Analysis of TPA Task 2: Instructing and Engaging Students

What Evidence Does the Teacher Performance Assessment Reveal about Science Education Teacher Candidates' Understanding of Inquiry-based Instruction?

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Dedication

This dissertation is dedicated to my patient and loving husband, Mark,

our two wonderful children, Madeline and Connor,

and to all of the science teachers in the 2010-2011 cohort.

Abstract

In secondary science, the 2011 Teacher Performance Assessment (TPA) was designed to represent a teacher candidate's ability to both apply their understanding of their science content knowledge and pedagogical content knowledge, and to allow the candidates to reflect on student learning. Specifically, Task 2 of the TPA requires teacher candidates to observe their students in action, and to reflect upon both the levels and types of student engagement present in their video.

Inquiry-based instruction is a key component of educational reform in science. While scientific inquiry may be difficult for teacher candidates, this video-based commentary provides the opportunity for them to focus on developing an inquiry-based learning environment in their classroom. During the pilot year of the TPA, findings in this study revealed that teacher candidates' scores on the TPA were directly related to their ability to hear, understand, and evaluate the content of student conversations. Most candidates had appropriate views of inquiry-based instruction, and revealed strong reflective practice in both their written commentary and their reflective journal postings. However, the teacher candidates struggled to implement inquiry in meaningful ways, and to capture good evidence of inquiry-based instruction and student engagement for the TPA Task 2. Cross case analysis considered six teacher candidates' TPA scores, reflective journal postings, and semi-structured interviews. Four of the six candidates who were interviewed passed the TPA Task 2, and revealed rich descriptions of inquiry in their commentary, reflective journals and interviews, including all five essential features of inquiry. The two low-

scoring candidates, however, had vague descriptions of inquiry, and left out one or more essential feature of inquiry. Additionally, one candidate maintained misunderstandings in their interview.

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Chapter I: Introduction

Rationale

Inquiry-based instruction is a key component of educational reform in science. National and state standards equally emphasize a need for teachers to learn and apply the five essential features of inquiry. When students are engaged in scientifically-oriented questions, they are asked to give evidence when responding, and they articulate explanations from their evidence; connect these explanations to science content; and communicate and justify their explanations (National Research Council [NRC], 2000). These essential features are supported by the many discussions among educational researchers, and also by philosophers of science (Lederman, 1992; McComas & Olson, 1998; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). These features also promote scientific literacy (American Association for the Advancement of Science [AAAS], 1993; Fogleman, McNeill, & Krajcik, 2011; NRC, 1996).

Multiple studies have reported on professional development programs designed to promote inquiry-based instruction in order to encourage teachers to move from traditional classroom instruction to other methods including student-driven inquiry activities. Many of these studies, however, have found that even practicing teachers continue to struggle with implementing inquiry-based instruction, even after professional development interventions (Fogleman et al., 2011; Kimble, Yager, & Yager, 2006; Lotter, Harwood, & Bonner, 2006; Wee, Shepardson, Fast, & Harbor, 2007). Scientific inquiry proves to be difficult to implement not only for experienced in-service teachers, but also for preservice teachers (Melville, Fazio, Bartley, & Jones, 2008; Windschitl, 2004; Windschitl, 2002) and beginning teachers (Eick & Reed 2002; Keys & Bryan 2001; Lustick, 2009; Roehrig & Luft, 2004; Roth, McGinn, & Bowen, 1998; Simmons et al., 1999).

Since The National Commission on Excellence in Education published *A Nation at Risk* in 1983, our country's educational system has been under close scrutiny. Traditional measures of the conferring of licensure to preservice teachers are in question (Darling-Hammond, 1997; National Commission on Excellence in Education, 1983; National Commission on Teaching & America's Future, 1996). In 1994, the National Commission on Teaching & America's Future (NCTAF) was founded to "provide an action agenda for meeting America's educational challenges" and "develop policies and practices aimed at ensuring powerful teaching and learning in all communities as America's schools and children enter the 21st century" (NCTAF, 1996, p. 4). The five recommendations by the commission point to fundamental flaws in the system of teacher preparation. The recommendations included: "get serious about standards for both students and teachers"; "reinvent teacher preparation and professional development"; "fix teacher recruitment"; "encourage and reward teacher knowledge and skill"; and "create schools that are organized for student and teacher success" (NCTAF, 1996, p. 11). The focus on "reinventing" and "fixing" teacher education were at the heart of their report, which not only opened the door for continued efforts of improvement, but also for increased accountability in teacher education programs across the country.

The main thrust behind re-conceptualizing current licensure requirements is the idea that better teachers equate to better teaching, and that better teaching leads to better student learning. Ultimately, the driver for national and state educational reforms, including assessment of preservice teachers, comes down to improving achievement for all students. A significant national trend in preservice teacher education includes the wide adoption of the Teacher Performance Assessment (TPA), endorsed by the partnership between the American Association of Colleges for Teacher Education (AACTE) and the Council of Chief School Officers (CCSSO). The TPA is designed to be an authentic assessment which evaluates a teacher candidate through four tasks: 1) lesson planning, 2) instructing and engaging students, 3) student learning through assessment, and 4) an overall reflection on three to five days of teaching. The TPA in secondary science is designed to reveal the teacher candidate's (TC's) ability to apply their understanding of both their science content knowledge and pedagogical content knowledge with a focus on inquiry-based instruction, as well as assess the candidates' ability to reflect on student learning.

Research has shown that authentic assessments similar to the TPA have been associated with successful teaching (Bransford, Brown, & Cocking, 1999; Darling-Hammond, 1998; Pecheone & Chung, 2006; Shulman, 1987). With these results in mind, policymakers and teacher educators have proposed the TPA as the new mandated high-stakes assessment for preservice teachers or TCs to complete for licensure.

Statement of the Problem

Given that national science education reforms (AAAS, 1993; NRC, 1996) propose science teachers should implement scientific inquiry in their classrooms, authentic teacher performance assessments such as the TPA should measure a TC's understanding of scientific inquiry and their implementation of inquiry-based instruction. Thus, while the TPA's authentic tasks are meant for both student teacher evaluations as well as teacher education program evaluations, the focus of this study is on teacher candidates—and, more specifically, on what the TPA Task 2 reveals about science education teacher candidates' understanding of inquiry-based instruction. An attempt to better understand how to implement the TPA at the institutional level may assist other teacher education programs prepare to implement these assessments.

Research Questions

The following research questions frame and guide this study of secondary science TPA:

1. What does the Teacher Performance Assessment reveal about science education teacher candidates' understanding of inquiry-based instruction?
2. How do the candidates represent their knowledge of inquiry in their reflections?

Overview of the Following Chapters

In this dissertation, the following chapters are structured to reveal the knowledge of inquiry-based instruction of six secondary science education teacher candidates during the TPA pilot year. Chapter II is a literature review of teachers' reflective practice, as well as a review of the relevant practical and theoretical underpinnings of scientific inquiry in secondary science classrooms. Chapter II will also provide the context of placing reflective practice, and the practice of inquiry-based instruction, into the Teacher Performance Assessment.

Chapter III will describe the research design and methodology for this multiple case study. This study occurred in two phases: phase one and phase two data collection and qualitative data analysis will be explained, including the cross case analysis of the interviewed candidates. In addition, the context of the initial licensure program in which the teacher candidates were enrolled will be portrayed. Lastly, the researcher background and trustworthiness of this qualitative case study analysis will be elaborated.

Chapter IV is divided into two parts. In the first part, phase one represents the data collected from the 26 teacher candidates' scores on the TPA Task 2, and the four themes that arose out of the data. In phase two, the case study narratives are presented for each of the six teacher candidates who were interviewed and the enhanced themes that became prevalent as a result of the interviews. Case narratives were constructed using the candidates TPA scores, commentary and video clips, their reflective journal postings throughout their ten-months in the initial licensure program, and the semi-structured interview conducted after they had received their teaching licensure in science. Each narrative draws from the candidate's written and verbal reflections on inquiry-based instruction.

Chapter V is framed by the two research questions in this study. Each case is analyzed and described in depth for each research question, and is then followed by a cross case analysis of the six cases. The intent is to draw out what the TPA reveals of a teacher candidates understanding of inquiry-based instruction and how they represent their understanding in written and verbal reflections on their teaching practice.

Finally, Chapter VI is a summary of this multiple case study and the future implications for preservice teacher education, including conclusions on the implementation of the TPA in the pilot year and beyond for science teacher educators.

Chapter II: Review of the Literature

This study is framed by the concepts of reflective practice and scientific inquiry. What follows is a review of the relevant literature of a teacher's reflective practice, as well as the practical and theoretical underpinnings of scientific inquiry in secondary science classrooms. This chapter will also provide the context of placing reflective practice and the practice of inquiry-based instruction into that of the Teacher Performance Assessment.

Schön's Reflective Practice

Schön's (1987) theory of reflective practice combines the theoretical understandings of a profession as determined by research and the artistry required to make decisions during the day-to-day practice of one's profession. While his book does not focus exclusively on teachers and teaching, there are two aspects of reflective practice that can be applied to teaching: namely, reflection-on-action and reflection-in-action (Schön, 1987). Reflection-on-action occurs after a teacher has completed instruction, and it pertains to the type of reflection TCs do when reviewing video footage of their teaching. Reflection-in-action occurs during a teaching event, and it represents the type of growth TCs could reveal in written commentary when prompted to reflect on changes they made in their instructional plans.

Schön also described the power of the practicum experience of professional preparation, which could be applied to student teaching:

> When someone learns a practice, he is initiated into the traditions of a community of practitioners and the practice world they inhabit. He learns their

> conventions, constraints, languages, and appreciative systems, their repertoire of exemplars, systematic knowledge, and patterns of knowing-in-action. (1987, p. 36-37)

The use of video clips and written commentary for the assessments' second task affords teacher candidates a highly structured opportunity to reflect-on-action using the language and conventions of science educators. For instance, the first prompt states the following: "In the instruction seen in the clips, describe strategies you used to engage students intellectually while collecting, analyzing, and interpreting data from a scientific inquiry" (Stanford Center for Assessment, Learning, and Equity [SCALE], 2011, p. 14). Engaging students, describing strategies and scientific inquiry are all parts of a science educator's repertoire. The TPA requires TCs utilize Schön's reflective practice when completing each of the assessment tasks. In the TPA's second task, the TCs were asked to reflect on video clips of their teaching. This study will look at what is revealed by a TC's reflective practice on their understanding of inquiry-based instruction in the analysis of their teaching.

Scientific Inquiry

The second theoretical framework that organizes this study is the collaborative and iterative nature of scientific inquiry. Teachers, educators and scientists have described inquiry-based instruction in a number of different ways. Many of these descriptions have aspects of constructivism embedded within them. Educators are encouraged to teach about scientific inquiry as practiced by scientists, as well as to teach through inquiry-based instructional methods. Two examples of pedagogical approaches for teaching through inquiry include; the three-stage learning cycle model of explore, concept introduction and concept application (Karplus & Butts, 1977) and the Biological Sciences Curriculum Study's (BSCS) 5E instructional model (BSCS, 2006). The 5E model includes five overlapping stages for teaching and learning through inquiry: engagement, exploration, explanation, elaboration and evaluation.

