclusion

In summary, although there was significant overlap in the subjects' beliefs about teaching and learning science, more differences became apparent in their inquiry-specific responses. In Chapter Five I discuss these findings in light of the literature related to preservice science teachers' understanding of inquiry instruction. Also implications for science teacher preparation programs involved in promoting teaching science as inquiry are discussed as well as recommendations for future studies.

CHAPTER 5: DISCUSSION and CONCLUSIONS

The purpose of this study was to explore how a select group of preservice science teachers who espoused having inquiry-based teaching orientations conceptualized the teaching and learning of science through inquiry. The study also focused on identifying particular junctures in the prospective science teachers' teacher education preparation (early, middle, advanced, and program completion) that might impact their understanding about inquiry. This chapter discusses the findings specific to the following research questions:

1. How do preservice science teachers who indicate preferences for inquiry instruction describe their beliefs about teaching and learning science?
2. How do these preservice science teachers define and describe inquiry instruction?
3. What justifications do these preservice science teachers provide for utilizing (or not utilizing) inquiry instruction in the science classroom?
    - How do these preservices science teachers' beliefs, conceptions of inquiry instruction, and their subsequent justifications for using it compare at various stages of their teacher education program?

In this chapter, I also report on the implication of the findings, suggest recommendations for changes to the Arkansas UTeach courses of instruction, and I discuss the implications for future research.

Beliefs about Teaching and Learning Science

Teachers' beliefs are good indicators of the decisions they will ultimately make when in the classroom (Anderson, 1996; Pajores, 1992; Prawat, 1992). Likewise, teachers' beliefs about teaching and learning science likely affect their views of teaching science through inquiry (Crawford, 2007; Wallace & Kang, 2004; Tillitson & Young, 2013). This section summarizes the beliefs about science teaching and learning espoused by select preservice science teachers' at various stages (early, middle, advanced, and completed) in a teacher preparation program that emphasizes inquiry instruction. As a reminder, all of the subjects discussed here were selected for this study because of their self-described inquiry orientations. Although the discussion that follows includes information specific to all levels of the program (early program through program completion), most involves the participants in the latter three levels of program implementation (middle, advanced, and completion) due to a lack of common and reoccurring themes among the subjects in the early program level. Also, the conclusions described represent the majority of subjects' responses in each category of the program unless otherwise stated.

At *all* levels of program implementation, two ideas emerged. First is the belief that science content knowledge is the intended target for what students should learn in science class. As one of the early program subjects said, the purpose of science is to "give students the scientific base and facts they [students] need so that they may make informed and analytic decisions in the future." Likewise, Beverly, who just completed all eight courses in the program, said close to the same:

> *The primary purpose of teaching science in high school should just get students excited about science so they will put in the effort to actually learn the content. The next purpose is to teach [the students] content knowledge that will benefit them as they further their education*. (L-IV: Completer)

By most subjects' accounts, content knowledge referred specifically to the facts and principles in science.

A second idea common to the preservice science teachers at all levels is that students should be *actively engaged* in learning science content. By engagement, prospective teachers described students actively engaged in hands'-on and/or minds-on learning. Multiple subjects' responses made explicit references to the idea that learning science is more than memorizing facts that can be easily "regurgitated," and teaching is more than telling. Whereas the subjects in the recruitment courses (early program) provided brief statements of this nature, those in the latter three categories (middle, advanced and program completers) provided elaborate and detailed descriptions of students engaged in the learning process. Brielle's (L-II: Middle) response illustrates:

> *The first thing that comes to mind when I read "good science teaching" is an image of engaged students. The second thing that comes to mind, is the many different ways those students are engaged: hands on activities, research, group work, presentations, exploring, discovering, making connections with between other topics in science and even in other subjects.*

Additionally, most subjects described learning in terms of students asking questions to learn more about a particular topic and by explaining things in their own words. Morgan (L-I), an early level subject said, "I recognize that the students in my class are learning when they can explain or exemplify a concept to me in their own words and way. When they aren't just spitting out the exact words I gave them earlier," Also, according to Warren, an advanced subject (L-IV), "When my students are asking questions, I know they are thinking. If they're thinking, they're learning"

As represented by their responses, at all levels of the program, two particular ideas seem to become integrated into the subjects' experiences early in the program and remain static throughout. Furthermore, these ideas are somewhat at odds to each other. First, is the idea that science class is purposed to teach students the facts of science, a traditionalist notion. By traditional, I refer to Tsai's (2002), interpretation: "Science provides correct answers, or science represents the truth" (p. 776). However these subjects also had constructivists' notions of teaching and learning science. By constructivist learning, I mean that students construct their own understanding, and constructivist teaching just means helping students construct their own knowledge. Evidences of these ideas are reflected in their descriptions of teaching and learning. Evidence supporting this finding is also present in subjects' emphasis that teachers should not tell students the facts, but rather engage students in their own learning. This is illustrated in

Deanna’s (L-II: Early) response to what advice might she give a previous science teacher about how to improve her own learning: “Don't just lecture and expect me to understand. Let me see it for myself, let me do it, let me experience it and I will remember it better.”

The majority of subjects at the middle, advanced and completed program levels described beliefs about teaching and learning science that engaged students in at least one of the *inquiry practices*. The most consistent responses among all these subjects related to ways to engage students in asking questions and defining problems, designing and carrying out investigations, and data interpretation. Representative responses from the middle, advanced, and completion levels of the program follow:

- *The main purpose of teaching science in high school should be to get an educated population that can examine data, determine what is real or not, and to get a more curious population that will critically examine the world around them.* (L-II: Middle)
- *I know students are learning when they are working in groups, evaluating their peers' presentations, and they are able to ask questions of others, correct mistakes, and teach others.* (L-III: Advanced)
- *The purpose of science class is to teach students to be scientific learners. Although understanding the material in the subject taught is an unquestionable goal for teachers, one of my main purposes in teaching science is that students can think and learn like scientists by using critical thinking skills, non-biased judgment, and can understand and interpret data.* (L-IV: Completer)

Although they did not represent the majority of responses in their respective program levels, subjects in the middle level (L-II) and the program completers, those who have completed all their coursework (L-IV), described three to five specific inquiry practices in their responses to questions about the purpose of science, and their conceptions of effective teaching and learning: Engaging students in scientifically oriented questions, planning and carrying out investigations, analyzing and interpreting data, engaging in argument from evidence, constructing explanations from evidence. One particularly astute student (program completer) with robust descriptions of inquiry teaching and learning illustrates a number of these practices:

> *If students are asking questions, you know that they have a classroom environment where the nature of science as an investigation of the world around them is being fostered. It's also indicative of students finding internal incentive. Good science teaching has the students behaving like scientists: questioning the value of statements, looking for empirical evidence, having rationale behind their own conclusions, testing hypotheses before making assumptions, etc.* (L-IV: Program completer)

Another common theme among those in the upper three categories were vivid and pronounced descriptions of the teachers' roles and responsibilities during instruction. For example, the middle level subjects and the program completers believe teachers should utilize diverse teaching strategies (e.g. hands-on activities, research, group work, laboratory experiences, projects) to help engage all learners. Beverly's response illustrates:

> *Teaching science should be fun! This includes labs, discussions, and activities that don't need much lecture time. On the flip side to having a more student-centered classroom, sometimes students are lost and the only/best way to bring students back to the topic is to have a lecture day or a longer lecture period than on a typical day. This lecture period should not be teachers talking at students, but giving students the scaffolding they need in order to reach the performance expectation and learning goal that is being aimed for.* (L-IV)

Likewise, Camryn (L-III: Advanced) said, "Inquiry instruction is starting with questions or concepts and then help students build understanding through experiment, exploration, activity etc." The advanced subjects also believe that teachers are responsible for bringing in real-world examples into their instruction. The program completers brought in these same ideas and had even more descriptive details concerning teacher specific roles. For example, besides providing engaging learning experiences, teachers must actively foster classroom environments that promote student-centered learning, and they must continually assess students' learning in order to modify instruction if needed to improve student-learning opportunities. At no time did any of the subjects describe students actively initiating their own inquiry investigations independently of the teacher's assistance.

Finally, a reoccurring theme among subjects in the advanced (L-III) and program completer (L-IV) levels of program implementation was the idea that science class should be structured to help students develop particular life skills. The majority of subjects described teaching and learning as being significantly interactive. For example, while learning science, students should also learn to work collaboratively with others. This is well illustrated by Beverly (L-IV: Completer) who said in science class "students learn to work together with their peers. In almost any job that the students may have one day, they will have to work with others whether they like them or agree with them or not." Another idea well represented among these subjects is that science class should help students develop problem solving, and critical thinking skills to help them succeed in the real world. Camryn (L-IV: Advanced) said, "Much of making informed decisions about the world and life situations has some basis in science, and everyday we need critical thinking skills." Furthermore, these same subjects believe that science class should prepare students for future academic endeavors, primarily college.

As evidenced by their expressed beliefs about learning and teaching, the top three categories of subjects indicate beliefs that are somewhat aligned with Constructivist Learning Theory (CLT), at least in broad terms. McComas (2014) describes constructivism in terms of student responsibility for learning:

> *In a classroom guided by constructivist learning theory, students are responsible for tackling problems and making sense of experiences; they share ideas with their peers, and teacher, and the teacher performs a vital role in the learning process by interacting with students in scaffolding their thinking and providing information when needed.* (p. 21)

CLT emphasizes active learning and knowledge construction in opposition to knowledge transmission. The following representative quotes taken from each program level illustrates this idea of knowledge construction as opposed to knowledge transmission:

- *The main purpose for teaching science in high school should not be to memorize facts about different topics, but to give the students an understanding of how to learn these facts for themselves through research.* (L-I: Early)
- *Good teaching is not just passing along information that students will be able to recite from memory. Set up more group activities to search for an answer to a question before it is given.* (L-II: Middle)
- *Effective science teaching should be centered on a question that creates a 'need to know in students. Fostering an environment that creates intrinsic motivation creates good opportunities for teaching.* (L-III: Advanced)
- *Most of the class should be devoted to students talking to their peers in some type of group or even writing what they are thinking down. Cooperative learning allows students to see the perspective(s) of their peers.* (L-IV: Completer)

As these quotes illustrate, at all levels of program implementation, subjects revealed beliefs about teaching and learning science that are correlated with CLT. Teaching should engage students in their learning so they are more likely to engage in the learning experiences, and students are actively working together and learning from one another. As such, subjects described students involved in discussions, asking questions, and explaining their understanding. Ultimately, according to their beliefs about learning, students in the classroom should figure things out rather than being told them.

The evidence here is that almost all selected prospective teachers' responses to the open-ended questions about science teaching and learning involved significant student-centered perspectives, which likely portends inquiry instruction (Luft & Roehrig, 2007; Hashweh, 1996). However, because many subjects also had an untoward focus on students learning the facts of science suggests that inquiry-orientations do not necessarily correlate to knowledge about the nature of science inquiry, excluding the majority of subjects in Level IV. This is further evidenced in subjects' rationales for why they chose particular pedagogical methods. This finding is consistent with Lakin and Crawford's (2015) finding that suggested middle school teachers' preferences for inquiry were negatively correlated with their knowledge of the inquiry practices.

These findings provide reasons to optimistically look forward to what these teachers will do in the classroom. Although this study does not attempt to describe these preservice science teachers actual teaching practice, there is research that asserts teachers' student-centered beliefs tend to correspond with their teaching practice in the classroom (Luft & Roehrig, 2007; Hashweh, 1996). However, there is also reason for caution. Although, according to Luft and Roehrig (2007), teachers having student-centered ideologies are likely to develop into more reformed minded teachers with adequate support, they could also revert to traditional minded teachers *without* adequate support. Because we know that most classroom climates do not support constructivist classrooms, teacher preparation programs not only have to support preservice science teachers learning to use inquiry instruction during their preservice training but they also have to prepare them for actual classroom climates that may not support constructivist learning.