For this study, the following definition of inquiry-based instruction from the National Science Education Standards was utilized:

> 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. (NRC, 1996, p. 23)

Scientific inquiry includes:

> making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. Students will engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world, but they also should develop the capacity to conduct complete inquiries. (NRC, 1996, p. 23)

Inquiry-based instruction includes the five essential features listed by the NRC: where students are engaged in scientifically-oriented questions, they are asked to give evidence when responding; they articulate explanations from their evidence; they connect these explanations to science content; and they communicate and justify their explanations (NRC, 2000).

Inquiry-based instruction is not a single scientific method; rather, it exists along a continuum ranging from more teacher-centered activities to more student-centered activities (NRC, 2000). This framework for pedagogical practice can pervade more than just hands-on scientific laboratory activities. In fact, inquiry-based instruction can involve a wide array of activities including modeling, library research, classroom discussions, problem solving, and thought experiments (Lotter et al., 2009; Lustick, 2009; Martin-Hansen, 2002; Windschitl, 2004). The NRC (2000) also included a chart revealing the five variations of inquiry-based instruction ranging from more teacher-directed inquiry to more student-directed inquiry (see Table 2.1). Inquiry-based instruction requires that educators move away from a teacher-centered style of delivering scientific content through lectures to one that is student-centered, where concepts are framed and reinforced by the teacher, but understanding and knowledge is generated and negotiated by students.

Table 2.1
Essential Features of Classroom Inquiry and their Variations.
***Inquiry and the National Science Education Standards* by the National Academy of Sciences (NRC 2000, p. 29).**

Essential Feature	**Variations**			
1. 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 source
2. 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
3. Learner formulates explanations from evidence	Learner formulates explanations 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
4. 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	
5. 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 sharpen communication	Learner given steps and procedures for communication

More ---------------------------------------Amount of Learner Self-Direction --Less

Less ------------------------------ Amount of Direction from Teacher or Material --------------------------------- More

Gooding and Metz (2012) recommend that the desired level of inquiry-based instruction is one where the teacher poses the problem, then provides the students opportunities to plan and carry out the rest of the inquiry activity. The opportunities include the design and perform laboratory procedures, as well as supply justifications, for the evidence they collect and connect their findings to further instruction.

This inquiry framework for teaching and learning claims to be effective at increasing students' understanding of science concepts, achievement, and motivation in science classes (AAAS, 1993, Minnesota Department of Education, 2009; NRC, 1996). This claim is supported by three studies that will be elaborated upon. One ambitious study called STeLLA (Science Teachers Learning from Lesson Analysis) offered professional development to elementary science teachers during a year-long program with the goal of improving teaching practices and student learning. The study found that not only did the teachers increase their use of constructivist and inquiry-based practices in their classrooms, but student learning improved more than expected (Roth, Garnier, Chen, Lemmens, Schille & Wickler, 2011). A second study looked specifically at formative assessment of students during inquiry activities. The teachers who completed more in-depth formative assessment using a complete cycle of eliciting student responses, recognizing those responses, and using this information to promote student learning, had students with higher performances on assessment (Ruiz-Primo & Furtak, 2006). A third study found that "teachers who had previously taught the inquiry-oriented curriculum had greater student gains. For activity structure, students who completed investigations themselves had greater learning gains compared to students in classrooms who observed their teacher completing the investigations as demonstrations" (Fogelman, McNeill, & Krajcik, 2011, p. 149). Inquiry-based instruction provides students with the methodology of scientific inquiry that leads to scientific literacy, critical thinking and problem-solving skills (Fogleman, McNeill, & Krajcik, 2011; NRC, 1996).

Implicit in these two frameworks is the process of teacher development. There is limited research on science teacher candidates' capacity to implement inquiry-based instruction. Due to their proximity to their licensure programs, however, the research on beginning teachers' implementation of inquiry will also be considered in the following section. What follows is a description of some of the education research on teachers (preservice and in-service) regarding the implementation of inquiry-based instruction, the current research on TPAs, and the use of video footage of teaching events to assist in self-reflection and professional growth.

Inquiry-Based Instruction and Teacher Candidates

Educational research has shown that teacher candidates often struggle to teach student-centered inquiry-based lessons (Lustick, 2009; Melville, Fazio, Bartley & Jones, 2008; Windschitl, 2004). Lustick (2009) described in detail his failure as a methods instructor to prepare his TCs to successfully implement inquiry lessons. His TCs described inquiry as a "time consuming activity", and "an inefficient way of teaching science." The result was that students described having a "growing animosity towards inquiry" (p. 591). He posited a threefold cause of this unease:

> First, new teachers struggle with classroom management, assessment practices, and the administrative demands associated with 120 individual learners. Second, teachers experience a pervasive and powerful pressure to prepare students for the state science exam at the end of the year…Finally, the scope and sequence of mandated curriculum is so dense, teachers see little opportunity to realistically explore any one topic in depth. Students are expected to learn about such a wide array of content objectives, that teachers feel a need to 'cover' material rather than 'uncover' knowledge. Such an approach to science education does not foster opportunities for open-ended inquiry with learners. (Lustick, 2009, p. 597)

Windschitl (2004) also described his failed efforts as a science education methods instructor. His TCs were prompted to describe their experiences with scientific inquiry prior to the methods course. During the course, the TCs completed an inquiry project over an eight-week period. While there were some candidates with various prior experiences, (i.e. years of working in a laboratory, having experienced inquiry in college courses, or no prior experience with inquiry) most of the students were not able to describe an understanding of all five essential features of inquiry. "Absent almost entirely from participants' accounts was talk about claims being supported by argument, consideration of alternative explanations for results, and the kind of discourse generally related to the epistemological bases of inquiry" (Windschitl, 2004, p. 491). He summarized that the TC-led inquiry projects were not enough to convince the TCs to implement inquiry in their student teaching classrooms.

In his case, the TCs who did implement inquiry lessons were not necessarily the ones who reflected more deeply about their projects or could state the evidence for the best-practices of inquiry-based instruction: "…rather, they were individuals who had significant undergraduate or career experiences with authentic science research" (Windschitl, 2004, p. 484).

Melville, Fazio, Bartley and Jones (2008) found that teacher candidates who had extensive experiences with scientific inquiry prior to their teacher preparation programs were more likely to use inquiry-based instruction in their classrooms. The candidates perceived different challenges to implementation than teacher candidates with limited inquiry experiences. They stated:

> Preservice teachers with extensive inquiry experiences view implementation challenges in terms of teaching and student learning…this contrasts starkly with the perceptions of preservice teachers with limited inquiry experience. For this cohort, the main concerns relate to time, the curriculum, and materials. (Melville, Fazio, Bartley, & Jones, 2008, p. 490)

The teacher candidates with limited inquiry experience also perceived more negative reactions from students and other stakeholders in the school and community. Their analysis indicated that teacher candidates, "with this content knowledge were empowered by the C&I courses to move beyond the immediate demands of teaching and onto consideration of the most appropriate teaching and learning strategies for students" (Melville, Fazio, Bartley & Jones, 2008, p. 491).

In addition to experience and exposure to inquiry, TCs successful implementation of inquiry-based instruction often hinges on a supportive cooperating teacher who provides the TCs with the materials, the space, and the freedom to implement it (Crawford, 1999). While the context of the student teaching placement is beyond the scope of this study for all candidates, it was considered in the cases, and proves to be an important consideration for teachers with limited inquiry experience.

Inquiry-Based Instruction and Beginning Teachers

As stated above, there is limited research on science teacher candidates' capacity to implement inquiry-based instruction. Therefore, a brief analysis of three studies on inquiry-based instruction in beginning science teachers' classrooms will be considered next. Simmons et al. (1999), in a very large study including nine university research sites, described five teacher cases. They followed these beginning teachers for three years after leaving their institutions rich in inquiry-based teaching strategies. They learned that these teachers moved from a more student-centered inquiry-based classroom as learned in their methods courses to one that was more teacher-centered over three years' time. Simmons et al (1999) stated, "It is evident from the data reported in this study that changing the actions of teacher, especially toward the use of more inquiry-oriented teaching approaches is more complex than originally thought" (p. 948).

In their study of beginning secondary science teachers, Luft, Roehrig and Patterson (2003) examined the impact of different induction programs. The teachers received one of three different programs of induction after their teacher preparation programs. The first program offered subject specific support for the beginning teachers; the second program offered general support, and the third group had no formal support. They learned that "the secondary science teachers in science-focused support program implemented more student-centered inquiry lessons, held beliefs aligned with student-centered practices, and felt fewer constraints in their teaching than did the other two groups of teachers" (Luft, Roehrig, & Patterson, 2003, p. 77). The targeted induction support offered an avenue for some of these beginning teachers to use reform-based teaching strategies such as inquiry.

And finally, Roehrig and Luft (2004), in another study of beginning teachers who participated in an induction program to support their efforts in implementing inquiry, looked more closely at the constraints that beginning teachers experience when implementing inquiry-based instruction. They reported five constraints for beginning teachers in their study. These included: an understanding of the nature of science; their content knowledge, and their pedagogical content knowledge; their beliefs about teaching; and concerns about classroom management and students. They learned that, "the most prevalent self-reported constraint among the beginning teachers was low student ability and motivation. If the students were perceived as being 'low ability', they often did not see 'science as inquiry' as an effective instructional strategy" (Roehrig & Luft, 2004, p. 20). Beginning teachers, and teacher candidates alike, require ongoing support and positive inquiry experiences to be able to overcome some of the constraints of implementing inquiry in their science classrooms.

Teacher Performance Assessment

In her article “School Reform at the Crossroads”, Linda Darling-Hammond (1997) spoke at length about the challenges and policies regarding K-12 educational reform since the 1983 Reagan-era *Nation at Risk* report. She stated:

> Although many important reforms have been launched over the past decade, we have reached an impasse. We have learned that most schools and teachers cannot provide the kind of teaching for all students that new reforms demand, not because they do not want to but because they do not know how. (p. 153)

Darling-Hammond urged changes to our nation’s “teacher development system” in a five point restructuring plan (1997, p. 162). She outlined the same five recommendations that were published in the report “*What Matters Most: Teaching for America’s Future*” of the National Commission on Teaching & America’s Future, of which she was also an author (NCTAF, 1996). The first change she recommended was the “enactment of professional standards for teachers that reflect the demands of new student standards and reflect current knowledge about teaching” (Darling-Hammond, 1997, p. 163). This would include national standards for teacher preparation, retention and evaluation in an effort to prepare and develop high-quality teachers. She indicated:

> Candidates for teaching would have more fruitful guidance in learning to teach and more meaningful standards for attaining a license—standards that are enacted through performance assessments of subject matter and teaching

> knowledge that capture teaching and serve as learning vehicles. (Darling-Hammond, 1997, p. 163)

This recommendation has led to the development of the Teacher Performance Assessment, an authentic assessment of preservice teacher preparation and readiness. It is one assessment that can serve as a requirement for licensure, alongside subject area content and pedagogy exams, education course work at institutions of higher education and student teaching experiences.

The TPA is designed to be an authentic assessment which evaluates a teacher candidate through four tasks; 1) lesson planning, 2) instructing and engaging students, 3) student learning through assessment, and 4) an overall reflection on three to five days of teaching. The TPA in secondary science is designed to reveal the teacher candidate's ability to apply their understanding of both their science content knowledge and pedagogical content knowledge with a focus on inquiry-based instruction, as well as assess the candidates' ability to reflect on student learning.

The TPA for secondary science is modeled after the preliminary versions of Performance Assessment for California Teachers' (PACT) authentic assessment model and includes four tasks that are linked to a three-to-five day set of lessons (SCALE, 2011). TCs are expected to submit artifacts for each of the tasks and written commentaries in response to structured prompts within each task. The four tasks include: 1) lesson planning, 2) instructing and engaging students, 3) student learning through assessment, and 4) final retrospective reflection of instruction. In addition, TCs complete a Context for Learning form that allows them to look at their specific students and the learning needs for one class. Examples of evidence gathered about the class' context are: subject taught, class schedule, presence of ability tracking, resources available, grade of students, number of students identified as gifted and talented, students with Individualized Education Plans (IEPs), and students who are English language learners (SCALE, 2011). This information is intended to help the TCs frame their instructional planning as well as their teaching strategies as they prepare to teach.

There is one publication to date that looks specifically at the Performance Assessment for California Teachers (PACT) in secondary science, however, this study also looked at five other licensure areas and how the PACT informed the participating programs to better support teacher candidate learning (Pecheone & Chung, 2006). Their findings revealed, "[S]tudents who receive targeted support in their development of the TE [teaching event] view their experience more positively and report that the process of constructing their TEs strengthened their teaching" (Pecheone & Chung, 2006, p. 32). A brief overview of some of the current literature on TPA and PACT evaluation follows, with three foci: first, a brief look at the TPA both as it impacts institutions of higher education and the teaching profession (Guaglianone et al., 2009; Mayer, 2005); second, TPAs as a means to observe teachers through their induction and tenure period (Darling-Hammond, 2010; Newton, 2010). And third, a review of the TPAs impact on TCs' learning and personal lives (Bunch et al., 2009; Carlile, 2006; Chung, 2008; Hafner & Maxie, 2006; Okhremtchouk et al.; 2009; Pecheone & Chung, 2006; vanEs & Conroy, 2009).

Impact of the TPA on education. The TPA was designed to serve dual evaluation purposes. Institutions of higher education that prepare teachers for licensure can evaluate their programs utilizing the TPA as an aggregated authentic assessment of their TCs. Additionally, the TPA can be used to evaluate and qualify individual TCs. There is a desire for a predictive tool for teacher quality, since the current high-stakes multiple-choice tests are insufficient at predicting teacher quality (Darling-Hammond, 2010; Mayer, 2005). Mayer's (2005) hope is that, in time, these performance assessments can help reinvigorate the professionalization of teaching, increase the mechanisms for accountability within the profession, and serve as a means of self-governance. There is also some pressure for these assessments to be tied to value-added studies (Darling-Hammond, 2010; Newton, 2010). In the case of value-added studies, the teacher candidates would be followed into their first jobs to observe student achievement in relation to the scores the teachers received on the TPA during their licensure programs. This approach not only assists in program evaluation but also could reward teachers by moving them up the pay scale—assuming policies were put in place similar to those of National Board Certified teachers (Darling-Hammond, 2010; Newton, 2010; Park & Oliver, 2008).

Impact of TPA on TCs. The second purpose of the TPA is to evaluate TCs with this authentic assessment and determine whether they are qualified for teacher licensure. Many studies have looked at the California PACT (a precursor to the current TPA, to which it bears similarities) and analyzed their effectiveness at preparing TCs for teaching (Bunch et al., 2009; Chung, 2008; Okhremtchouk et al;

2009; Pecheone & Chung, 2006; vanEs & Conroy, 2009). All of the evidence in the literature to date points to one notable fact, that TCs from a variety of credential areas, including elementary math, elementary literacy, secondary English, secondary English, secondary math, secondary social studies, and secondary science, showed improvement in their ability to reflect on their teaching and student learning. This lead to improved teacher quality (Bunch et al., 2009; Carlile, 2006; Chung, 2008; Hafner & Maxie, 2006; Okhremtchouk et al; 2009; Pecheone & Chung, 2006; vanEs & Conroy, 2009). According to these studies, the process of completing the TPA is at once formative and summative. Teacher candidates' reflective practices reveal developing expertise and the final document itself can be utilized to determine a TC's ability to qualify for their teaching license.

Perceptions of the impact of the TPA on TCs. Some studies, however, in addition to TC growth, also revealed negative perceptions related to TPA implementation. There was evidence of frustrations and exhaustion from both students and instructors, due to the level of effort required to complete the TPA (Hafner & Maxie, 2006; Larsen, 2009; Okhremtchouk et al., 2009) and a sense that the TPA negatively affected their personal lives. Candidates responded that they were, "physically ill from all of the stress of the process and from a lack of time for exercise and healthy eating" (Okhremtchouk et al., 2009, p. 56). In some studies there was a clear need for increased support for the TCs to frame the tasks prior to and during their completion of the PACT (Carlile, 2006; Okhremtchouk et al., 2009; Pecheone & Chung, 2006). Another study refutes this claim, stating instead that candidates' attitudes were more important predictors than instructor support (Chung, 2008). In an attempt to ease a TC's schedule during their student teaching, different teacher education programs implemented the TPA early or late during student teaching. However, it appears that neither the beginning of student teaching nor the end were the best time to complete the TPA; students' and instructors' negative perceptions persisted (Okhremtchouk et al., 2009).

Evidence exists that the TPAs support TCs' learning and growth as teachers; however, there are some valid concerns around potential negative side effects to this high-stakes authentic assessment. These concerns have not gone without notice in Minnesota. The following is a quote from a February 11, 2011 meeting of Minnesota Board of Teaching regarding the Teacher Performance Assessment:

> MACTE [Minnesota Association of College for Teacher Education] continues to support the reforms taking place at all levels in teacher education. We have a major role in pilot-testing and launching Minnesota's much anticipated Teacher Performance Assessment (TPA). We are collaborating on the development of Program Effectiveness Report for Continuing Approval (PERCA). We are contributing to a review of the Board's institutional approval rule (8700.7600). We make these investments because we value the promise of such reforms for preparing more effective teachers. At the same time our experience tells us that these systemic changes pose risks that, if not anticipated, can weaken their effect to the detriment of our candidates and ultimately, Minnesota's K-12 students. We need to take the time to reflect,

> anticipate, and counter those risks to our shared goal of attracting and retaining the candidates who will become effective teachers of Minnesota's students. If we change too much, too soon, with too little reflection on the undesired consequences of those changes, we will be forced to spend time and money to repair their unanticipated effects. Let's all take a breath, slow down, and think through how we can assure our preparation and licensing of the best educators for Minnesota's students without risking our pursuit of that goal. (Minnesota Department of Education, 2011, p.6)

There is hope that the TPA can be implemented successfully. According to Carlile, the TCs "…didn't see it [the TPA] as just another required assessment but rather a meaningful part of their training" (2006, p. 28). She goes on to say, "[f]or many this part of the TPA fieldwork was the first time that they were required to practice theories and strategies that they had learned in earlier courses" (2006, p. 29).

MACTE's current objectives for the Minnesota TPA, which have been built out of the partnership with the AACTE, CCSSO and Stanford University, include the following three goals of the TPA project:

1) Allow school districts to analyze teachers' ability to support and advance student achievement.

2) Play a key role in a system of state assessments, beginning with educator preparation and used in the professional development of in-service educators throughout their careers.

> 3) Contribute in an important way to the development of a more coherent national policy environment for teacher licensure, recruitment, and in-service evaluation and to a more effective national agenda for improvement of teacher quality. (MACTE, 2010)

MACTE is clearly looking beyond the use for initial licensure. Similarly, Linda Darling-Hammond outlined in her Center for American Progress publication, *Evaluating Teacher Effectiveness: How Teacher Performance Assessments can Measure and Improve Teaching,* the potential of using a TPA at three tiers of professional advancement. Tier 1 is intended to represent the first step for teachers, initial licensure. Tier 2, a second TPA, would come after three years in the field, for consideration for tenure and the professional license. Tier 3, a third TPA, would be used similar to National Board Certification to evaluate expert mentor teachers and could be used for differentiated compensation (Darling-Hammond, 2010, p. 13).

Reflective Practice

Research has found that individual TC self-reflection during and after reviewing their teaching videos (Lotter et al., 2009; Okhremtchouk et al., 2009; Roth, Garnier, Chen, Lemmens, Schwille, & Wickler, 2011; vanEs & Conroy, 2009) or collaboratively in small learning communities (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Kang, 2007; Sherin & Han, 2004) have been effective at improving the candidates' teaching and students' learning. Most of these studies reflect specifically on TCs' views of inquiry. While some were an inquiry into their own teaching practices (Borko et al, 2008; Kang, 2007; Roth et al., 2011; Sherin & Han, 2004) others focused on student learning through inquiry (Lotter et al., 2009; vanEs & Conroy, 2009). Educational research supports the use of video clips of one's own teaching as a tool for structured reflective practice. The clips could provide both a formative and a summative assessment of an individual's development through the teacher licensure program. Seven of the studies on reflective practice mentioned here are elaborated below.

Two of these studies of reflective practice focused on the benefits of structured reflection on science teacher candidates. In one, Lotter, Singer and Godley (2009) offered highly scaffolded opportunities for self-reflection where both the university methods instructor and the cooperating teacher assisted in interpreting and analyzing three practice teaching events. The instructors were looking specifically for teacher candidates' increased implementation of scientific inquiry and their views of the nature of science. They stated, "positive changes in the preservice teachers' beliefs and practice of inquiry and NOS [nature of science] were observed through the program's gradual building of instructional responsibilities … the key to changes in the students' teaching skills came through the guided reflections tied to the teaching experiences" (Lotter, Singer, & Godley, 2009, p. 574). In the second study, Okhremtchouk et al (2009) analyzed science teacher candidates who completed the PACT–the early version of the California TPA. One of their findings indicated the significance of support by teacher educators. "The support received, type of support received, and the time of the received support…. proved to be very significant in preservice teachers' experiences during the PACT preparation" (Okhremtchouk, 2009, p. 57). This study also found that TCs gained insights into their own practice through the process of guided reflection-on-action. In fact, 70 percent of the science teacher candidates found the PACT was effective in improving their instructional practice (Okhremtchouk, 2009).