Although all subjects indicate constructivists' beliefs about teaching and learning, there appear to be two junctures in their learning progress. Evidence supporting this statement is found in their congruent responses within categories and the in the depth of their responses. For example, all levels, subjects indicated agreement that students should be actively engaged in figuring things out for themselves rather than being told information. However, the middle and advanced groups also define and describe an additional role for teachers and students during the learning process. For example teachers should include real-world scenarios, utilize diverse strategies during instruction, and students should actively participate in discussions. Furthermore, students have significant autonomy and responsibility for learning. Although the program completers (L-IV) had similar descriptions of inquiry teaching and learning, they also had much more depth and congruence within their responses that attended to inquiry specific activities. Like the middle and advanced groups, the program completers also included the same descriptions about the teachers' and students' roles in the learning and teaching processes. However, distinctive to this category, these subjects also agreed that teachers have to build a classroom culture conducive to inquiry learning and constantly assess students' understanding. They also described students involved in asking their own questions they are interested in pursuing answers to as well as sharing and comparing ideas with their peers. The majority of program completer's, unlike the earlier subjects, tended to focus on the inquiry process as the intention not the means to achieve content knowledge.

Subjects' Descriptions of Inquiry Teaching and Learning

Although inquiry is a useful label that describes many aspects of science teaching and learning, it also has become a catchphrase that comprises multiple ideas depending on the contexts. As such, defining inquiry instruction has been historically problematic and imprecise (Anderson, 2007). Likewise, in this study, there were varying degrees of student understanding about inquiry, and most all subjects' responses had limited and naive understanding of inquiry.

Subjects in the early levels of their teacher education program described inquiry in terms of students exploring to figure something out. Although, their explanations lacked important details, most prevalent, was the idea that inquiry instruction means the teacher poses a question to facilitate student learning. As Melinda said, inquiry means, "The teacher proposes a question. Then the students discuss and learn." However, how students actually construct their understanding is left undefined. Except for descriptions of inquiry as students finding out the answer to the teacher's questions, there were virtually no other references to any of the inquiry practices. This finding poses no concern to the researcher at this point due to the fact these prospective science teachers are very early into their teacher preparation programs, and have had limited theoretical or practical experiences. Therefore, future discussion will pertain only to the upper three levels of program implementation: Levels II (middle), III (advanced), and IV (completer).

Subjects in these upper two levels of the program described inquiry in terms of a teacher-guided inquiry such that the teacher poses a question, and the students "*solve, explore, or discover"* the answer. Kylah's response follows:

> *Inquiry instruction is a type of instruction based on explorative learning in the classroom. Students are given a problem or question that they are expected to solve. Throughout the project, students slowly gain the skills and knowledge necessary to solve the problem or answer the question. Inquiry instruction provides much freedom and autonomy in the classroom, but is still guided by the instructor.* (L- III: Advanced)

Like Kylah's response, most subjects' descriptions of what students do while exploring implied significant student autonomy and responsibility for developing their own procedures and interpreting the outcomes. As Camryn (L-III: Advanced) said, " It is important that the students are the ones participating in the inquiry, which is more than just following procedure and completing a task." However, these subjects' references to the word *explore* is somewhat problematic. Not only is it difficult to ascertain what they perceive students are actually doing during the *exploration,* but the ambiguity likely indicates a lack of understanding and an inability to clearly articulate what students and teachers are doing during the inquiry-based events.

Level IV subjects also described inquiry in terms of a teacher- guided exploration. However they added more details to explicate their descriptions. The majority of subjects described various methods of exploration (labs, research, projects, discussions). Stefani's response illustrates:

> *Inquiry instruction is a student-focused teaching practice where the activity/lab/project/lesson is planned around the use of high-order thinking skills usually to either investigate a scientific query or problem-solve. In the classroom it is often seen in the form of guided inquiry, where for example, a teacher may pose a question and*

> *students must design and perform an experiment to investigate. True inquiry, where the process of developing the inquiry and carrying out the investigation are entirely the responsibility of the student.* (L-IV: Program Completer)

In addition to identifying inquiry learning as occurring through an activity, lab, project, or a lesson, Stefani also describes inquiry learning in this particular example in terms of an experiment that students might perform in order to investigate a phenomenon.

Some subjects in Level II, the majority of subjects in Levels III, and one subject in Level IV described inquiry using explicit descriptions of various stages of the 5E Instructional Model. The 5Es are based on learning theories about how children learn (Bransford, 2000) “and the observation that students need time and opportunities to formulate or reconstruct concepts and abilities” (Bybee, 2014, p.11). Subject responses support this constructivist view of learning, as there was a strong consensus that students are actively thinking during inquiry learning activities. Below are three subjects’ (at each level of the program) responses to the survey prompt asking students to “Identify and describe any specific teaching practices/strategies that account for inquiry instruction as you understand it.” I include these descriptions in their entirety because they so clearly articulate inquiry instruction in terms of three or more of the learning cycle:

> *The teacher presents class with a question and provides the students with a way to work toward the answer to the question. The teacher asks engaging questions to the students, keeps an eye out to make sure students are on the right track, minimizes the "procedure list" and gives minimal strict instruction. Students use resources, information, or the materials provided will work toward a solution to the question, may reach dead ends in attempts, may use trial and error. Students (for the most part) come up with their own procedures and do not follow a checklist. Students may come up with different answers to the question. The teacher can use this to discuss the variety of the answers or even error. The teacher doesn't actually present the students with the "textbook information" until after the students have done their own investigation. "Textbook information" is the goal topic or main take away from the lesson.* (L-II: Middle)

> *The teacher engages the students in the topic through a demonstration, video, activity, or game that is somehow related to the topic being taught. The student participates and gives the teacher a platform to build off of. The teacher provides an opportunity for the students to investigate or explore an idea. The teacher provides the instruction that is*

> *needed. Although I don't think there is one "right" way to do inquiry, I believe here the teacher provides some end goal such as a broad question or parameters for the students to work under. The students work with the concepts whether that is through a lab, an investigation, or activity. The teacher should have students recall their prior knowledge to show what they know from their experience, maybe what they think will happen in certain situations, or how they perceive something. This allows for something to refer back to after inquiry is completed. Students should have the opportunity to explain. Maybe students are asked a question and the teacher has each student think individually and then partner with someone else. Defending answers and giving explanations is an important part to inquiry so students should make sure to do this when talking with a partner. Then I think students should also have the opportunity to present to their class. The teacher should create an environment that has open communication where students can disagree and present their "arguments." I think one final piece that brings it all together is having students transfer their knowledge to a new situation. I'm not really exactly sure how to do this always, but the teacher can provide opportunities for the students to put their knowledge in another context, another scenario, etc.* (L-III: Advanced)

> *For instance, in a lesson teaching homeostasis, the teacher "could" tell the students a definition, a few examples, and move on. However, with inquiry instruction, the teacher might start off the lesson by asking students to make a prediction on what their temperature would be inside versus outside on a hot summer day (assuming the temperature is much colder inside than out). After students write down their predictions, students are allowed to test their predictions by using thermometers After students measure their body temperatures inside the building and then outside in the hot summer heat, and it is the same temperature, a classroom discussion might follow about why they think that happened. Students are free to agree or disagree and discuss explain their thoughts. This discussion could lead to the definition of homeostasis. The students would use the example of body temperature to define homeostasis without ever hearing the word. The teacher could then introduce the term. Following the investigation, discussion, and lecture, the students could think of other examples besides body temperature that fit that term and definition. Thus, a lesson is completed that involved student activity, interaction and students' own questions and answers.* (L-IV: Completer)

Each of the afore mentioned descriptions of inquiry-based instructional strategies in the 5E context have components of inquiry embedded within them. For example, from the three examples above the following inquiry practices are in evidence: Conduct investigations; explain using evidence, and hypothesis testing. As any science teacher should agree, the subjects' descriptions of inquiry and the 5E teaching and learning events are thoughtful, strategic, engaging, and substantive. Congruent with the work of other researchers (Duran & Duran 2004;

Goldston et al., 2013; Lakin & Wallace, 2015), these findings suggests that "using a learning cycle approach in the classroom can help facilitate inquiry practices because learning cycles focus on constructivist principles and emphasize the explanation and investigation of phenomena, the use of evidence to back up conclusions, and experimental design" (Duran & Duran, 2004, p. 49). The findings in this study support their research. However, I also suggest caution should be taken regarding this finding. Evidence also suggests that multiple subjects in this study conflated inquiry practices with phases in the 5E learning sequences. Are they describing constructive-based learning or inquiry, or both? These findings suggests the stages of the 5E Instructional Model and learning science through inquiry are synonymous constructs in the minds of many of the prospective science teachers. This finding supports Minner and colleagues (2009) suggestion that researchers need to clearly distinguish between inquiry and constructivist's learning practices.

Although multiple subjects in the middle two categories of the program described inquiry learning in terms of significant cognitive engagement, many of their descriptions consisted of students pursuing a single "correct" answer sometimes even referring to the textbook answer. The majority of subjects in the middle category (Level II) explicitly stated this. For example, Brielle said, "Textbook information is the goal topic or main take away from the lesson." Although they don't represent the majority of responses, various subjects in the advanced (L-III) and completer levels (L-IV) of the program also suggested this idea. For instance, when sharing his concerns about inquiry Sydney (L-III) said, "My main concern would be that the students would not reach the 'right' answer and may draw the wrong conclusions and remember that instead of the textbook response." Likewise, Sophia (L-IV) said that after students do their investigation, a "discussion could lead to the definition [of homeostasis]."Although learning concepts through inquiry is a good thing if it meets the intended goal of the lesson, the fact that multiple responses included only the idea of a single correct answer suggests that many subjects have a limited view that the sole purpose of inquiry instruction is to learn concepts through inquiry. Yet twenty years ago the *NSES* (NRC, 1996) strongly recommended less emphasis on the facts and information of science and more on understanding science concepts in conjunction with learning to do inquiry.

Albeit there were limited references to helping students develop the abilities to do inquiry or learn about inquiry, a few subjects particularly in Level IV referenced a more open-ended view of inquiry such that the outcome was unknown to any of the participants, including the teacher. Warren's response follows:

> *My understanding of inquiry instruction is that it is instruction centered around the students exploring their own ideas and interpretations of evidence. To facilitate inquiry instruction, you provide the opportunity for and allow for students to investigate questions and problems with as little teacher influence as possible. This does not necessarily mean throwing the students into the deep water and letting them sink or swim. Inquiry instruction can include modifications such as having the initial investigation set up by the instructor.* (L-IV: Completer)

Even though Warren seems to have a robust understanding of inquiry in terms of student autonomy and teacher guidance, (open and guided inquiry), his use of the term *exploration* is somewhat ambiguous regarding specific student activities during the exploration.

The majority of respondents made frequent references to *multiple ways* to do inquiry: Investigations, research, laboratory, group discussions, hands-on, group work, presentations etc. Although it is unclear what the subjects actually mean when using these terms, this finding suggests they do not think of inquiry as a single method. As such, this finding is contrary to the misconception that inquiry involves a single scientific method (McComas, 1998; 2005). In all three upper categories of subjects (middle, advanced, & completer), the majority of subjects described inquiry in terms of students engaged in scientifically oriented questions and planning and carrying out investigations. Select subjects in all three categories also described students giving evidenced-based explanations. Subjects in Levels II and IV referenced students analyzing and interpreting data.

Also common throughout multiple responses were descriptions of student collaboration and student discourse. Several participants made references to students presenting their information to the whole class. Furthermore, these references were usually in conjunction with an evaluative component such that students might change or modify their thinking as a result of hearing multiple perspectives. Although multiple descriptions of inquiry involved students explaining their understanding in their own words, there were few explicit references to constructing evidence based explanations, and no explicit attention was given to ensuring students' explanations aligned to scientific knowledge. Writers of the *NSES* (NRC, 1996*)* envisioned less emphasis on students getting an answer and more emphasis on "using evidence and strategies for developing or revising an explanation" (p. 113). Although there were multiple descriptions of students explaining their understanding, it was primarily in the context of "explaining in their own words" rather than using evidence related to subjects' defending their own thinking. Although such an idea is laudable and important, it does not place any emphasis on students using evidence to support their explanations. This finding is congruent with other researchers (Kang et al., 2008; Minner et al., 2009; Young, 2013) who also found certain science practices are more represented in teachers' conceptions of inquiry than others. Similar to this study, particularly lacking are the practices of students constructing evidence-based explanations and evaluating the explanations in light of science knowledge (Kang et al., 2008).