Two other studies of reflective practice looked at professional development programs for elementary science teachers (Roth et al, 2011 and Kang, 2007). Both studies utilized video-based lesson analysis; however, while it was the main focus of the Roth et al study, it was only one part of a portfolio in the Kang study. Roth et al (2011) evaluated the STeLLA project (Science Teachers Learning from Lesson Analysis), which was a yearlong professional development (PD) program for assisting elementary science teachers to improve their science content knowledge and their ability to analyze their science teaching. What these researchers observed was that the elementary teachers not only improved their content knowledge through observing and reflecting on video-cases, but student learning improved as well. This project does not necessarily require teachers to use inquiry-based instruction; however, they recommend it. Roth et al stated:

> PD programs should focus on helping teachers engage students in scientific inquiry... we found teachers focused on and interested in engaging students in science “inquiry” activities, with much less focus and interest on engaging students in thinking about the science ideas connected to those experiences… the coherent development of science ideas is both critical in scientific inquiry

> and often overlooked in science teaching (and maybe especially by) teachers who view themselves as using inquiry teaching approaches. (2011, p. 141)

The second study of elementary teachers focused on 14 teachers completing projects that were inquiries into their own teaching practices. The teachers completed portfolios that included: a literature review on student ideas, an analysis of the context of their classroom, lesson plans, and written analysis of their own teaching through collaborative self-video reflection. They found through collaborative self-reflection that elementary science teachers "need extensive guidance in applying educational theories to their interpretation of teaching practice and teaching methods" (Kang, 2007, p. 489). Purposeful, guided reflection-on-action assisted teacher learning.

Two other studies of reflective practice using video-recorded lessons focused on two professional development programs for middle school mathematics teachers. In one, Borko, Jacobs, Eiteljorg and Pittman (2008) analyzed the effectiveness of a two-year professional development program through the use of teacher videos of their own classrooms. The videos were used as "a tool for fostering productive discussions" over a two-year period (Borko, Jacobs, Eiteljorg & Pittman, 2008, p. 417). By the end of the program, "the teachers appeared to feel more comfortable addressing limitations in their understanding of the mathematics content, without continually making reference to their students or otherwise couching the conversation" (Borko, Jacobs, Eiteljorg & Pittman, 2008, p. 433). The second study also utilized a "video club meeting" format. The findings in the Sherin and Han (2003) study, however, revealed teachers shifted from focusing primarily on their own actions to those actions of their students and their students' ideas. Both of these studies represent meaningful reflection-on-action in the collaborative analysis of video-recorded lessons, which allowed teachers to move beyond making excuses due to their students' abilities to thoughtful reflections that promoted teacher growth and student thinking and learning.

Finally, in the seventh study, research by van Es and Conroy (2009) in elementary and middle school mathematics instruction revealed differences in high and low performing TCs' reflective practice. These authors chose two high performing candidates and two low performing candidates. They observed a difference in how these candidates reflected on their teaching of mathematics for understanding; they documented what the candidates noticed about their teaching and student learning (van Es & Conroy, 2009). Their findings revealed that the high performing TCs offered specific examples from their instruction that supported their claims, while the low performing candidates offered, "superficial, global claims without pinpointing specific events or interactions to support claims of best practices in their teaching" (p. 97). While the focus of their research was on what the candidates noticed in their teaching through interviews; this study instead focused on what is revealed about candidates' understanding of inquiry during TPA Task 2 using the frameworks of reflective practice and inquiry-based instruction.

The rationale for this study focusses on the national and state standards suggestion that science teachers should teach about scientific inquiry and utilize inquiry-based instructional methods in their classes. Due to the fact that science teachers, of all levels of experience, struggle to implement inquiry-based instruction in their classrooms, there is an inherent challenge to this national reform. The new TPA Task 2 requires candidates to implement and reflect upon inquiry-based instruction. As defined by the NRC, inquiry-based instruction requires students to participate in the five essential features of inquiry. However, the question remains, what is revealed by this new state-wide assessment of TCs' understanding of inquiry? Are the TCs' understandings of inquiry-based instruction revealed by the TPA? Do they include all five essential features of inquiry in their reflections?

Chapter III will describe the research design and methodology for this multiple case study. The research design occurred in two phases. Phase One includes the analysis of the TPA Task 2 for 26 TCs. The reflective practice of TCs with high scores on the TPA was compared to mid-scoring and low-scoring TCs. Phase Two will include the in depth analysis of the six TCs' cases.

Chapter III: Research Design and Methodology

This study was designed to understand whether Task 2 of the TPA—the instructing and engaging students in learning task—reveals an accurate assessment of a teacher candidates understanding of inquiry. The following two research questions guided the data collection and analysis for this study:

RQ1: What does the Teacher Performance Assessment (TPA) reveal about science education teacher candidates' (TCs') understanding of inquiry-based instruction?

RQ2: How do the candidates represent their knowledge of inquiry in their reflections?

The research design involved two phases of data collection and analysis. In Phase One data from the TPA and reflective journals were collected and analyzed from 26 secondary science TCs. In Phase Two of the research design, six TCs were purposefully selected to develop a deeper understanding of their knowledge of, and experience with, inquiry-based instruction using a case study design. In this second phase, TCs were interviewed to investigate their detailed understandings of inquiry-based instruction as it relates to their teaching experiences as well as the teaching analyzed in Task 2 of the TPA. Details on the research design, data collection, data analysis, and cross case analysis are included in the following sections of this chapter.

Case Study Design

Yin (2003) identifies five different types of case studies in terms of their outcomes: the method chosen here is the descriptive case study of the selected six TCs in science education during the pilot year of the TPA (2010-2011). Case study is a distinctive qualitative methodology by its required characteristic; a bounded case. A bounded case is any individual, group of individuals, a classroom, a school or a community. A bounded case "provides a unique example of real people in real situations, enabling readers to understand ideas more clearly than simply by presenting them with abstract theories or principles" (Cohen, Manion, & Morrison, 2000, p. 181). In this study each individual case represents a single teacher candidate bounded by time in the licensure program. The multiple-case study approach was utilized to determine the relationships between the individual TC's understandings of inquiry-based instruction as revealed in the TPA written commentary, video clips, and reflective journal postings and interviews, as well as to make comparisons across individuals (Miles & Huberman, 1994; Stake, 2006). The result is a narrative of the reflective practice of TCs on their instructing and engaging students as part of their three-to-five day lesson as framed by TPA Task 2 and their understanding of inquiry-based instruction as framed by the five essential features of inquiry (see Table 2.1).

Yin's (2003) defines case studies as a qualitative research method where: "a 'how' or 'why' question is being asked about a contemporary set of events, over which the investigator has little or no control" (p. 9). While research question 2 is clearly a "how" question and therefore is a natural fit for case study methodologies, research question 1 needs some interpretation to fit Yin's definition.

It could be argued that RQ1 could be reframed to state: "How" does the TPA reveal science education teacher candidates' understanding of inquiry-based instruction? However, RQ1 was carefully considered during the research design. In this study I am less interested in *how* the TPA reveals the candidates' understanding but, rather, in *what* it can reveal. If RQ1 were strictly a "how" question, it could be potentially be answered simply as, "The TPA reveals that TCs understand inquiry-based instruction well." While this might be good information, this study's intention was to look deeper than whether the TPA revealed that candidates understand inquiry-based instruction well, or not, but rather what precisely is revealed through careful analysis of the case narratives and cross-case analysis. Recall that the theoretical frameworks on which this study is built include inquiry-based instruction as defined by the NRC (2000) and Schön's (1987) theory of reflective practice. The aim of RQ1 is to include a rich narrative of the TCs' reflective practice and understanding of inquiry-based instruction, as well as what is revealed by the individual and collective narratives regarding Task 2 of the TPA.

Program Description

The initial licensure program (ILP) at this institution of higher education was a 15-month graduate program. TCs began the program in May 2010 and completed coursework for their teaching licensure by July of 2011. All TCs had a bachelor's degree in an area of science prior to acceptance into this program, and all of the TCs took educational foundations courses concurrently each semester with science method courses throughout the first 12 months of the ILP. Successful completion of the ILP meant TCs were ready to teach, apply for teaching positions, and consider completing the additional coursework for their Masters of Education degree within the next seven years. Upon completion of the ILP, all TCs in science earned a 9-12 teaching license in their area of science: life, earth, physics, or chemistry; some TCs opted to also secure their 5-8 middle school science endorsement.

Science methods courses. The science methods course in which the TPA was piloted was the third in a series of three science methods courses. The TCs started the summer with a three-week intensive study of laboratory-based instruction for secondary science, with a heavy emphasis on inquiry-based instruction. This course met four days a week for three hours each day. This course was organized by six major principles of teaching and learning: constructivism, scientific literacy, inquiry-based instruction, the nature of science, analysis of classroom cases, and instructional theory.

In the fall, the TCs enrolled in a middle school science methods course concurrent with a twelve-week practicum experience. The fall methods course met twice a week, for two hours each meeting, and was organized by six major concepts: scientific inquiry and inquiry-based instructional strategies, planning instruction, assessing student learning, reflective practice on instruction, differentiated instruction for diverse adolescent learners, and, lastly, gender and cultural differences in science. During the practicum, the TCs were partnered with a peer from the cohort in a science classroom for two class periods each day. TCs prepared and taught three mini-units to middle school science students for three to five days for each teaching event. A university supervisor observed one day’s lesson of each mini-unit for each TC.

Supervisors provided written feedback and a 30-60 minute reflective debriefing session following each teaching event.

In addition, university supervisors and TCs annotated and critiqued one video of a teaching event. The utilized tool, VideoAnt, is an online video annotation tool that allows TCs and supervisors access to watch and annotate video clips of teaching events. Additionally, TCs can link their comments directly to a particular moment in the teaching event. First, the candidate reflects on their teaching event and adds those annotations to their VideoAnt file. Second, the university supervisor offers comments and asks additional questions for consideration; and third, the candidate returns to the video and responds to the supervisor's annotations. This tool is provided to all currently enrolled university students and provides an enriched experience for reflecting-on-action.

In the spring, the TCs completed high school science methods, the third methods course in the sequence, and its completion was concurrent with their twelve-week full-time student teaching placement. This course met weekly for three hours at-a-time and incorporated the main concepts from the earlier methods courses. The course also included: subject-specific pedagogical content knowledge, the reflective practitioner, integrating engineering, integrating technology, science safety and curriculum design. TCs observed their mentor teachers for one week with some instructional implementation. The TCs then took over one or two science classes the second week and were teaching four sections of high school science by the third week. A university supervisor observed four days of instruction for each TC over the 12-

week period. Supervisors provided written feedback and a 30-60 minute reflective debriefing session following each teaching event, as well as co-critiquing an additional lesson utilizing a videotaped teaching event.

Participants

In this study, participants were twenty-nine (29) secondary science—26 white, 2 Asian and 1 Latina—education students at a large Midwestern university. The teacher licensure program is a post-baccalaureate program; thus, all participants held a bachelor's degree in a science discipline required for admission into the program. Additionally, many of the students had prior experience working in scientific laboratories or field settings. All of these students were considered teacher candidates during this study, as they were granted their teaching license after successful completion of the course work, both foundational and methods, as well as their student teaching experience. Three of the TCs' video clips—or TPA commentaries—were not available at the time of analysis. Therefore, this study focused on the twenty-six TCs with complete data. More detail regarding this cohort of participants by gender; whether they were a career changer or straight from their undergraduate experience; area of science licensure earned; and race are found in Table 3.1.

Table 3.1

Number of Teacher Candidates in Science Cohort (N=29) by Gender, Career Change, Licensure Area and Race

Gender		***Career Changers (1 to 28 years between degree and ILP)***		
Male	Female	Yes	No	
10	19	19	10	
9-12 Grade Licensure Areas				
Life	Chemistry	Physics	Earth	Dual Life/Ch
13	8	5	2	1
Race				
White	Asian	Latina		
26	2	1		

Study Overview and Procedures

This overview briefly describes the data collection and analysis phases. Each will be described in more detail in further sections. Data collection in case studies is typically deep and numerous. Yin (2003) describes in detail "Three Principles of Data Collection" (p. 97). The three principles considered in the research design, data collection and data analysis phases of this study, were:

- Principle 1: Use Multiple Sources of Evidence,
- Principle 2: Create a Case Study Data Base, and

- Principle 3: Maintain a Chain of Evidence. (Yin, 2003)

Principle 1 was upheld as there are three main data sources for this study and the analysis was completed in two phases. The three data sources include: (1) the written commentary regarding TPA Task 2: Instruction and Engaging Students in Learning and the associated video clip completed by twenty-six TCs; (2) the reflective journal postings that span the ten-months that the TCs were enrolled in the methods courses for the twenty-six TCs and three additional reflection journal postings for the six TCs interviewed; and (3) semi-structured interviews of six TCs. Each of these data sources is described in detail in the following section. Figure 3.1 shows how these data sources were included in Phase One (all 26 TCs, colored in green) and Phase Two (6 TC case studies, colored in orange).

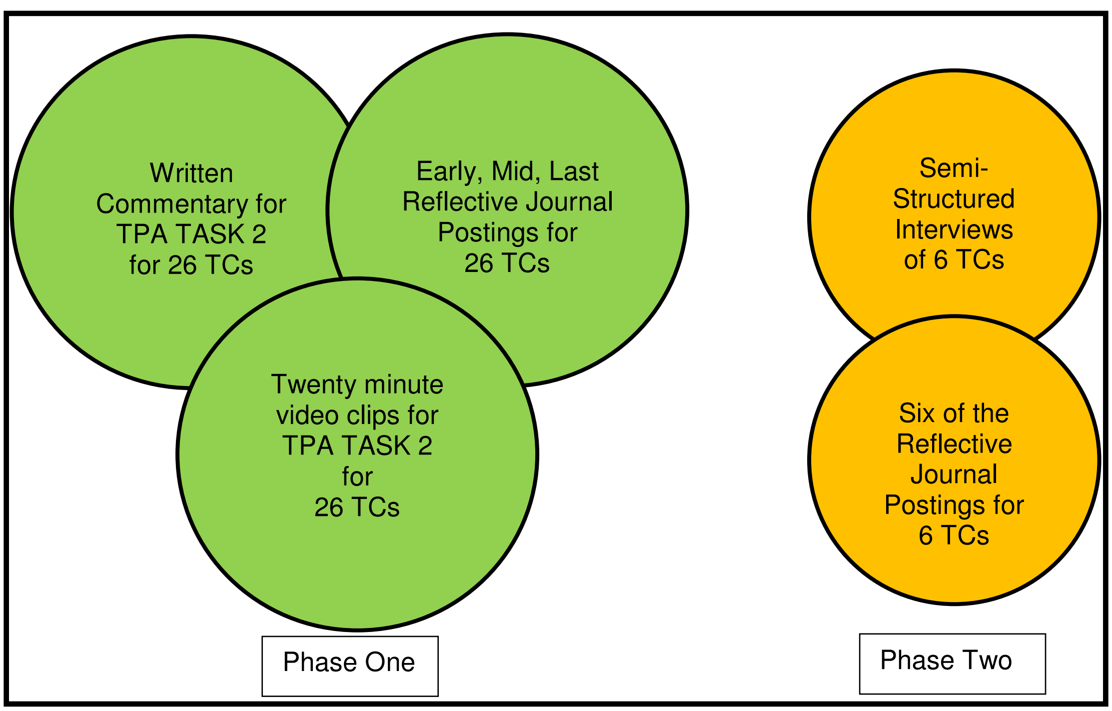


Figure 3.1. Data collection: Phase One in green, Phase Two in orange.

Principle 2 was maintained. All documents were assembled into an electronic database and are stored on a secure server. A database was built in Microsoft Excel to categorize and store the narratives, interpretations, codes, and personal notes of each teacher's data sources. As the database grew, multiple pages were cross-referenced in the Excel file. Details on the data analysis and the development of the codes follow the data collection section.

Yin (2003) stated that for principle 3, it is important to maintain a chain of evidence to increase reliability.

> The principle is to allow an external observer –in this situation, the reader of the case study—to follow the derivation of any evidence, ranging from initial research questions to ultimate case study conclusions… with clear cross-referencing to methodological procedures and to the resulting evidence. (p. 105)

The chain of evidence can best be visualized in Table 3.2. Note that, while there was some overlap in the timing of the collection of the data between Phase One and Phase Two of the analysis, the phases are distinctive due to the number of participants for each phase.

Table 3.2

Data Sources and Dates of Collection

Phase One: Data for 26 Teacher Candidates			
Data Source	**Detail**	**Research Question**	**Collection Date(s)**
Written Commentary & 20 minute video clips for TPA Task 2	Two rubrics: S4 Instruction: engaging students in learning, S5 Instruction: deepening student learning during instruction See also TPA Task 2 Commentary & Rubrics Appendix A	RQ1	February 2011
Early, Mid, Last Reflective Journal Postings	Early: Defining Inquiry	RQ2	072010 (Adele 071911)
	Mid: Growth as a Teacher, some chose to reflect on inquiry (open response)	RQ2	121010
	Last: Growth as a Teacher, some chose to reflect on inquiry (open response)	RQ2	042811
Phase Two: Data for 6 Teacher Candidates			
Data Source	**Detail**	**Research Question**	**Collection Date(s)**
Six Reflective Journal Postings	Early: Same as Early above	RQ1 & RQ2	072010 (Adele 071911)
	Mid1: Same as Mid above	RQ1 & RQ2	121010
	Mid2: Reflecting on student teaching context and potential barriers	RQ1 & RQ2	020311
	Mid3: Open response	RQ1 & RQ2	031011
	Late: Teaching Philosophy Statement	RQ1 & RQ2	040711
	Last: Same as Last above	RQ1 & RQ2	042811
Semi-Structured Interviews	Interview questions are on page 15	RQ1 & RQ2	072111, 082611, 083111, 090111

Data Sources and Collection

As previously noted and illustrated in Figure 3.1 and Table 3.2, this study occurred in two phases. Data sources and collection procedures for each of the phases are described below.

Phase one data collection. Data sources for Phase One included the video clips and written commentaries for TPA Task 2 for all 26 TCs and three reflective journal postings for all 26 TCs. Each of these data sources are described in detail in the following section.

TPA Task 2: Instructing and engaging students in learning. Task 2: Instructing and Engaging Students in Learning has been described in Chapter 2; however, it will is briefly outlined again here. The TPA protocol required TCs to videotape twenty-minutes of instruction that included students collecting, analyzing, and interpreting data. After video recording, TCs reflected on their video and wrote a 2-to-4 page commentary providing responses to the TPA's prompts, thereby describing and interpreting the footage of their own teaching. This task required that the TCs observe their students in action, and reflect on the levels and types of student engagement present in their video. While scientific inquiry may be difficult for TCs to accomplish they had within this video clip and commentary the need to focus almost exclusively on an inquiry-based learning environment in their classroom. The prompts for TPA Task 2 instructional commentary include the requests for TC reflection: "Cite examples of strategies aimed at engaging all your students"; "cite examples of language supports”; “describe strategies for eliciting student thinking”; “reflect on students learning of concepts and academic language”; and “what might you have done to take advantage of missed opportunities” (SCALE, p. 14, 2011). (For the complete TPA Task 2 directions, prompts, and rubrics see Appendix A).

Reflective journal postings. The second data source was the TCs’ reflective journal postings that were completed over the ten-month period of the summer, fall and spring methods courses. In all, the TCs responded to 26 journal postings. Many of the reflective journals were guided by prompts asking the TCs to consider their teaching contexts, practical issues of classroom management, and theoretical issues of different aspects of pedagogical content knowledge. Some TCs were open to any reflection the candidates felt they wanted to consider more deeply. Three reflective journal postings were used as data sources from the 26 TCs. The three reflective journal postings included: the first posting in the summer methods course (“Early”), the last posting for fall (“Mid”), and the last posting in the spring (“Last”).

The first reflective journal posting asked candidates to reflect on their understanding of inquiry-based instruction. It stated, “You will hear a lot in this class about 'inquiry’ - in your own words describe what inquiry means to you, if I were to walk in your classroom and you were teaching an inquiry lesson what would I see?” (Journal, 072010).

The second reflective journal posting asked the TCs to reflect on their learning over the past two semesters, and their practicum experiences in the middle schools:

> Please look back over your journal entries from earlier in the semester, or even last summer's inquiry class. Reflect on areas of growth during these past few months, in particular, in your experience in the classroom with your middle school students; the curriculum, planning, implementation, assessment. (Journal, 121010)

Some of the TCs chose to reflect on inquiry-based instruction in this reflective journal posting. However, due to the fact that it is a more open response format, not every TC did reflect on inquiry-based instruction at this stage of their development as teachers.

The third and final reflective journal posting used as a data source in Phase One asked TCs:

> For our last reflection, please take some time to review your own growth and learning this year... by looking back at all of your responses to the forum discussions... look back to the summer course, fall methods, and this semester too. As you read, reflect on how your understanding of teaching secondary science students has grown, deepened, and broadened, on some of the big concepts/objectives we've had for the year, i.e. Were/are there aha! moments? How have your conceptions changed on...? (Journal, 042811)

Phase two data collection. The scores and codes to reflective journal postings were used as guides for selecting teachers to interview in Phase Two. Six teachers were sent requests to be interviewed about their TPA Task 2 using purposive sampling (Melville, Fazio, Bartley, & Jones, 2008). The sampling attempted to balance the candidates with two high, two mid, and two low scores; both genders; and three areas of science licensure. A detailed description of each of the cases can be found in Chapter IV.

Phase Two included analysis of three additional reflective journal postings. These reflections were completed by all TCs as part of their methods course assignments. Only the additional postings of the six TC cases, however, were included in the case analysis. From the analysis of all 26 TC TPAs, six cases were purposefully selected, and semi-structured interviews were conducted with each of these six TCs. In the following section, the additional reflective journals, participant selection, and interviews are described in detail.

Additional reflective journal postings. In addition to the three journal postings from Phase One, three additional postings were included in the analysis of Phase Two. The fourth reflective journal posting asked candidates to consider barriers in their teaching contexts.