As presented here, participants' descriptions of inquiry were closely aligned with Minner and colleagues (2009) broadly defined description of inquiry. These authors defined inquiry instruction in terms of the presence of four common elements: (a) the importance of science content, (b) student engagement with phenomena, and (c) some degree of student responsibility for learning (active decision making), and (d) instruction that included one or more parts of the investigative cycle (questioning, investigative design, data collection, evidence based conclusion, and communication). The subjects' responses in this study repetitively described students engaged with and actively constructing understanding of science concepts. Also in their responses, because students had autonomy and took some form of responsibility for their own learning, the subjects believed students were motivated to learn and were more likely to master the content better. The learning environments in the subjects' responses described a lot of collaboration, student discourse, and active thinking. As such, students were always engaged with a scientific question (typically teacher provided), and usually some form of exploration (projects, research, experiments, discussions etc.) that often involved a hands-on component. This finding is in stark contrast to teaching science as process skills devoid of content and active intellectual engagement (DeBoer, 1991; Young, 2013) common in the misconceptions about inquiry literature (Bybee et al, 2005; Llewellyn, 2002; NRC, 2000; Trautman et al., 2004; Wilcox et al., 2015).

In summary, most subjects described inquiry in terms of one or more of the inquiry practices. Certain features, however, are more prevalent in their discussions than others. As such, their conceptions of inquiry teaching and learning are incomplete. Furthermore, the fact that subjects tended to place an untoward focus on the idea of *explorative learning* suggests they may think inquiry learning is synonymous with exploration. The term inquiry intuitively connotes actively trying to figure something out. However, the act of having students actively exploring does not represent inquiry as much as it represents inquisitive, engaged learning. Although student engagement is a good thing, of course, it does not ensure students develop the abilities to do inquiry and learn about inquiry. The following section will highlight the rationales subjects' used to describe why inquiry is and is *not* a worthy undertaking.

Rationales for and against Inquiry Instruction

Stated Benefits of Inquiry Learning

Regarding the goals and purposes of inquiry teaching and learning, participant responses indicated prevalent constructivist rationales. The most prevalent rationale expressed by subjects at all levels of the program was that inquiry results in better learning opportunities and retention of concepts (i.e. the facts of science) because students have to figure them out. Melinda, a participant early in the program said, "The students remember what they learned better because they actually have to go through all the thought processes in their head to reach a conclusion. It isn't given to them, and that's what really makes it stick." Camryn's (L-III: Advanced) response also illustrates this idea:

> *I see inquiry learning as having an experience with Newton's law of motion and making predictions and seeing cause and effect relationships or relationships between variables before defining the laws and just "memorizing them.*

Also, as Camryn's response suggests, multiple subjects in Levels II and III described inquiry exclusively in terms of students exploring before the teacher lectured. This idea is somewhat congruent with Schwab's (1960) suggestion that to incorporate inquiry into lessons, at the very least, the laboratory could precede lecture. To illustrate, Addison (L-III) said, "Inquiry instruction is something that builds context and experience and then [the teacher] provides further explanation and definitions." Although some inquiry practices were embedded into the subjects' descriptions of what students do during the *explore* phase of the 5E instructional model, the primary intent here, according to Addison and others, seems to be to give students in the classroom context for what comes next (i.e. lecture). Although such an idea is laudable and even accurate, participants' explanations often referred to the right answer, textbook information, and the right conclusion as the intended goal of a lesson. This finding suggests the prospective science teachers view inquiry instruction as "explore first, lecture second" with almost a single-minded purpose being to help students build context for the pending lecture. These ideas are closely tied to constructivist learning theory and the first three stages of the learning cycle. This findings is consistent with other studies (Duran & Duran, Bybee, 2015; Lakin & Wallace, 2015; Slykhius, 2009) that suggest 5E Instructional Model is a helpful tool that impacts subjects' interpretation of how to sequence learning events to create teachable moments and incorporate inquiry.

To justify using inquiry instruction in the classroom, participants also described various affective factors (curiosity, motivation, excitement) in conjunction with cognitive and social learning outcomes. Subjects in Levels III and IV assert that inquiry-based lessons are more interactive and engaging. Also because the lessons have real-world applications, they are more meaningful and students are curious and interested in learning. Lastly, the autonomy afforded students during inquiry learning motivates them. These same subjects agree that inquiry instruction is important because it helps students develop real-world skills that will benefit them outside the classroom. For example, students develop their problem solving skills, and they learn how to discuss and collaborate respectfully.

The *NSES* (NRC, 1996; 2000) clearly envisioned students working in groups, analyzing and synthesizing data, and publicly communicating their ideas to their classmates, in part, because it is how scientists do their work. Likewise in this study, most subjects emphasized student discourse and collaboration as inherent in inquiry learning. According to their descriptions, students typically work in small groups; they collaborate to figure things out, and they share and compare ideas. Ultimately, they communicate their ideas and compare them to other students' explanations informally, per se. This is a significant and valuable finding in any science teacher education program. According to subjects' responses, students also can learn from one another sometimes more than listening to the teacher. This description of collaborative learning is closely akin to the inquiry practice of students comparing alternative conceptions. Although the *NSES* (NRC, 1996) intended to emphasize "science as argument and explanation" (p. 113), in this study, there was very little explicit attention given to the quality of evidence or to students connecting evidence to the application of relevant science knowledge.

Additionally, the idea of collaborating and sharing ideas also has value because it represents how science knowledge is created in communities of practice and critical peer review. Yet, participants failed to recognize the value of public communication as a science practice and a reason for participating in inquiry learning. Rather, they valued inquiry learning for developing students' soft skills more than for its representation of the scientific enterprise. According to Addison (L-III), "Most of the time, inquiry learning is done in groups, so it teaches students to collaborate with their peers. This is another very important life skill that will benefit them well beyond the science classroom."

Although the majority of subjects did not specify rationales that pertained to the inquiry practices per se or to learning about inquiry, a couple of subjects in each of the upper three levels of the program did. Representative responses follow:

- *If done well enough not only do the students learn the topic they also learn how to question scientific ideas and respectfully interact in discussions. They have to reason out* *the understanding for themselves and not just take the teacher or textbook at their word* (L-II: Middle)

- *Inquiry instruction allows students to see other group's solutions, which provides students opportunities to analyze various approaches to solving problems. In a small way, students mimic scientific researchers, working through the scientific process.* (L-III: Advanced)
- *Students learn how to research* (l-IV: Completer).

An interesting finding is that although these subjects described benefits that pertained specifically to helping students develop the abilities to do inquiry, interestingly, they focused on the rational aspects of inquiry with almost no emphasis on the procedural aspects of investigative practices. In fact, there were limited references to students conducting experiments, developing hypotheses, collecting data, per se, analyzing data etc. This is in contrast to the misconception literature that suggests when teachers emphasize inquiry learning it usually is in the context of the procedural components of inquiry devoid of subject matter (Bybee et al, 2005; Llewellyn, 2002; NRC, 2000; Trautman et al., 2004; Wilcox, et al., 2015).

Perhaps due more to implementation than intent, Osborne (2014) suggests the profession has overemphasized inquiry as a teaching strategy at the expense of inquiry as a learning theory about how students best learn in the classroom as a rationale for including inquiry in the science classrooms (Bybee, 2004.) This causes confusion, and teachers mistakenly think inquiry is the preferred methodology of teaching (Osborne, 2014). However, in contrast, the findings in this study suggest the prospective science teachers value inquiry instruction because it is how students learn best. At the same time, however, they failed to describe inquiry as a learning outcome such that students learn how to conduct inquiries procedurally or that students learn about the nature of science inquiry. This lack of explicit attention to the experimental component of inquiry among all the subjects is concerning because hypothesis testing is certainly an integral part of the inquiry process.

Clearly, teachers must be well informed about the distinction between teaching science the processes of inquiry (using investigative methodologies to teach about investigative processes) and using inquiry for learning and teaching (Abd-El-Khalick et al., 2004; Osborne, 2014) the concepts of science. However, in this study, multiple of the prospective teachers were unable to distinguish between inquiry specific and constructivists learning strategies; nor did they seems to realize that inquiry teaching and learning is important due to its science-like characters.

The Challenges of Inquiry Teaching and Learning

Whether stated as challenges of inquiry instruction or misconceptions about it, in the literature, teachers (preservice and experienced alike) report substantial challenges and barriers that inhibit inquiry instruction (Lotter, 2004; Roerig & Luft, 2007; Trautman et al., 2004). Likewise, in this study the preservice science teachers' also perceived substantial challenges. The most prevalent challenge reported by subjects in this study was the idea of teacher efficacy. By teacher efficacy, I refer to the prospective teachers' confidence in themselves to effectively implement inquiry in the classroom. The majority of subjects suggested they did not feel prepared to implement inquiry effectively for various reasons: Classroom management is more difficult; the lessons take a lot of time to prepare, and it is difficult to construct inquiry lessons that are meaningful to students. Furthermore, it is unsettling not knowing what students might do or ask in the course of learning activities.

Additionally, several participants cited concerns about students' learning experiences during inquiry instruction. For example, according to some respondents, some students don't do as well with inquiry as other students. For example, Kylah (L-III) said, “To some extent, not all students may respond well to all inquiry instruction projects.” Another concern was that students might not get the *right answer*. As such, inquiry could lead to more misconceptions. Also according to Stefani (L-IV), inquiry can be overwhelming, and students may become frustrated or even “paralyzed by indecision” and won’t know what to do. However, unlike the misconception literature that indicates many teachers believe inquiry is only for some students (Llewellyn, 2002; Wilcox et al., 2015), no one in this study suggested that particular groups of students (e.g. ability levels) are more or less inclined toward inquiry learning. However, they did commonly state that advanced and complex topics were both challenging and inappropriate for inquiry learning. Rather didactic methodologies were necessary to provide the right background. This finding is consistent with misconceptions literature. Also, the instructional sequence of learning activities in a unit seemed to justify or disqualify an inquiry approach. According to multiple participants, students need more structured instruction when the teacher is introducing new topics and reviewing old concepts. As such, this finding, according to my knowledge, is not prevalent in the literature.

Another misconception in the literature is that inquiry is not an efficient use of time (Llewellyn, 2002; Wilcox et al., 2015). Certainly, inquiry instruction when implemented well in the classroom will take a longer amount of time to implement. However, since students learn the concepts better, develop more in-depth understanding, and they develop higher order thinking skills, in addition to developing a greater understanding of the scientific enterprise, there is a strong argument for the contrary that inquiry learning can be an efficient use of time. However, a frequent concern stated among participants was that inquiry instruction takes increased classroom time to implement. According to various research participants, the standards require teachers to *cover* a lot of information, and often there just isn’t enough time to conduct in-depth explorations. Furthermore, because of the emphasis on testing, inquiry learning was viewed somewhat as a luxury rather than a valued way to learn science. Although multiple subjects described this challenge, *all* subjects in the middle category of subjects stated this concern. Likewise, there was a strong consensus among multiple subjects in the middle, advanced and completion levels of the program that certain topics, due to their nature, were not inquiry-worthy. For example, vocabulary, facts, easy to understand concepts, and "unimportant" topics should not be taught via inquiry instructional methods. The primary rationale provided was that it was not an efficient use of time. That said, in this case, the subjects seem to recognize that vocabulary or *easy to learn* concepts are not inquiry worthy. As such, they seem to distinguish nicely between learning through inquiry for understanding and learning for memorization.

As illustrated repeatedly in the literature (Keys & Bryan, 2001; Lotter, 2004; Trautman et al., 2004) and in this study as well, the tension between the benefits of inquiry and the realities of a classroom culture clash considerably. Enacting inquiry instruction in the classroom is difficult. Despite a changing educational focus over the years, and despite incredible resources invested to change the science classroom culture to one that embraces inquiry in the intended sense, enacting inquiry instruction still remains a daunting challenge. Reality trumps theory.

> *Teachers hold personal beliefs that inquiry promotes the scientific thinking and learning autonomy they want for their students; yet, enacting inquiry is mediated by cultural beliefs, such as transmission and efficiency. These dual belief sets cause tension for teachers who are attempting to use inquiry-based instruction.* (Keys & Bryan, 2001, p. 636).

The present study identified preservice teachers' rationales for using inquiry that are aligned with years of research. Although effective inquiry instruction in the science classroom should not perpetuate these ideas, clearly they are relevant in the lives of these subjects whether as students in their own academic preparation or as in their practice teaching experiences. The questions remain, why is inquiry worth all the trouble? Are the benefits worth the challenges?

Historically, the answer is obviously “not enough.” Rather, preservice science must see inquiry instruction as possible, efficient (Crawford, 2007), and targeted to specific learning outcomes. Preservice science teachers must have positive experiences learning science in inquiry environments, doing inquiry research, and teaching science as inquiry.

These survey questions eliciting subjects concerns and challenges about inquiry instruction also revealed certain misconceptions these preservice science teachers have about inquiry instruction. Various researchers have identified common misconceptions (or myths) about inquiry (Bybee et al., 2005; Llewellyn, 2002; NRC, 2000; Trautman et al., 2004; Wilcox, et al., 2015). Likewise, multiple subjects in this study also identified with several of these myths, particularly in their reasons for why inquiry is not appropriate. For example, the following “myths” were found in participants responses: Inquiry teaching and learning (a) can be chaotic, (b) is not [always] an efficient use of time, (c), does not promote college and career readiness, and (d) is not appropriate for advanced topics. Stated as concerns, multiple of these ideas were prevalent in participants’ responses. Several subjects also mentioned that is impossible to teach science as inquiry in every lesson. Such a statement implies a belief that maybe they think their science teacher professors might support this idea. This misconception is commonly perpetuated in the literature as well (Bybee et al., 2005; Llewellyn, 2002).

An equally relevant finding is that with limited exceptions, the subjects in this study did not perpetuate certain myths. Such myths include: (a) Inquiry learning means students discover on their own; (b) hands-on activities are considered inquiry learning, (c) experiments and laboratory activities are the only way to do inquiry. However, in contrast to the misconceptions about inquiry being pure discovery and student-led (Brown et al., 2006; Kirschner et al., 2006), in this research study, participants viewed the teacher’s role as extensive and critical to students’ learning. In all subjects' responses, teachers supplied guidance and structure to all learning events. In particular, teachers engaged students in lessons typically by providing a problem or a question that created a need for exploration and investigation that would lead to the solution or the answer. They also constantly assessed students understanding by asking probing questions to assess students' knowledge and to promote more in-depth thinking. As such, most participants in this study valued inquiry as an exploration guided by the teacher.

Also absent from their views of inquiry were the misconceptions of inquiry as hands-on activities exclusive of a content focus. Although multiple subjects suggested that inquiry involved hands-on experiences, only a couple of participants at the earliest level in the program alluded to this hands-on exploration exclusive of the minds-on component. Such an emphasis on thinking is in stark contrast to the science as process approach, which emphasizes "process skills out of context" (NRC, 1996, p. 113). Furthermore, only two participants equated inquiry with laboratory experimental processes exclusively.

Implications and Specific Recommendations for Practice in the Arkansas UTeach Programs

Osborne (2014) asserts that, "it is difficult to imagine a single lesson of science that would not raise an opportunity to highlight one of these [science practices]" (p. 595). As such, subjects in this study did a great job connecting science content and inquiry. Never in the upper three levels of the program did they separate inquiry as pedagogy from inquiry as content. This is a refreshing and optimistic finding although why subjects tended to make these connections is less understood. Clearly something good is happening.

However, if we want to promote a clearly defined understanding of inquiry instruction as intended by science education reformers, more is needed. Being able to use the 5Es (Engage, Explore, Explain, Elaborate, and Evaluate) to plan for and guide instruction is one thing. Being able to explicitly explain and describe these inquiry practice into their descriptions of effective science instruction is another thing entirely. Not being able to clearly define inquiry independently from the 5Es, and not understanding why it is a valuable instructional strategy undermines its potential effectiveness.

In the Arkanass Uteach Program there are eight courses specific to the teaching and learning of science. Evidence presented here, indicated by the congruence of participants' descriptions and explanations of *inquiry as exploration* and as *exploration before lecture*, the program does positively impact preservice teachers' thinking. However, what is lacking from these participants' descriptions of inquiry is a clearly defined definition of inquiry that explicitly connects to the inquiry practices (essential features and science and engineering practices) for reasons asserted in science education reform literature that help students abilities to do inquiry and learn about inquiry.

As such, this study's findings support Binns and Popp's (2013) conclusion that teacher education should present a more unified conception of inquiry instruction and how to identify it. Not only should prospective science teachers should be able to clearly articulate inquiry instruction and distinguish it from constructivist-based learning, but also they should be able to explain why it is important. These findings suggests that each course needs more explicit opportunities for instruction and reflection on what it means to teach science through inquiry (Crawford, 2014; Schwartz, Lederman, & Crawford, 2004), a clear definition of inquiry including its many variations, how to recognize it explicitly, and why it is a worthwhile endeavor (Binns & Popps, 2013).

Evident in subjects descriptions of inquiry was an untoward focus on rationales for using inquiry in the context of it is engaging, and students learn the concepts better (learning through inquiry). Although these statements are true, they do not reflect the essence of what learning through inquiry is all about. Borrowing from Osborne (2014): “Engaging in practice [inquiry] only has value if (a) it helps students to develop a deeper and broader understanding of what we know, how we know, and the epistemic and procedural constructs that guide its practice; (b) if it is a more effective means of developing such knowledge; and (c) it presents a more authentic picture of the endeavor that is science” (p. 587). I suggest that Osborne’s ideas could provide an organizing framework the Arkansas UTeach courses of instruction to help preservice science teachers develop in-depth understanding of the science as inquiry standards. Also, rather than promoting inquiry writ-large in the courses of instruction, I suggest specific courses be identified to target specified understandings.

In this spirit, I offer some potential suggestions for changes that could potentially impact these described learning outcomes. Certainly, however, rather than intending to be presprictive in any ways, these suggestions are intended to provoke thoughtful conversations among invested program faculty and administration regarding ways to improve these courses.

Step I and II (recruitment courses)

Because all preservice science teachers at all levels of the program described student-centered beliefs about teaching and learning science suggests the instructional focus at early levels of the program is effective and therefore should continue as it is. However, in order to help participants clearly distinguish the 5Es from inquiry per se, the findings here suggest the language change from *inquiry-based* teaching and learning to *student-centered* teaching and learning. When prospective teachers are first learning to teach science, it stands to reason they need fewer goals in order to have successful experiences. This study suggests that the terminology needs to change. If we want preservice teachers to value inquiry for its content (inquiry as a learning outcome) emphasis, more instruction is needed to make the learning contexts and rationales explicit. I agree with Minner and colleagues (2009): "One way in which this term [inquiry] should be further clarified is by distinguishing it from constructivist teaching practices, which can be applied across disciplinary boundaries, such as questioning strategies that encourage active student thinking and knowledge construction" (p. 20). This suggestion is also congruent with Hodson's assertion that learning science is different from learning to do science or learning about science. According to Hodson (2014), "Different goals demand different methods" (p. 2534).

Project-based Instruction (PBI)

There are two courses particularly conducive to incorporating specific elements of inquiry instruction: Project-based Instruction (PBI) and Research Methods (RM). The UTeach Institute (2013) explicates how the NGSS Science and Engineering Practices are integrated into these courses. (See Appendix I for matrix describing this integration.) In the PBI course, students are asked to develop and reflect upon rigorous and in-depth inquiry units that are driven by a project-based learning. Three of the course objectives follow:

- Discuss and critique the merits of project-based instruction in terms of students' cognitive development, equity, and motivation.
- Distinguish between project-based instruction and other instructional approaches.
- Decide which approach best fits instructional goals based on the benefits and limitations of each. (UTeach, 204, p. 28).

Based on the evidence presented in this research study, I offer some practical suggestions for more explicit instruction targeting the teaching science as inquiry standards.

By its very nature, PBI emphasizes a complex form of inquiry that incorporates connections to the essential features of inquiry and the inquiry continuum. However, there needs to be an explicit effort to help prospective science teachers move from the mindset that inquiry is important due to its value as an engaging and motivating pedagogy (which it is) to a pedagogy that is valuable more so for its science like nature and its ability to develop students' inquiry skills as a component of literacy. This author is unaware of any reference to the NSES inquiry continuum in any of the course documents (syllabi and supporting document). As such, I propose a subtle change at the practical level to explicitly include this into a unit of study specific to *inquiry teaching and learning* per se. The express intent, of course, is to target helping prospective science teachers define inquiry concisely, understand the multiple levels of inquiry that could exist in a given lesson (using the inquiry continuum and relevant documents as support), and understand the nature of this pedagogical strategy. Although the course already includes the overarching ideas, the suggestion here is purely a practical matter that could result in participants developing intended learning outcome specific to the teaching science as inquiry standards: "Engaging in practice [inquiry] only has value if (a) it helps students to develop a deeper and broader understanding of what we know, how we know, and the epistemic and procedural constructs that guide its practice; (b) if it is a more effective means of developing such knowledge; and (c) it presents a more authentic picture of the endeavor that is science" (Osborne, 2014, p. 587).

Research Methods (RM)

The research methods course is primarily a lab course that provides prospective science teachers the opportunities to engage in scientific inquiries as if they were scientists. According to the Instructional Program (UTeach Institute, 2014), "Research Methods simultaneously provides students specific techniques needed to address scientific questions and examples of how to provide this sort of training for students through individualized instruction" (p. 5-36). As such prospective science teachers should learn how to engage in inquiry research and learn more about how scientific knowledge develops. The following statement describes the essence of the RM course:

> *Learning about science includes both learning material that has already been established (e.g., the structure of DNA, how to find forces on blocks being pushed up a ramp, the definition of an acid) and learning how scientists gained this knowledge (e.g., how new discoveries gain authority and are adopted by the scientific community, how to evaluate scientific claims when they conflict, how to design and carry out investigations to answer new questions).* UTeach, 2014, pp. 35-36)

As such, this course provides much needed experiences for prospective science teachers who are learning to do inquiry and learn about it. However, evidence in this study suggests the prospective science teachers are not translating their learning to do research experiences into their conceptions about teaching and learning science through inquiry. The evidence behind this statement is that most subjects' descriptions of inquiry teaching and learning lacked explicit references to experiments, collecting and analyzing data- even though multiple subjects had completed this course. Additionally, multiple references to inquiry in terms of the 5Es rather than to the inquiry practices per se is further evidence.

As such, I propose the Arkansas UTeach research methods course could add explicit attention to the pedagogical implications of inquiry to classroom practices. This idea is congruent with Melville and colleagues (2013) suggestion that in order to effectively link theory to classroom practice, when science teachers engage in authentic inquiry, appropriate scaffolding will constantly relate these inquiry investigations to practical applications in the classroom. Furthermore, although there is nothing I could find in the UTeach Instructional Program (UTeach Institute 2014) that explicitly delineated the essential features of inquiry per se, it was evident that to conduct these inquiries, course participants would engage in all the essential inquiry practices (NRC, 2000; 2012) on a continuum, ultimately conducting an open inquiry. Appropriate scaffolding that makes these connections explicit will likely add more in-depth understanding about the classroom implications of inquiry instruction Melville et al., 2013).

Perspectives

In the Perspectives course, students learn about the history and nature of science, which are separate content goals distinguished from *science as inquiry* standards. Additionally, however, the Perspectives course also gives explicit attention to what is science and why is it different from other ways of knowing, which portends an explicit inquiry focus though not necessarily in a *learning through inquiry* context. Therefore, I suggest that elements of instruction might carefully delineate between the nature of inquiry and the nature of science and how these pertain to instruction specifically.

For example, having preservice science teachers evaluate three different model lessons that explicitly target a specific inquiry oriented learning outcome: (a) engaging students in inquiry, (b) learning about inquiry, (c) learning about the nature of science- all focused on the same content specific goals (e.g. Newton's Laws)- could be a productive way to help them see the subtle differences embedded within each type of lesson design. Furthermore, such an assignment could also correlate to how actual enactments of teaching in the classroom are not often representative of the intended curriculum. These ideas correlate nicely to how science knowledge also has a messy history and is sometimes misconstrued as it moves through science communities eventually making its way to the textbooks. Likewise, the inquiry standards also have a messy and difficult history. The intention of the standards movement has manifested in confusing and misapplied enactments.

In conclusion, assuming we all agree on the value of the science as inquiry standards, and assuming we all agree that future science teachers need to understand its multifaceted nature, both theoretical and practical, a rigorous examination at the course level about intended learning gains and purposes of science as inquiry is called for. Most importantly, all science methods courses and instructors should explicitly promote accurate conceptions of inquiry instruction by modeling how to implement it effectively, making it explicit what they are doing and why they are doing it. Furthermore they should help preservice science teachers learn to identify inquiry when they see it (Binns & Popp, 2013; Melville et al., 2008). As such, efforts should be made to ensure that all instructors in any teacher education course understand the practical and theoretical nature of the three aspects of inquiry in the secondary classroom. Further, there should be continuous explicit and reflective efforts to focus instruction on these aspects of inquiry in all the instructional courses. This suggests a continual action research effort by research faculty who are invested in seeing the science as inquiry standards enacted in courses of instruction.