> Looking at your classroom (or whole school), what factors or practices promote and/or hinder the teaching and learning of science? Reflect on daily practices in your classroom and contextual factors (i.e. resource availability, language etc...) For those practices that hinder the teaching and learning of science, what do you intend to do to enhance student learning? If your classroom is running smoothly for the most part, what will your contribution be, what will you add to the classroom? (Journal, 020311)

The fifth posting was an open response. Candidates were prompted to reflect on any topic. “This week's student teaching reflection is OPEN response. In other words, write about some aspect of your teaching that you want to reflect more on this week" (Journal, 031011). Finally, the sixth reflective journal posting analyzed was their teaching philosophy statements. The TCs had already drafted their teaching philosophy statements in summer and fall, so this posting reflected the final version of their teaching philosophy.

> Here's your chance to hone your Teaching Philosophy Statement. As we discussed earlier, this is something that you may be asked to state in a job interview or include on a job application. I recommend unearthing the statement you wrote in August and rereading it before you start. You may also want to look at the Teaching Rationale that you wrote in December for pointers. (Journal, 040711)

These six reflective journal postings are sequenced in Table 3.2

Interviews of TC cases. The third and final data source was an individual interview with each of the six TC cases. After all of the TCs had completed their coursework and had earned their secondary science teaching licenses, interviews were conducted during the summer of 2011. The intent was to allow the six candidates selected to reflect on their TPA assignment regarding the content they taught, their implementation of the lesson, and their current understanding of inquiry-based instruction, as well as the technological barriers they may have encountered when preparing to video-record a class of high school science students. The interviews were recorded, and they lasted between 34 and 59 minutes. The prepared interview questions were as follows:

1. Describe the activity that you used in your science classroom for Task 2 of the TPA, the video analysis task.
2. What aspects of your methods courses did you employ in your classroom for the videotaped lesson?
3. How would you describe these strategies to a friend, who is not a teacher?
4. Where does this activity fit in the different variations of the Essential Features of Inquiry chart? Show candidate chart on next page.
5. Describe how this activity does or does not meet the requirements of inquiry-based instruction.
6. Describe how your lesson is tied to the nature of science.
7. What barriers do you encounter when implementing strategies of inquiry-based teaching?
8. Describe how you will explicitly teach inquiry to your science students.
9. How do you anticipate students will benefit from your strategies?
10. When will you begin to incorporate these inquiry teaching strategies in your classroom next year?
11. Do you have any additional information you'd like to share regarding this video analysis task or your inquiry-based instruction?

Data Analysis Procedures

A qualitative-interpretive lens was utilized to analyze the data in Phase One and Phase Two (Denzin & Lincoln, 2011). The two phases define the two different, but overlapping, sets of data sources, rather than two distinct periods of analysis. Phase

One includes the data analyzed for the 26 TCs in the cohort. Phase Two includes the data analyzed for the six TC cases. While the two phases overlapped considerably in time, only Phase One analysis was completed prior to commencing Phase Two analysis. (See Figure 3.2.)

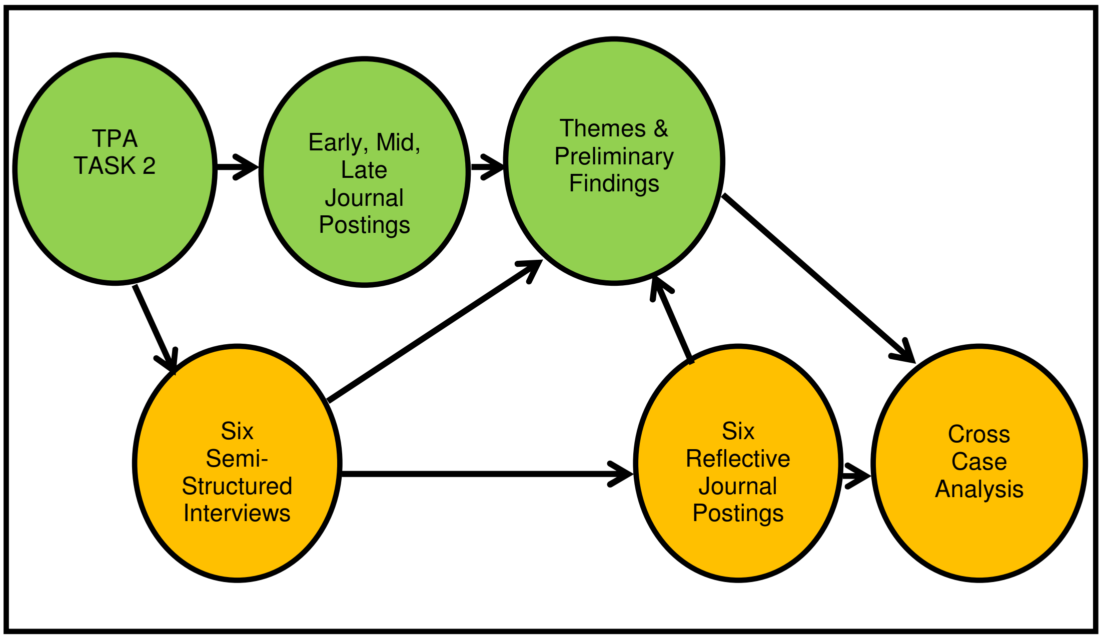


Figure 3.2 Data analysis flowchart. The green ovals indicate Phase One of data analysis and the orange ovals represent Phase Two of data analysis.

Phase one analysis. Phase One of the data analysis included scoring and analysis of the twenty-six complete TPA Task 2 commentaries and accompanying video footage. Following the analysis of the TPA data, three reflective journal postings over the ten-month span; Journal 1 on 072010, Journal 16, on 121010, and Journal 26 on 042811, for the twenty-six TCs with complete data were analyzed. Due to missing TPA data for three of the TCs, twenty-six TCs' data were analyzed. The analysis is described in detail in the following sections.

TPA Task 2 analysis. Each task of the TPA is aligned with one or more scoring rubrics; there were eleven rubrics in all in the 2010 version. These rubrics included:

S1 Planning: planning focused, sequenced instruction,

S2 Planning: using knowledge of students to inform teaching,

S3 Planning: planning assessments to monitor and support student learning,

S4 Instruction: engaging students in learning,

S5 Instruction: deepening student learning during instruction,

S6 Assessment: analyzing student work,

S7 Assessment: using assessment to inform instruction,

S8 Assessment: using feedback to guide further learning,

S9 Reflection: Monitoring student progress and adjusting instruction,

S10 Academic Language: understanding language demands and resources, and

S11 Academic Language: developing students' academic language repertoire.

Each of the rubrics was based on a four-point scale. Scores of level 2, 3, and 4 were considered passing scores, with a 2 representing a typical beginning teacher score. A score of 1 was considered a non-passing score. If a TC received two or more scores of level 1 on any of the rubrics they did not pass the TPA.

Each of the 26 TPAs were scored using the two TPA rubrics relevant to Task 2: S4 Engaging Students in Learning and S5 Deepening Student Learning during Instruction. These two rubrics define the requirements for Task 2; each was framed by a question, the question is divided between two criteria, and each criterion were defined by the four levels of achievement. For rubric S4 the question was stated, "[H]ow does the candidate actively engage students in their own understanding of collecting, analyzing, and interpreting scientific data?" (SCALE, 2011, p. 16). Note that this question that framed the rubrics was part of the parameters by which the TCs were scored. The possible levels for each rubric were defined by two different criteria. For instance, in rubric S4, where the TCs were required to show evidence of engaging students in learning, a level 1 for the first criterion stated: "Strategies for intellectual engagement seen in the clips **limit opportunities for students to collect, analyze, and interpret scientific data**"[1] (SCALE, 2011). Whereas, a score achieving level 2—a passing score for this criterion—must include evidence of: "Strategies for intellectual engagement seen in the clips **offer opportunities for students to collect, analyze, and interpret scientific data.** These strategies reflect **attention to students' academic or language development, social/emotional development, and/or cultural and lived experiences**" (SCALE, 2011, p. 16). Note the differences in the bolded portion of each statement for the variation between a level 1 failing score (where students were offered limited opportunities to do inquiry) and a level 2 passing score for this criterion (where students were afforded opportunities to do inquiry).

The failing score, level 1, for the second criterion for S4 stated, "Candidate accurately **identifies successful and unsuccessful teaching practices**. **OR Student behavior or candidate's disrespect for one or more students severely limits students' engagement in learning**" (SCALE, 2011, p. 16). On the other hand, a passing score of 2 for this second criterion reflects a TC's ability to recommend

[1] Text bolded on in the quotations on this and the following page were bolded in the original. See also Appendix A.

improvements to the lesson, "Candidates accurately identifies successful and unsuccessful teaching practices and proposes reasonable improvements" (SCALE, 2011, p. 16).

The question framing rubric S5 was stated, "[H]ow does the candidate elicit and monitor students' responses to deepen their abilities to collect, analyze, and interpret scientific data?" (SCALE, 2011, p. 17). The level 1 criterion for this rubric stated: "Candidate primarily asks **surface-level questions** and evaluates student responses as **correct or incorrect**" (SCALE, 2011, p. 17). However, for TCs receiving a passing score, level 2 requires, "[t]he candidate **elicit student responses that require thinking about science concepts, explanations, and the quality of data**" (SCALE, 2011, p. 17). To achieve a passing score for this criterion, TCs must elicit student thinking through questioning, rather than simply telling students they are right or wrong.

The level 1 failing score for the second criterion for S5 stated, "**[f]ew connections** are observed being made between and among **science concepts, analyses and interpretations of science data**. OR Materials or candidate responses include **significant content inaccuracies** that will lead to student misunderstandings" (SCALE, 2011, p. 17). To pass this second criterion, a TC had to clearly make connections for students between their hands-on activity and the science concepts they were exploring. It stated, "[c]andidate makes connections between and among science concepts, analyses and interpretations of science data" (SCALE, 2001, p. 17). The rubrics are included in Appendix A for further reference.

Each criterion and rubric was scored on a scale of level 1 to level 4 for the 26 TCs. These scores for S4 and S5 provided a measure of the TCs' understanding of student engagement and instruction and were documented for each of the 26 TCs.

Reflective journal postings analysis. For Phase One, the three reflective journal postings, "Early", "Mid" and "Last" (See Table 3.2) and commentaries for the 26 TCs who had complete TPA Task 2 data were read, analyzed, and coded. The data from both sources were carefully analyzed and examined multiple times; open coding was used to categorize responses and trends in the data. During this first pass of coding, six broad codes emerged revealing how the TCs talked about *student qualities for inquiry, teacher qualities for inquiry, definitions of inquiry, barriers to inquiry, misconceptions of inquiry*, and *personal experiences* in their classrooms. Descriptions and details of these code categories are provided in Chapter IV.

Next, the presence the five essential features of inquiry were coded for each TC's TPA commentaries:

1. Learner engages in scientifically oriented questions,
2. Learner gives priority to evidence in responding to questions,
3. Learner formulates explanations from evidence,
4. Learner connects explanations to scientific knowledge,
5. Learner communicates and justifies explanations (NRC, 2000, p. 29).