Implications for Future Research

A limitation of this study is that is was broad and overarching across all courses of instruction. Therefore, first and foremost, consistent action research at the course level especially in the key courses of instruction described above is essential to achieve targeted learning outcomes. This suggestion is also consistent with the UTeach Instructional philosophy:

> *It is important to review UTeach courses and curriculum on an ongoing basis to ensure course alignment, minimize redundant assignments, identify gaps, and ensure compliance with state requirements and national guidelines. In addition, to maintain a leading edge in instruction, pedagogical courses often need to be updated according to current learning research.* (p. 5)

As such, I suggest these three programs, and others like them, make a concerted effort to ensure we are preparing science teachers who are prepared with the knowledge and skills that identify them as well-equipped and effective science teachers *as defined at the course level*. However, to do this means a collaborative effort is necessary on behalf of all instructional program faculty and staff. Research could continually explore how to improve the teaching and learning of science through inquiry, particularly in these courses.

Another limitation to this study is that it only considered the perspectives of the preservice science teachers. A valuable addition would have been to include the perspectives of the instructors in all the courses. Understanding their beliefs and conceptions about teaching and learning science through inquiry would have added considerable insights to help situate the preservice science teachers' perspectives. Likewise, knowing that instructors in the program have different areas of expertise (science, math, and education), exploring their different perspectives of inquiry instruction would also shed valuable light to how the prospective teachers develop their own understanding. How might the subjects' perspectives about inquiry teaching and learning differ when a math teacher expert versus a science teacher expert teaches a method's course? More research is warranted to know more about this.

Likewise, this study only pursued understanding the prospective *science* teachers' views and conceptions of inquiry. Prospective math teachers also take the same methods' courses as the science students. As such, exploring their interpretation of inquiry and comparing it to those who have more in depth science knowledge could also add valuable insights to course development and improvements.

The study conducted here involved a cross-case comparison study to explore how subjects in the program conceptualized inquiry at various levels in the program. A more valuable undertaking would be to conduct a longitudinal study to see how individual participants develop their understanding of inquiry as they move through the various courses of instruction.

Understanding their learning progressions could provide crucial information to help science teacher educators foster more effective teaching and learning opportunities to help prospective science teacher develop accurate conceptions of inquiry instruction. Subsequently, following those individuals who have accurate conceptions and who express preferences for it as a teaching strategy as they become actual classroom teachers and researching their attempts to utilize inquiry instruction or not will add to the knowledge base about why some teachers value it and others do not.

The 5E Instructional Model is widely used in curriculum materials as well as various professional development settings (science and non-science disciplines) (Bybee, et al., 2006). The present study suggests the AR Uteach program impacts preservice science teachers understanding of teaching and learning and of inquiry instruction that is correlated to the 5E Instructional Model. Continued research should pursue ways to use the 5E Model more effectively to help scaffold new teachers learning to use inquiry instruction in ways that are less complicated and ambiguous to the developing teachers. Most importantly helping prospective teachers distinguish constructivism from inquiry could be a worthwhile endeavor. Research studies exploring this idea could advance teacher education in general as well as inquiry-based instruction in science.

Constructivism as a guiding framework in a science teacher education program provides a potential opportunity to move a generation of science teachers from a strong transmissive instructional perspective to a student-centered one. As science teacher educator, I appreciate the genuine interactive and student-centered focus evident in most subjects' responses. Furthermore, I value how subjects emphasized cognitive engagement in their descriptions of student learning. As such, the limited use of one 5E Instructional Model throughout the participants learning to teach experiences could have been a significant contributor to these two very important outcomes. However, more research is warranted to know for sure. This particular study explored a bigger picture. Does the near exclusive use of one instructional model better prepare prospective science teachers for classroom teaching, or might it hinder their development and flexibility regarding their abilities to implement diverse pedagogies as classroom teachers? Future research should focus on these teachers' actual practice. Do they utilize more inquiry practices than teachers not prepared in teacher education programs that integrate content and pedagogy using limited instructional approaches? Although limited, there have been studies conducted that support its effectiveness (Duran & Duran, 2004; Taylor et al., 2007; Wilson et al., 2010) in terms of student learning gains when used as intended. Future studies are also needed to see how inquiry taught via a 5E lesson impacts students learning about inquiry versus learning about inquiry outside of the 5E context.

Lakin and Wallace conducted a study to find out if teachers' inquiry teaching preferences- using an earlier version of the POSTT called the Pedagogy of Science Inquiry Teaching Test (POSITT-F)- would correlate to their knowledge of inquiry and found a negative correlation. The authors suggested that teachers who had more knowledge about inquiry practices actually had negative attitudes toward it. Is this true in this study as well? Do these subjects in this study who express intentions and preferences to inquiry just not fully understand what it is? Although this study desired to know how these prospective teachers conceptualized inquiry instruction, there was no explicit attempt to uncover their knowledge base per se about inquiry. Understanding more about preservice science teachers' preferences for and understanding of science as inquiry is an area of research that could add to this literature base.

The results of this study suggest subjects lack understanding about the nature of science inquiry as a guiding framework for their personal instructional preferences, which is consistent with decades of research. I agree with Minner and colleagues (2009) that inquiry teaching and learning should be distinguished from constructivists' practices. Furthermore, I tend to agree with Hodson (2014), that the way inquiry is presented results in too goals for a single lesson. Perhaps, using the term *science practices* in lieu of inquiry is a start. However, these findings also suggest a need for a more explicit 5E model designed to develop prospective teachers science as inquiry awareness and purpose. Might there be a future for another instructional model perhaps conveniently labeled the "5E-I" (5Es for Inquiry) instructional model, which is specific to inquiry teaching and learning in science? Creating and using such a model could provide its users a simple reminder that teaching science as inquiry should have a specific focus and purpose unique to the teaching and learning of science. Future research could focus how using these two similar but distinct instructional models might impact preservice science teachers' knowledge of inquiry instruction.

Final Thoughts

My own thinking and learning about science as inquiry has changed tremendously since I began this study. I know I will teach differently in the future, and I will constantly evaluate my own students' (prospective science teachers) understanding about teaching and learning science content through inquiry. I have spent untold hours developing my current understanding of teaching science as inquiry, and I know I will learn more tomorrow. I feel strongly that my students will gain much from what I have learned. I am convinced that, as science teacher educators, we have to know what we are doing before we teach those who teach science. We have limited opportunities to influence future generations, but we have them. We are no different than the students we teach or the teachers they will become. Just like science teachers in the classroom, we have knowledge and insights that our students need to become more thoughtful and informed practitioners. What is the best way to teach our subject? How do we know? What is the evidence? Nothing short of seeking answers to these questions continuously is acceptable for the challenge we are called to meet. I look forward to working with my colleagues to establish a more united and well-defined understanding of what is effective teaching, and what role can a focus on inquiry-based instruction play as we continue to evaluate and improve our own teacher education program. If the intention is to make explicit the science as inquiry standards, those who model inquiry instruction in the teacher education courses must be adept and efficient utilizing such strategies; furthermore they must know and understand what inquiry is and why it is a valuable pedagogy. Finally, we must also be able to effectively help others develop these same understandings. The challenge is daunting, but as science teacher educators, we should be adept learners of our own teacher practices.

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Appendix A: An Overview of the BSCS 5E Instructional Model

Stages	What the Teacher Does	What Students Do
Engagement	• Piques students’ curiosity and interest • Determines students’ current understanding (prior knowledge) of a concept or idea • Invites students to express what they think • Invites students to raise their own questions	• Become interested in and curious about the concept/topic • Express current understanding of a concept or idea • Raise questions such as what do I already know about this? What do I want to know about this?
Exploration	• Encourages student-to-student interaction • Observes and listens to the students as they interact • Asks probing questions to redirect the students’ investigation when necessary • Asks questions to help students make sense of their experiences • Provides time for student to puzzle through problems	• “Mess around” with materials and ideas • Conduct investigations in which they observe, describe, and record data • Try different ways to answer a question • Acquire a common set of experiences so they can compare results and ideas • Compare their ideas with those of others
Explanation	• Encourages students to use their common experiences and data to develop explanations • Ask questions that help students express understanding and explanations • Requests justification (evidence) for students’ explanations • Provides time for students to compare their ideas with those of others and perhaps to revise their thinking • Introduces terminology and alternative explanations after students express their ideas	• Explain concepts and ideas in their own words • Base their explanations on evidence acquires during previous investigations • Become involved in student-to-student conversations in which they debate their ideas • Record their ideas and current understanding • Reflect on and perhaps revise their ideas • Express their ideas with what scientists know and understand
Elaboration	• Focuses students’ attention on conceptual connections between new and past experiences • Encourages students to use what they have learned to explain a new event or idea • Reinforces students’ use of scientific terms and descriptions previously introduced • Asks questions that help students draw reasonable conclusions for evidence	• Make conceptual connections between new and past experiences • Use what they have learned to explain a new object, event, organism, or idea • Use scientific terms and descriptions • Draw reasonable conclusions from evidence and data • Communicate their understanding to others

Stages	What the Teacher Does	What Students Do
Evaluation	• Observes and records as students demonstrate their understanding of concepts and performance of skills • Provides time for students to compare their ideas with those of others and perhaps to revise their thinking • Interviews students as a means of assessing their developing understanding • Encourages students to assess their own progress	• Demonstrate what they understand about the concepts and how well they can implement a thinking skill • Compare their current thinking with that of others and perhaps revise their ideas • Assess their own progress by comparing their current understanding with their prior knowledge • Ask new questions that take them deeper in a concept or topic area

Note. Adapted from *Bioinformatics and the Human Genome Project: A Curriculum Supplement for High School Biology*, BSCS, 2003, pp. 3-4. BS

Appendix B: Arkansas UTeach Curriculum Matrix

	Step 1: Inquiry Approaches to Teaching	Step 2: Inquiry Based Lesson Design	Knowing and Learning	Classroom Interactions	Project Based Instruction	Apprentice Teaching	Research Methods	Perspectives
Credit Hours	1	1	3	3	3	7	3	3
Category	**Recruitment Courses**		**College of Education Course Sequence**		**Final Practicum**		**Specially Designed Content Courses**	
Instructor	Master Teacher	Master Teacher	Science/Math Education Faculty	Science/Math Education Faculty	Science/Math Education Faculty	Master Teacher	Sciences Faculty Team	History or Philosophy Faculty
Goals	Prepare, practice, implement and reflect on 5E lessons based on well-tested activities	Prepare, practice, implement and reflect on 5E lessons aligned with district math and science curriculum	Explore the implications of learning theories on individual learning, social (classroom) learning, and within the context of larger social justice issues	Apply theoretical and practical frameworks to analyze various instructional activities, focusing on content development through teacher-student, student-student, and group interactions	Design, implement and evaluate problem- and project-based curricula and processes	Engage in an intensive, culminating experience that equips UTeach students with the tools needed for their first teaching experience	Design and carry out independent scientific inquiries employing the tools used by scientists	Explore historical perspectives that have shaped the content and direction of the sciences; apply historical content and information to K-12 educational context.
Observation Hours	2	2	NA	3	4	40	NA	NA
Teaching Hours	3	3	NA	5	10	380	NA	NA
Total Field Hours	5	5	NA	8	23	420	NA	NA
Instructional Level	Upper Elementary	Middle School	NA	High School	Middle or High School	Middle or High School	NA	NA

Note. This table represents approximate descriptions of the courses of instruction for each of the Arkansas UTeach Programs. Also, no attempt was made to ensure exact field placement hours are represented for each of the three programs. Adapted from Chapter 5: The Uteach Instructional Program, UTeach, 2014, p. 5-52

Appendix C: Demographic Survey

Dear Research Participant:

Thank you for agreeing to participate in this research study. Your responses to the questions below will be used to help the researcher better understand how preservice science teachers in this program learn to teach science. All information collected will be kept confidential to the extent allowed by law and University policy. A code number will be assigned to each survey so responses will be anonymous during the analysis process.

Please answer each of the demographic questions that follow.

Gender
- Male
- Female

Academic Classification (Estimate as close as you can):
- Freshmen (1-30 credit hours)
- Sophomore (31-60 credit hours)
- Junior (61-90 credit hours)
- Senior (91+ credit hours)
- Graduate
- Other (Please specify)

Highest degree earned:
- High school
- BA/BS
- MA/MS
- Specialist
- Doctorate
- Other (Please explain)

Teacher Education Program you are currently enrolled:
- University of Arkansas (UAteach)
- University of Arkansas at Little Rock (UALRTeach)
- University of Central Arkansas (STEMteach)
- UA MAT
- Other (Please specify)

What degree are you pursuing?
- Bachelor of Arts (BA)
- Bachelor of Science (BS)
- Master of Arts (MA)
- Master of Science (MS)
- Specialists (Please specify)

- ○ Doctorate (Ph.D. or Ed.D) (Please specify)
- ○ Undecided
- ○ Other (Please specify) : _________
- ○ None (Please explain) : _________

What is your major?

- ○ Biology
- ○ Chemistry
- ○ Earth/Space Science
- ○ Engineering
- ○ Math
- ○ Physics
- ○ Other (Please specify) : _________

What are your primary plans when you graduate?

- ○ Teach high school math
- ○ Teach high school math/science (specify science discipline): _________
- ○ Teach high school science (specify discipline): _________
- ○ Graduate school
- ○ Medical school
- ○ Research
- ○ Other (Please specify) : _________

Which grade level do you prefer to teach?

- ○ Elementary (grades K-6)
- ○ Middle Childhood (grades 4-8)
- ○ Secondary (7-12)
- ○ All levels
- ○ Other (Please specify): _________

Which of the following UTeach courses are you currently taking? (Choose all that apply.)

- ○ Step 1
- ○ Step 2
- ○ Knowing and Learning
- ○ Classroom Interactions
- ○ Problem Based Instruction
- ○ Functions, Foundations, and Models
- ○ Perspectives
- ○ Research Methods
- ○ Apprentice Teaching
- ○ None (Please explain): _________

Which of the following UTeach courses have you completed? (Choose all that apply.)

- ○ Step 1
- ○ Step 2
- ○ Knowing and Learning

- Classroom Interactions
- Problem Based Instruction
- Functions, Foundations, and Models
- Perspectives
- Research Methods
- Apprentice Teaching
- None of the above (explain)

Note. This survey was administered via Qualtrics$^{\text{TM}}$ (2015) concurrently with the POSTT$_{\text{M}}$-Biology and POSTT$_{\text{M}}$-Physics surveys.

Appendix D: POSTT$_{M}$-Biology

(This instrument has been modified from Cobern, et al., 2013)

Dear Research Participant,

Thank you for agreeing to participate in this research study. Your responses to the questions below will be used to help the researcher better understand how preservice science teachers in this program learn to teach science. All information collected will be kept confidential to the extent allowed by law and University policy. A code number will be assigned to each survey, so responses will be completely anonymous during the analysis process.

This portion of the research study is composed of classroom science teaching vignettes similar to teaching practices one can find in any classroom today. Practicing teachers contributed ideas for many of the vignettes; others are based on teacher observations, or on science curriculum standards. **There are no right or wrong answers.** Rather, the researcher wants to know *what you think* is the better way to teach these particular science topics and why. As you read each vignette, think about how you might teach science in a similar situation. Respond accordingly.

Please select the disciplinary subject area closest to your major:

- Biology
- Physics

Thinking about Biology Teaching

1. **Inheritance:** Mr. Montgomery was teaching his 10th grade students about inheritance. After introducing the topic and demonstrating how to use a Punnett square to determine genotypes and phenotypes of possible offspring, he asked students to solve a variety of application problems in small groups.

	T	**t**
T	**TT**	**Tt**
t	**Tt**	**tt**

Thinking about how you would teach, how would you end this lesson?

a. Since students would have already discussed the problems in their small groups and developed their own understanding of the topic, I would end the lesson here.

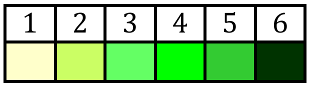
b. I would give the students the right answers to the problems.

c. I would ask students to explain their answers to the class. Drawing on their explanations, I would guide them to the correct answers.

d. I would review the correct answers to the problems with the students as a class discussion.

2. **Open Response:** Please explain WHY you chose this particular instructional strategy over the other three options. (I.e. Why is it better than another approach?) Please include any clarifying information you think will help the researcher understand your response better.

3. **Photosynthesis:** Ms. Hamid has been teaching her10th grade students about photosynthesis, and in particular that chlorophyll production in plant leaves is light induced. She sets up an example to illustrate this. She has placed fast-growing seedlings where they are exposed to different levels of light intensity. The students observe the growing plants over several days and estimate the amount of chlorophyll using a color chart to record leaf color. They record their data in their science notebooks and on a classroom data table. On the last day, Ms. Hamid reviews the role of light in chlorophyll production as illustrated by the activity.



1	2	3	4	5	6

Thinking about how you would teach this topic, of the following, which is the best evaluation of her lesson?

a. This is a good lesson design overall because Ms. Hamid begins with an explanation of the concepts she wants the students to learn followed by an activity for students to confirm that chlorophyll production is light-induced.

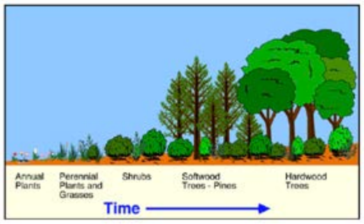
b. Ms. Hamid begins appropriately with an explanation of the concepts she wants the students to learn. This being so, it is not clear that the activity is needed, especially since it requires so much class time.

c. Ms. Hamid's approach is too pre-organized and prescriptive. It would be better for students themselves to decide how to set up plants and lights, see what happens, and figure out a way to compare chlorophyll production in the leaves.

d. The instructional sequence would be better if the students do the plant observations first, showing that chlorophyll is light-induced, after which Ms. Hamid can explain the process more fully.

4. **Open Response:** Please explain WHY you chose this particular instructional strategy over the other three options. (I.e. Why is it better than another approach?) Please include any clarifying information you think will help the researcher understand your response better.

5. **Plant Succession:** Ms. Tutt's biology class has just finished an introductory lesson on plant succession. The students now understand that succession can be initiated either by the formation of a new, unoccupied habitat (*primary succession*) or by some form of disturbance of an existing community (*secondary succession*). She is now considering the use of a follow up activity at a green space near campus and has several options.



Thinking about how you would teach, of the following, which is most similar to what you would do?

a. Provide the students with a map of the green space demarcating succession. I would then walk the students through the succession areas pointing out the plant life specific to each area.

b. Provide the students with a map of the green space demarcating succession. The students' task would be to identify the types of plant life in each succession area.

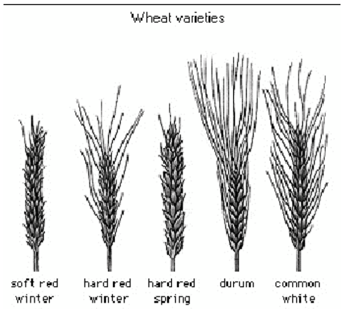
c. Ask the students if they thought they could identify succession and how they would do it. Then we would go to the green space, and the students' task would be to map out succession at the green space, developing and documenting their own maps.

d. Take the students to the green space and ask them to observe as much as they could corresponding to our recent studies on succession. I would leave it to the students' own imaginations on how best to use their observations of a real succession environment, and how to document those observations.

6. **Open Response:** Please explain WHY you chose this particular instructional strategy over the other three options. (I.e. Why is it better than another approach?) Please include any clarifying information you think will help the researcher understand your response better.

7. **Varieties of wheat:** Ms. Coker is teaching a 7th grade life science unit on edible plants. Today's topic is that wheat comes in many different varieties.

   Thinking about how you would teach, of the following, which is most similar to how you would use a transparency such as the one shown in this diagram?



a. I would give my students many types of wheat to sort by appearance. Once the task was completed, I would show the transparency and ask the students how their sorting compared with the pictures on the transparency. I would then conclude the lesson by reviewing the intended learning outcome.

b. I would give my students samples of wheat to look at. As I explained the concepts to be learned, I would have them identify the wheat samples by referring to the transparency.

c. It is important to state the intended learning outcome at the start of the lesson, so I would use the transparency as I explain the concepts to be learned, and show them an example of a wheat stalk of each kind.

d. I would not use a transparency such as this, as it would make the lesson too teacher directed. I would give my students samples of wheat to sort by characteristics of their choosing and then record their results. The lesson would conclude with a discussion of their findings.

8. **Open Response:** Please explain WHY you chose this particular instructional strategy over the other three options. (I.e. Why is it better than another approach?) Please include any clarifying information you think will help the researcher understand your response better.

9. **Classification:** Mr. Clark is introducing his 10th grade students to the classification of organisms. He provided them with pictures of 25 organisms, representing the five Kingdoms, and had students group them according to observable characteristics. The class then discussed their ideas only to discover that they had chosen different characteristics on which to group the organisms. At this point, Mr. Clark told the class that scientists eliminated confusion over the classification of living things by adopting the Linnaean system of classification as a universal standard. Mr. Clark then explained that in this system, more characteristics are used than what can be seen in a photograph, such as what an organism eats.

   Thinking of how you would teach, of the following, how would you evaluate Mr. Clark's introductory lesson?

   a. This is a good approach as it is.

   b. Instead of first having students group the pictures in their own way, which could be confusing, he should have explicitly explained the Linnaean system of classification, and then had his students apply the system to the organisms in the photographs.

   c. Instead of having students group the pictures in their own way, which could be confusing, he should have explicitly explained the Linnaean system of classification, using the photographs as examples.

   d. Rather than explaining the Linnaean system, Mr. Clark should have had his students discuss their reasoning for how they classified the organisms.

10. Optional Open Response: Is there anything more you would like to share with the researcher about your responses, or about teaching science, student learning, or about the questions in general? Please write your response in the space provided.

11. Are you willing to participate in a follow-up open-ended survey asking you to respond to 10 questions about your views and perceptions about teaching science as inquiry?

    ○ NO, I do not want to participate in a follow up survey
    ○ YES, I am willing to participate in a follow up survey. If yes please provide your name contact information below.
        ○ Name
        ○ Email
        ○ Phone Number (optional)

Thank you for participating in this research survey!

Note. This survey was administered via Qualtrics^{TM} (2015).

Appendix E: POSTT$_{M}$-Physics

(Note: This instrument has been modified from Cobern, et al., 2013)

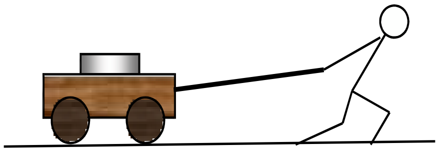
Dear Research Participant,

Thank you for agreeing to participate in this research study. Your responses to the questions below will be used to help the researcher better understand how preservice science teachers in this program learn to teach science. All information collected will be kept confidential to the extent allowed by law and University policy. A code number will be assigned to each survey, so responses will be completely anonymous during the analysis process.

This portion of the research study is composed of classroom science teaching vignettes similar to teaching practices one can find in any classroom today. Practicing teachers contributed ideas for many of the vignettes; others are based on teacher observations, or on science curriculum standards. **There are no right or wrong answers.** Rather, the researcher wants to know *what you think* is the better way to teach these particular science topics and why. As you read each vignette, think about how you might teach science in a similar situation. Respond accordingly.

Please select the disciplinary subject area closest to your major:

- Biology
- Physics



Thinking about Physics Teaching

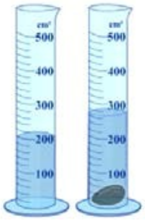
This portion of the research study is composed of classroom science teaching vignettes similar to teaching practices one can find in any classroom today. Practicing teachers contributed ideas for many of the vignettes; others are based on teacher observations, or on science curriculum standards. **There are no right or wrong answers.** Rather, the researcher wants to know *what you think* is the better way to teach these particular science topics and why. As you read each vignette, think about how you might teach science in a similar situation. Respond accordingly.

Please select the disciplinary subject area closest to your major:

- Biology
- Physics

1. **Lesson on Force and Motion:** Ms. Brandt is preparing a lesson to introduce her 9th grade students to the relationship between force and motion, namely that a net force will cause an object to speed up or slow down (Newton's 2nd Law). The classroom has available a loaded wagon to which a pulling force can be applied. Ms. Brandt is considering four different approaches to the lesson.