These five essential features were sub-codes under *teacher qualities for inquiry* and *student qualities for inquiry.*

In addition to scoring the TPA Task 2 documents for the twenty-six candidates, and coding their responses, an electronic word search was done on these TPA commentaries to determine the frequency of use of terms that relate strongly to inquiry-based instruction, “student” and “inquiry”. A frequency chart representing TCs use of these terms can be found in Chapter IV.

Phase two analysis. Phase Two included the six semi-structured interviews for the six cases as well as the six reflective journal postings over the course of the ten-months of science methods courses. The three reflective journal postings read for Phase One were re-analyzed and there was an in-depth look at the three additional reflective journal postings for these six candidates; Journal 18 on 020311, Journal 22 on 031011, and Journal 24 on 040711. The codes (described in detail in Chapter V) from Phase One were utilized to interpret the narratives of the interviews and the six reflective journal postings in Phase Two. The chain of evidence was maintained as an electronic folder of files as well as handwritten notes recorded during each step in the process of data collection and analysis. These data were used to determine what evidence the TPA revealed about the TCs’ understanding of inquiry-based instruction as well as how the candidates represent their knowledge of inquiry in their written and oral reflections.

Interviews. Interviews were recorded and transcribed for inclusion in Phase Two of the analysis. The six interview narratives were read, analyzed and interpreted using the existing coding scheme; the original codes persisted and new sub-codes emerged. A constant-comparative method was used across the cases to develop themes from the codes and interpretations that were made among the six teacher's narrative cases (Glaser & Strauss, 1967). Axial coding and selective coding followed open coding, where the original codes were reviewed and consolidated as necessary. For instance, it was determined that the TCs' descriptions of two codes; *student qualities for inquiry* and *teacher qualities for inquiry*, had many overlapping sub-codes, and therefore these two were consolidated into one theme *qualities for inquiry* which included the 28 sub-codes. Examples of sub-codes for this theme included relevance, collaboration, aspects of the 5E model of inquiry-based planning, and facilitation. It was also determined that the *personal experience* code reflected a TC's experience with inquiry in their classroom, which described what they did as teachers, what their students were doing, or definitions of inquiry. Therefore, this category was deleted and all codes under this heading were re-coded to merge into the other codes or theme.

Reflective journal postings. Following this level of coding and analysis, the six reflective journal postings were read and coded using the existing four codes, one theme, and numerous sub-codes. Sub-codes for the theme *qualities for inquiry* were consolidated again first to twenty-two sub-codes and then to eleven, and a model prepared to represent the understandings of the TCs. The three codes that remained, *definitions of inquiry*, *misunderstandings of inquiry*, and *barriers to inquiry*, were then classified as themes and the data they represent were utilized to provide answers to both research questions. These four themes are described in detail in Chapter V.

Cross case analysis. While cross case analysis most certainly occurred during the above Phase Two descriptions of coding the interviews and the reflective journal postings, this subsection will provide examples of new codes that arose during the constant-comparative method. This subsection is set apart here to clarify that these four new codes (themes) emerged from the analysis of all of the data sources for the six cases. These codes include two new themes and two enhanced themes. The two additional themes include *inquiry requires differentiation* and *it's actually easy.* The enhanced themes include *frustration for students can be good,* and some *barriers* are shared by more than one case.

The five essential features of inquiry from the theoretical framework for this study were further isolated for frequency counts and qualitative analysis of the TCs' representation of *qualities for inquiry*. A frequency table was prepared of *qualities for inquiry* for each case. (See Chapter IV for details.)

Following this qualitative-interpretive approach allowed for detailed case narratives to be written for six of the twenty-six TCs' views of inquiry-based instruction, as revealed by the TPA's Task 2. Finally, the cross-case analysis and syntheses of the narratives (Yin, 2003) was completed to analyze the cases, and to show what the TPA revealed about the teachers' individual and shared understandings of inquiry-based instruction and how they represent their knowledge of inquiry—thus providing details to answer both RQ1 and RQ2. In this final stage of analysis, the themes of the TCs' understanding of inquiry in their six reflective journal postings and semi-structured interviews were compared to their scores for the two rubrics, and to the TCs' TPA commentaries, to specifically address the research questions.

Researcher Background

I was the instructor of science education methods courses experienced by the 26 TCs. During the ten-month period that these TCs were participating in the initial licensure program, I was a third year doctoral candidate. I have taught the methods courses each year that I have been in the doctoral program, and helped to design the new methods course, Secondary Science Teaching: Laboratory-Based Instruction, which was taught in the summer. This course was offered for the first time during this year of instruction. Before starting the graduate program, I was a secondary science University Supervisor for three years of earlier cohorts of initial licensure TCs. I have a cumulative experience of teaching and mentoring science teachers in the licensure program of seven years. I relish the opportunity to work with new and beginning teachers to learn, understand, and implement effective science pedagogical content knowledge and guide them through their reflective practice.

I attended the TPAC (Teacher Performance Assessment Consortium) Training of Trainers workshop in January 2011, and became a calibrated scorer for the 2010-2011 version of the TPA. During this training, I gained familiarity with the Secondary Science TPA, the four Tasks, and the eleven rubrics. The 2010-2011 cohort of teacher candidates was required to complete the full TPA during this pilot year of this high stakes assessment and submit them as assignments in the methods course. External evaluators did not score the twenty-nine candidate TPAs during this pilot year. Due to my training and subsequent calibration for scoring the TPA, however, it can be assumed that the scores the candidates received on Task 2 would reflect the scores given by other calibrated scorers. But, as these TPAs were from the TCs that I had worked with all year, and not anonymous TCs, there could be room for bias in my evaluation of their work. To combat this, I discussed TC scores with the other science methods instructor who worked with this cohort of students. We were in agreement as to the scores the TCs received.

I am also a former high school biology teacher in a large suburban school district in this state. I taught general biology, honors biology, and human anatomy and physiology courses during my seven years as a science teacher. I hosted a student teacher during my tenure at my district. During my growth and development as a science teacher I had wonderful mentors, colleagues, and peers who supported my every move and decision along my path.

Trustworthiness

Member checks were utilized during the semi-structured interviews and peer debriefing during analysis to increase the validity and reliability of the data. The presence of multiple data sources (TCs' written commentary, video footage, reflective journal postings, and interviews) impart increased internal validity to the findings through triangulation. The external validity may be increased due to the choice of a multiple case study research design and that each case has undergone an in-depth cross-case analysis using all data sources. However, there are limitations to the generalizability of this data analysis. This study represents twenty-six of thirty TCs of one year's science education cohort. The description by Bunch et al. (2009) of their research on the PACT (Performance Assessment for California Teachers) and its generalizability was useful when considering this study's analysis.

> In order to go "beyond the scores" to examine the extensive teacher narratives of planning and practice called for by the PACT, we chose to conduct qualitative textual analyses in order to evaluate adequately the breadth and depth of the teacher candidate responses. While small sample sizes always raise questions about generalizability, the goal of case study and qualitative approaches is not to generalize to specific populations (Yin, 1994), but rather to identify and explore factors and processes at a fine-grained level. (p. 111-112)

The analysis of the data for this study allowed for a fine-grained look at what the TPA revealed of six candidates' understanding of inquiry. While the data might not able to be generalized to a larger population, the analysis of how the TPA measures TCs' views and understanding of inquiry-based instruction can inform practice for science teacher educators preparing to implement the TPA in their institutions.

The TPA scores and analysis for all 26 TCs and the individual case narratives will be presented in detail in Chapter IV. The cross-case analysis and resulting themes will be presented in detail in Chapter V.

Chapter IV: TPA Scores and Case Narratives

In this chapter, the data collected for both Phase One and Phase Two will be presented in separate sections. Phase One includes TPA scores, video clips, and commentary for twenty-six TCs; evidence from three reflective journal postings; and the themes that arose from this phase of the data collection and analysis. Phase Two includes a presentation of the six cases of Kurt, Bill, Nina, Jenny, Adele and Leah—all pseudonyms. Each case was detailed using their written and verbal reflections with limited analysis (detailed cross-case analysis is provided in chapter V). In each case, I paid particular attention to (RQ1) what the TPA revealed about each TC's understanding of inquiry-based instruction and (RQ2) how the TCs represent their knowledge of inquiry in their reflections.

Phase One: TPA Scores and Four Emergent Themes

Twenty-six candidates' TPAs were scored using the rubrics for Task 2. Figure 4.1 shows the scores that these candidates received. Rubric S4 focuses on the candidates' ability to engage students in learning, while rubric S5 focuses on deepening student learning during instruction (SCALE, 2011). Four candidates received high scores on their TPA rubrics, a 3 for each S4 "engaging students" and S5 "deepening student learning". One candidate scored a 1 and a 2 for S4 and S5, respectively, which represents a score that is in danger of failing. Four candidates did not pass the TPA, scoring a 1 for each rubric, while the remaining seventeen TCs earned passing scores of 2 for one or both rubrics.

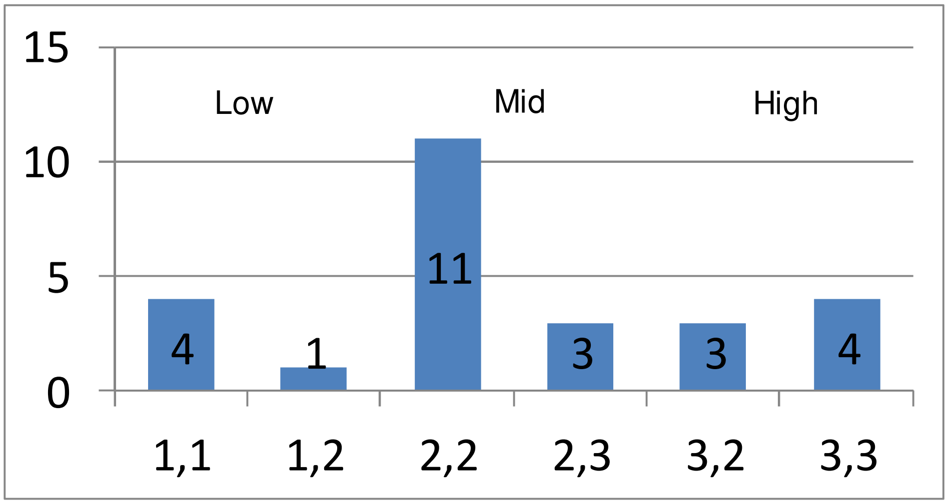


Figure 4.1 Twenty-six Teacher Candidates' TPA Scores on Rubrics S4, S5 Respectively

It should be noted that some of the candidates struggled to record good video evidence of their students engaged in conversation regarding the science concepts. Some had poor sound quality, while others had plenty of noise from student-to-student conversations but no discernible conversation beyond that of the teacher candidate. Still others had their camera so far away from the students that their lab work could not be even observed or heard. Rubric S5, Criterion 1, Level 3 specifically states that, "[c]andidates and/or other students build on what students are saying and/or doing to improve understanding of science concepts, explanations, and the quality of data" (SCALE, 2011). Due to poor sound quality or positioning of the video camera, the inability to hear student-to-student or student-to-teacher conversations had a negative impact on some candidates TPA scores.