Thinking about how you would want to teach this lesson, of the following, which one is most similar to what you would do?



a. After raising the question of what kind of motion results from a constant force, I would then guide my students to explore the question themselves by pulling on a loaded wagon and observing what happens. From the evidence they would then propose a possible law.

b. I would write a clear statement of Newton's 2nd Law on the board and explain it carefully for my students. I would then have the students verify the law by pulling on a loaded wagon themselves and confirming what type of motion results.

c. After raising the question of whether there is any relationship between force and motion, my students would then be free to explore this safely in the lab. Afterward we would have a class discussion of their findings.

d. After writing a clear statement of Newton's 2nd Law on the board and explaining it carefully for my students, then I would demonstrate the law by pulling on a loaded wagon with a constant force in front of the class as they observe the motion.

Open Response

1. Please explain WHY you chose this particular instructional strategy over the other three options. (I.e. Why is it better than another approach?) Please include any clarifying information you think will help the researcher understand your response better.

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2. **Volume and Displacement:** Ms. Katinka is doing a lesson on density in her 7th grade classroom. Part of the lesson will involve using a graduated cylinder partially filled with water for determining the volume of small irregular objects.

   Thinking about how you would teach this lesson, of the following choices, how would you advise Ms. Katinka to structure her lesson?

   a. Ms. Katinka should open the lesson by clearly stating the learning objective: the use of displacement as a measure of volume. The teacher then asks the students what happens to the water level in the bathtub when they climb in. She tells them that this is an example of displacement and then assigns an activity using graduated cylinders where the students measure the displacement caused by various objects.

   b. Ms. Katinka should open the lesson by asking the students what happens to the water level in the bathtub when they climb in. She uses their ideas to introduce an activity using graduated cylinders where the students measure the displacement caused by various objects. Following further discussion of their observations, the teacher clarifies that the students have been measuring volume.

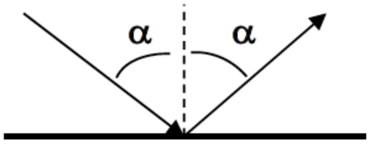
c. Ms. Katinka should open the lesson by having the students freely explore what happens when various objects are placed in the graduated cylinder. The students should first record their observations and then discuss their findings amongst themselves and with the teacher.

d. Ms. Katinka should assign an appropriate reading in a science textbook on volume and displacement.The students read in class, then the teacher shows the students how to determine the volume of an irregularly shaped object by water displacement in a graduated cylinder. The teacher then has the students find several objects around the room to test on their own using the displacement method.

Open Response

3. Please explain WHY you chose this particular instructional strategy over the other three options. (I.e. Why is it better than another approach?) Please include any clarifying information you think will help the researcher understand your response better.

4. **Light Reflection:** Mrs. Baker is teaching her students the Law of Reflection: When a ray of light strikes a mirrored surface, it leaves at the same angle as when it arrived. Ms. Baker has to decide how she will teach the lesson.



Thinking about your own teaching, of the following, which is most similar to how you would teach the lesson?

a. I would write the law of reflection on the board and illustrate with a diagram. Next I'd show them a real example, using a light ray source, mirror, and protractor. Then we would discuss any questions the students might have.

b. I would first pose a question about reflection for the students to explore. The students could investigate using light ray sources, mirrors, and protractors, and then discuss their findings. I would close the lesson by giving them a summary of the law of reflection.

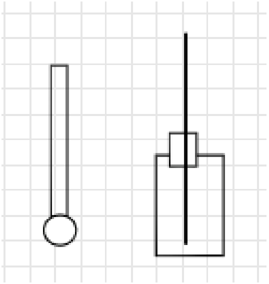
c. I would ask students to find out what they can about light behavior around mirrors by exploring on their own with an assortment of available items, including light ray sources, mirrors, and protractors. Then the students would report back on what they did and what they found out.

d. I would write the law of reflection on the board and illustrate with a diagram. Then I'd have the students verify the law using light ray sources, mirrors, and protractors. We would then discuss their findings.

Open Response

5. Please explain WHY you chose this particular instructional strategy over the other three options. (I.e. Why is it better than another approach?) Please include any clarifying information you think will help the researcher understand your response better.

6. **Thermometers and how they work:** Mr. Dole is developing a science lesson for his students, in which he would like them to acquire an understanding of thermometers and how they work. He has real thermometers available. He also has materials that students could use to assemble their own basic thermometers (small bottle as bulb, cork with hole, straws and colored water). Mr. Dole considers four different ideas about how to structure and teach the lesson.

   Thinking about how you would teach, which one of the following is most similar to the approach you would take?

   a. Start by telling the class that today they will discover something for themselves. Each group will have a bottle, cork, straw and colored water, plus containers of hot and cold water. Show them how to assemble the materials but give no further guidance. They can explore as they wish and come up with ideas, which they can then report to the class.

   b. Start by telling students that today they will make a mystery device, see how it behaves and then try to conclude what it might be used for. Then show the students how to put their materials together, and have them explore what happens to the water column in the straw when they put the bulb in cold and hot water. Ask them to suggest what they have 'invented' and what it can be used for. Finally wrap up with a discussion of thermometers and how they work.

   c. Ask the class what they know about thermometers. List student responses on the board, and then working from some of their ideas, draw a thermometer and explain how it works. Then have students use thermometers at their tables, measuring the temperatures of cold and hot water.

   d. Write the lesson title 'Thermometers' on the board and draw a thermometer diagram. Then explain how a thermometer works and answer student questions. Conclude by placing a real thermometer in cold and hot water and showing students how the thermometer reading changes.

Open Response

7. Please explain WHY you chose this particular instructional strategy over the other three options. (I.e. Why is it better than another approach?) Please include any clarifying information you think will help the researcher understand your response better.

8. Optional Open Response: Is there anything more you would like to share with the researcher about your responses, or about teaching science, student learning, or about the questions in general? Please write your response in the space provided.

9. Are you willing to participate in a follow-up open-ended survey asking you to respond to 10 questions about your views and perceptions about teaching science as inquiry?

    - ○ NO, I do not want to participate in a follow up survey
    - ○ YES, I am willing to participate in a follow up survey. If yes please provide your name contact information below.
        - ○ Name
        - ○ Email
        - ○ Phone Number (optional)

Thank you for participating in this research survey!

Note. This survey was administered via Qualtrics^{TM} (2015).

Appendix F: Open-Ended Survey

Dear Research Participant,

Thank you for agreeing to participate in this research study. Your responses to the questions below will be used to help the researcher better understand how preservice science teachers in this program learn to teach science. All information collected will be kept confidential to the extent allowed by law and University policy. A code number will be assigned to each survey so responses will be anonymous during the analysis process.

At the completion of this survey, you will be asked if you are willing to participate in a follow up survey and/or a face-to-face interview with the researcher (approx. 30 min) at your convenience. Your decision to participate in a follow-up survey and/or an interview is completely voluntary. Agreeing or refusing to participate will result in absolutely no consequences that could be construed as either beneficial or negative to participants.

Please answer the questions below completely and to the best of your ability.

1. What do you see as the most important goal(s) for teaching science in the secondary classroom? Please describe and elaborate to ensure clarity for the researcher.

2. (a) How do you define and describe effective science instruction? (b) In your opinion, what is the best measure of effective instruction? Please elaborate and provide details and/or examples to ensure clarity for the researcher.

3. How do you know/recognize when students are learning in the science classroom? Please elaborate and provide details and/or examples to ensure clarity for the researcher.

4. Please describe a particular course or an event in your current and/or your previous learning experiences that has helped you to understand more about what effective science teaching looks like in the science classroom.

5. Describe some teaching methods effective science teachers use regularly in the science classroom, and explain what makes them effective? Please describe and elaborate to ensure clarity for the researcher.

6. Since you have been in this program, you have had some teaching experiences in the classroom. (a) Describe one successful teaching event and elaborate upon its effectiveness. (b) What was your primary role in the teaching experience, and (c) what was the role of the students? (c) How did the students respond to your lesson?

7. In this teacher education program, you are leaning about how to teach science using inquiry methods of instruction. Please define and describe *inquiry instruction,* as best you understand it.

8. In your view, identify and describe any specific teaching practices that account for inquiry instruction? (There are many possible responses to this question.)

9. What are your views of *inquiry instruction* (benefits, challenges, concerns, questions and etc. you may have about using inquiry instruction in the science classroom)?

10. (a) Why should (or should not) science teachers utilize inquiry instruction in the science classroom? (b) What percentage of the time do you think inquiry instruction should be used in the science classroom? (As a frame of reference, consider one 45-50 minute class period 20% of instructional time.) Please explain the rationale behind your response.

Please check the appropriate box below to indicate you willingness to participate in a follow-up face-to face interview with the researcher. Your participation will allow the researcher to review your responses to the questions and pose follow-up questions to help clarify her understanding.

○ Yes, I am willing to participate in a face-to-face interview with the researcher, understanding it should take no more than 1 hour of my time. Participation is completely voluntary and will result in no penalties or benefits. My contact information follows:

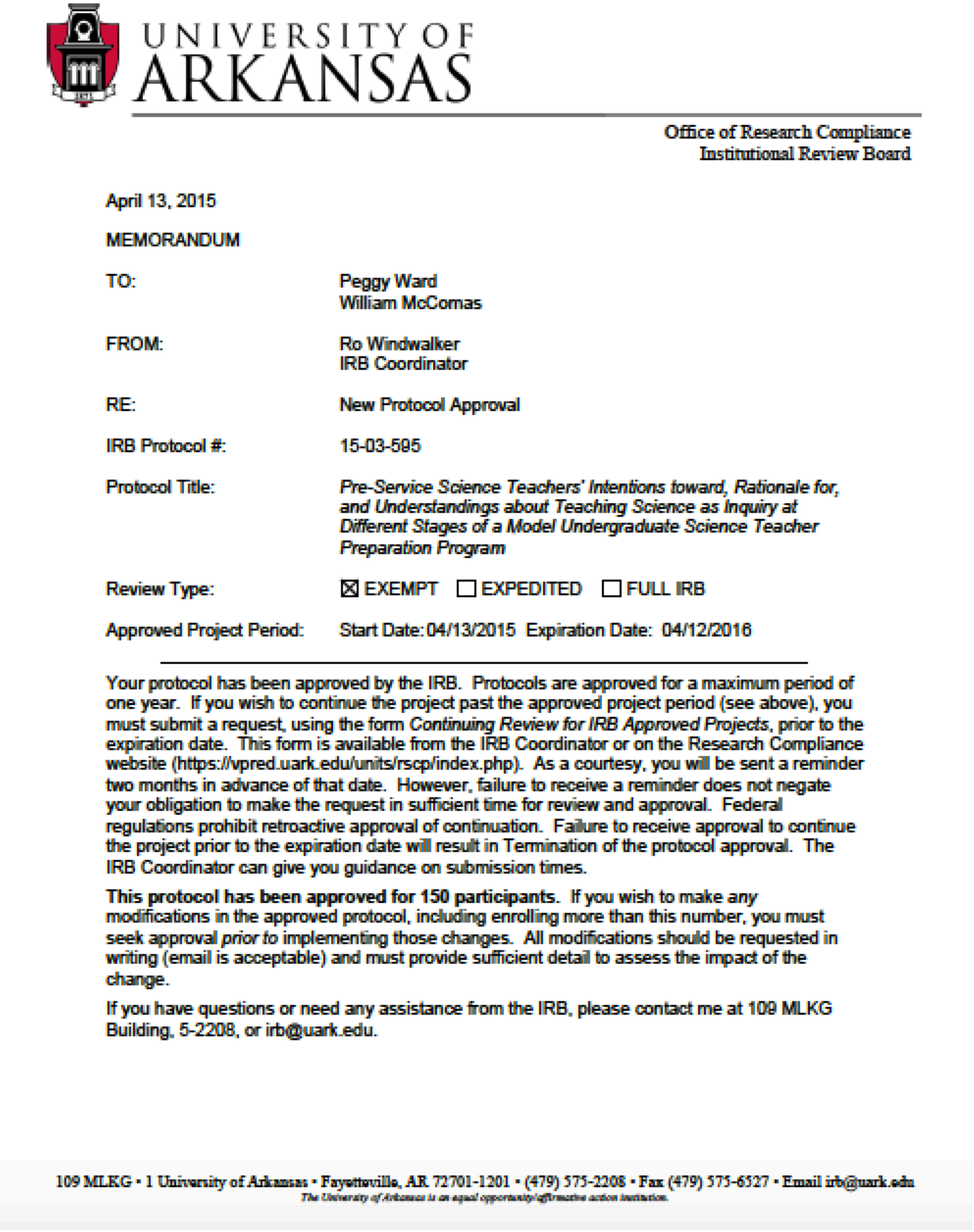
Name:
Email:
Phone Number:

○ No, I am not willing to participate in a follow-up interview with the researcher. Non-participation is completely voluntary and will result in no penalties or benefits.

Thank you for your participation in this research study!

Note. This survey was administered via Qualtrics^{TM} (2015).

Appendix G: IRB Protocol Approval Letter: UA-F



UNIVERSITY OF
ARKANSAS

Office of Research Compliance
Institutional Review Board

April 13, 2015

MEMORANDUM

TO:	Peggy Ward William McComas
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	15-03-595
Protocol Title:	*Pre-Service Science Teachers' Intentions toward, Rationale for, and Understandings about Teaching Science as Inquiry at Different Stages of a Model Undergraduate Science Teacher Preparation Program*
Review Type:	☒ EXEMPT ☐ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 04/13/2015 Expiration Date: 04/12/2016

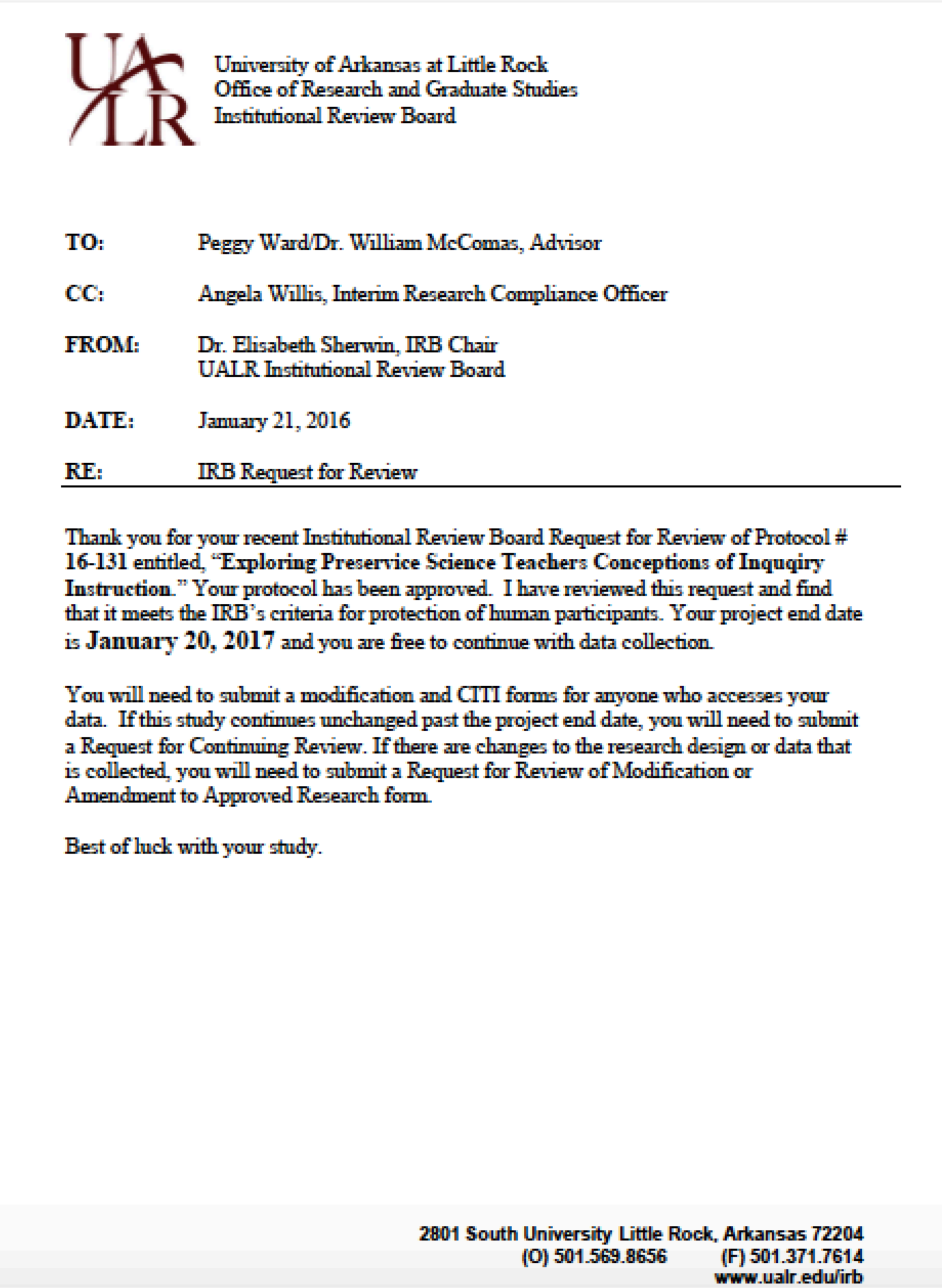
Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (https://vpred.uark.edu/units/rscp/index.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 150 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or irb@uark.edu.

109 MLKG • 1 University of Arkansas • Fayetteville, AR 72701-1201 • (479) 575-2208 • Fax (479) 575-6527 • Email irb@uark.edu
The University of Arkansas is an equal opportunity/affirmative action institution.

Appendix H: IRB Protocol Approval Letter: UA-LR



University of Arkansas at Little Rock
Office of Research and Graduate Studies
Institutional Review Board

TO: Peggy Ward/Dr. William McComas, Advisor

CC: Angela Willis, Interim Research Compliance Officer

FROM: Dr. Elisabeth Sherwin, IRB Chair
UALR Institutional Review Board

DATE: January 21, 2016

RE: IRB Request for Review

Thank you for your recent Institutional Review Board Request for Review of Protocol # **16-131** entitled, "**Exploring Preservice Science Teachers Conceptions of Inquqiry Instruction.**" Your protocol has been approved. I have reviewed this request and find that it meets the IRB's criteria for protection of human participants. Your project end date is **January 20, 2017** and you are free to continue with data collection.

You will need to submit a modification and CITI forms for anyone who accesses your data. If this study continues unchanged past the project end date, you will need to submit a Request for Continuing Review. If there are changes to the research design or data that is collected, you will need to submit a Request for Review of Modification or Amendment to Approved Research form.

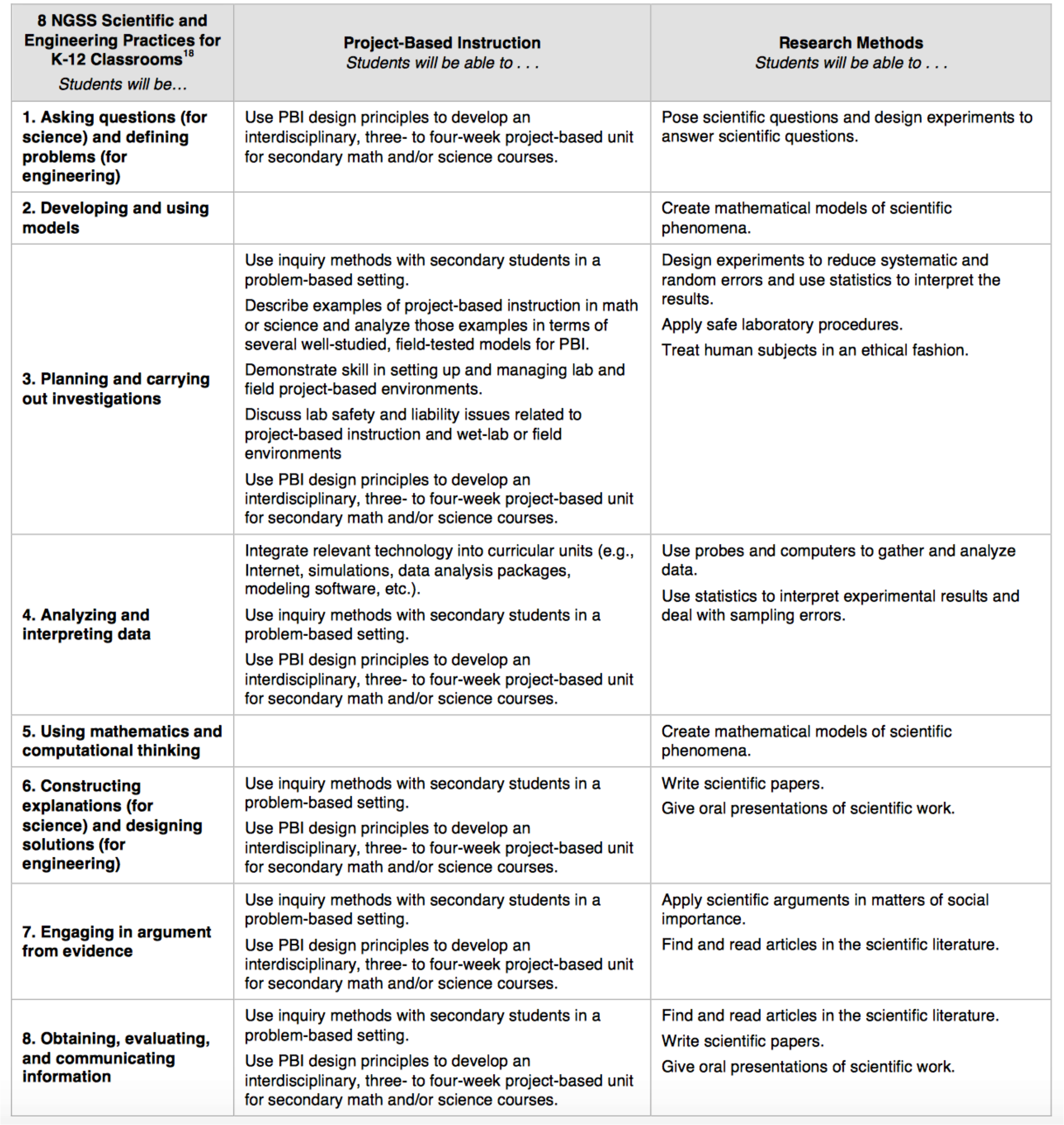
Best of luck with your study.

2801 South University Little Rock, Arkansas 72204
(O) 501.569.8656 (F) 501.371.7614
www.ualr.edu/irb

Appendix I: How Two UTeach Courses Address the Science and Engineering Practices

Table AI

A Matrix Depicting how two UTeach Courses—Project-Based Instruction and Research Methods—Address the Eight Scientific and Engineering Practices Outlined In the NGSS



8 NGSS Scientific and Engineering Practices for K-12 Classrooms[18] *Students will be…*	**Project-Based Instruction** *Students will be able to . . .*	**Research Methods** *Students will be able to . . .*
1. Asking questions (for science) and defining problems (for engineering)	Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Pose scientific questions and design experiments to answer scientific questions.
2. Developing and using models		Create mathematical models of scientific phenomena.
3. Planning and carrying out investigations	Use inquiry methods with secondary students in a problem-based setting. Describe examples of project-based instruction in math or science and analyze those examples in terms of several well-studied, field-tested models for PBI. Demonstrate skill in setting up and managing lab and field project-based environments. Discuss lab safety and liability issues related to project-based instruction and wet-lab or field environments Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Design experiments to reduce systematic and random errors and use statistics to interpret the results. Apply safe laboratory procedures. Treat human subjects in an ethical fashion.
4. Analyzing and interpreting data	Integrate relevant technology into curricular units (e.g., Internet, simulations, data analysis packages, modeling software, etc.). Use inquiry methods with secondary students in a problem-based setting. Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Use probes and computers to gather and analyze data. Use statistics to interpret experimental results and deal with sampling errors.
5. Using mathematics and computational thinking		Create mathematical models of scientific phenomena.
6. Constructing explanations (for science) and designing solutions (for engineering)	Use inquiry methods with secondary students in a problem-based setting. Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Write scientific papers. Give oral presentations of scientific work.
7. Engaging in argument from evidence	Use inquiry methods with secondary students in a problem-based setting. Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Apply scientific arguments in matters of social importance. Find and read articles in the scientific literature.
8. Obtaining, evaluating, and communicating information	Use inquiry methods with secondary students in a problem-based setting. Use PBI design principles to develop an interdisciplinary, three- to four-week project-based unit for secondary math and/or science courses.	Find and read articles in the scientific literature. Write scientific papers. Give oral presentations of scientific work.

Note. From *The UTeach Secondary STEM Teacher Preparation Model and Current Standards Reform Initiatives,* UTeach, 2013, p. 12.