Figure 4.2 reveals that the candidates used the word "student" frequently in their TPA commentaries; however, the word "inquiry" did not appear often. In fact, fifteen TCs never mentioned the word "inquiry," and five used "inquiry" only once. At most, one candidate directly referred to "inquiry" nine times in the written commentary for TPA Task 2. The TCs clearly showed a propensity to focus on what the students were doing during this teaching event, but they do not talk frequently about the activity as inquiry. Some never even mentioned the word in their TPA commentary. While the TCs' reflective practice may represent a student-centered disposition, there is little evidence that they directly focused on the activity as inquiry-based instruction.

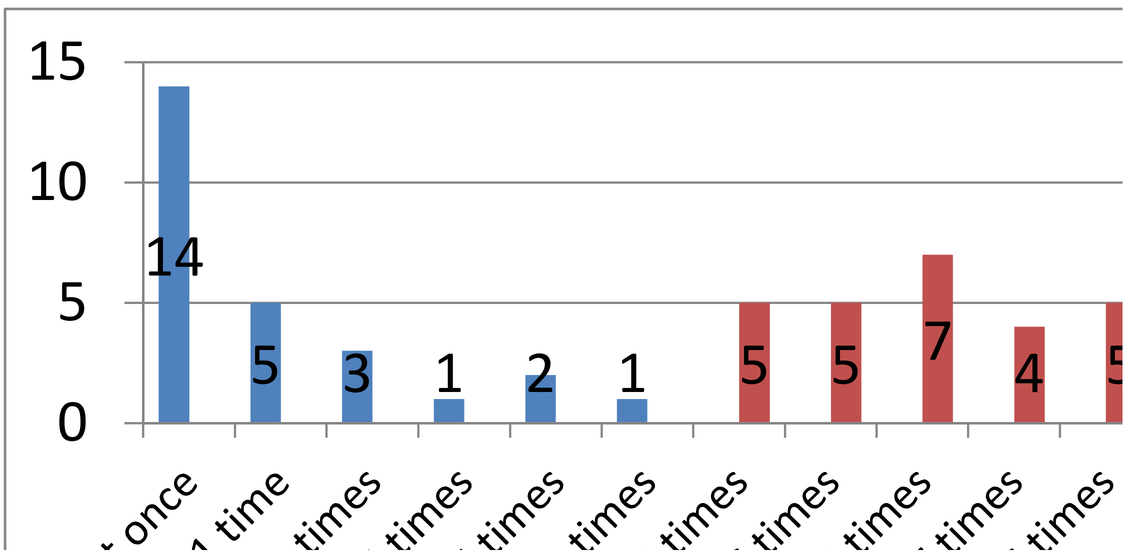


Figure 4.2 Frequency TCs Used "Inquiry" & "Student" in TPA Task 2

After analyzing and coding the TPA commentary, the three reflective journal postings for the twenty-six candidates, and comparing these themes to those that arose from the TPA commentary for Task 2, it was determined that five codes persisted: *teacher qualities required for inquiry, student qualities required for inquiry, definitions of inquiry, barriers to inquiry,* and *misunderstandings of inquiry*. These five codes included two codes, *teacher qualities required for inquiry* and *student qualities required for inquiry,* that had many overlapping sub-codes. These five codes then became four major themes from the reflective journal postings and TPA Commentary. These themes are: *qualities required for inquiry, definitions of inquiry, barriers to inquiry,* and *misunderstandings of inquiry*. A description of each theme is provided in the following section.

Qualities required for inquiry. Teacher candidates frequently mentioned the first theme, *qualities required for inquiry-based instruction*, in their reflective journal postings and TPA commentary. Teacher qualities included: posing questions, raising curiosity, and promoting critical thinking; careful planning, organization, preparation, adaptation, facilitating/coaching, encouraging students to experiment and explore; and relevance, eliciting prior knowledge, modeling, and scaffolding. When the candidates reflected on student qualities this theme included some common sub-themes to teacher qualities: ability to pose questions, design, implement investigations, resolve problems, revise and rework procedures, defend a scientific argument, record data, analyze results, interpret data, predict-observe-explain, collaborate, connect data to scientific content, life-long learning, and increased participation. As evident from these descriptions, teacher qualities for inquiry, and student qualities for inquiry as described by the TCs, had many overlapping, or common, sub-themes and therefore were reclassified as one theme for the analysis of the cases.

Definitions of inquiry. While similar to the first theme, the second theme, *definitions of inquiry*, was left as a separate category due to the more global or general descriptive language used by the candidates. The *definitions of inquiry* were not focused on individuals or groups working, but rather a general idea of inquiry as a concept. Examples included “means to find information” and “inquiry denotes asking questions and seeking answers.”

Some coded narratives of the candidates, however, included *definitions of inquiry* that were not stated in general terms, but, rather, had specific examples of teacher and student *qualities for inquiry* embedded in the definition. The following is an example of a verbal reflection that was coded as both *definition for inquiry* and *qualities for inquiry*:

> Inquiry can be entirely student centered, where the students pose all of the questions, they make all of the assumptions and provide all of the connections (resources) to reach a conclusion. Or, it can be teacher led, where the teacher poses the question, the students make some assumptions with guidance, and the teacher provides some of the connections or resources to help students read conclusions. (Adele, Interview, 072011)

Barriers to inquiry. While the second theme’s focus was on what it takes to do inquiry, the third theme that TCs reflected upon were the *barriers to inquiry*. Barriers that TCs encountered and reflected upon included: time to complete the lesson or activity, resources available for their classes, students’ willingness to participate in inquiry, and being a new teacher unfamiliar with inquiry. TCs may have reflected on more than one barrier, and some barriers were shared by more than one TC’s written reflections. These shared barriers will be discussed in more detail in Chapter V after the analysis of Phase Two.

Misunderstandings of inquiry. The final theme, *misunderstandings of inquiry*, did not arise for all candidates. However, it is still considered a major theme, due to concerns that misunderstandings could potentially lead to misconceptions or poorly implemented inquiry activities. Examples of *misunderstandings of inquiry* included: “open inquiry is the ideal form”, “it seems more of an opinion based type of learning”, and “never give them a direct answer”. The last two quotes are from the same candidate, Leah.

It was evident from the three data sources—TPA commentary and video, reflective journal postings, and, especially the interviews—that an individual’s understanding of inquiry-based instruction can and does change over time. In fact, during an interview, a TC could reflect on their teaching in ways that may represent a misunderstanding of scientific inquiry, only to restate their thinking to “correct” their misunderstanding. Therefore, the *misunderstandings* that were coded and counted for this study included those reflections that were not self-corrected.

Phase Two: Case Studies/Narratives and Two More Themes

Six individual case studies (two high, two mid, and two low scores) were written to represent the six teacher candidates who were interviewed. In this chapter, each case is described in detail utilizing the three sources of data collected and analyzed: 1) their analysis of Instructing and Engaging Students in Learning, Task 2 of the Teacher Performance Assessment (TPA), which includes video clips as well as a written commentary; 2) six of the twenty-six reflective journal postings throughout the year the teacher candidates were enrolled in the methods courses; and 3) an interview following the conclusion of their licensure program.

TPA commentary and video clips. The rubrics from the TPA include S4 and S5, each defined by four levels of achievement and framed by a different question. For S4, the question states: how does the candidate actively engage students in their own understanding of collecting, analyzing, and interpreting scientific data? For S5: how does the candidate elicit and monitor students' responses to deepen their abilities to collect, analyze, and interpret scientific data? A score of 2, 3, or 4 represents passing scores for the TPA. The scores for each candidate are listed in Table 4.1.

Table 4.1

Summary of Teacher Candidates Interviewed

				Scores TPA Task 2		
Name	**Licensure**	**Location of School**	**Course Taught for TPA/ Grade/ Other**	**S4 Rubric Scored 1 to 4**	**S5 Rubric Scored 1 to 4**	**Overall TPA Ranking**
Kurt	Life Science	Urban	General Biology/ 10^{th} grade/ 60% ESL & 20% IEP	3	3	High
Bill	Chemistry	Urban	Pre-IB & Pre-AP Chemistry/ 9^{th} & 10^{th} grade/ highly motivated learners	3	3	High
Nina	Physical Science	Suburban	Physical Science/9^{th} grade/ low math ability	2	3	Middle
Jenny	Life Science	Urban	Modern Biology/ 10^{th} grade/ high IEP	2	2	Middle
Adele	Physical Science	Suburban	Physical Science/ 9^{th} grade	1	2	Low
Leah	Chemistry	Suburban	Honors Chemistry/ 11^{th} grade	1	1	Low

Reflective journal postings. The teacher candidates completed a total of 26 reflective journal postings during the summer, fall and spring secondary science methods courses. Many of the reflective journal postings were guided by prompts; however, some were open to any reflection the candidates felt they wanted to consider more deeply. The case analysis included the three reflective journal postings that were analyzed for the 26 TCs who had completed TPA Task 2 documentation. These postings included the first summer journal posting "Early" (072010), the sixteenth posting at the end of the fall semester "Mid1" (121010), and the final (26^{th}) posting in the spring "Last" (042811).

Three additional reflective journal postings were chosen for the six TCs in the case analysis. Table 4.1 describes each teacher candidate including: their area of licensure, the location of their school for student teaching, the class they video recorded for the TPA, the TCs' scores on the TPA, and their ranking in the class by TPA score. The context for each candidate is described in their detailed case narratives in later sections of this chapter. Taken together, these six reflective journal postings offered candidates the opportunity to reflect on inquiry over the course of the three semesters and were used in the preparation of the cases. These included "Early" (072010), their first journal entry during their summer laboratory methods course. This entry occurred immediately after the candidates had read about and discussed inquiry in class. These entries could be classified as their early, perhaps naïve, views or preliminary conceptions. The second journal posting "Mid1" (121010) was used to develop the cases occurred at the end of the fall semester, after the candidates had completed their practicum in the middle school classrooms. It was an open response that requested the teacher candidates to reflect on areas of growth during these past few months—in particular, their experience in the classroom with their middle school students, including the curriculum, planning, implementation, and assessments. The third journal posting "Mid2" (020311) occurred early in spring student teaching in the high schools, the candidates were asked to consider what factors or practices promote and/or hinder the teaching and learning of science.

The fourth reflective journal posting used for case development "Mid3" (031011) occurred in the middle of the candidates' student teaching experience. It was an open response. The fifth journal posting used for case development "Late" (040711) requested that the candidates post their teaching philosophy. The final reflective journal posting used for case development, "Last" (042811) requested that the candidates look back over all of their reflective journal postings to read and reflect on how their understanding of teaching secondary science students had grown, deepened, and broadened on some of the overarching concepts of the methods courses, including inquiry-based instruction (See Table 3.2). Figure 4.3 reveals the frequency that each of the five codes appeared from each candidate's reflective journal postings. Note Kurt's frequent use of teacher qualities and student qualities required for inquiry.

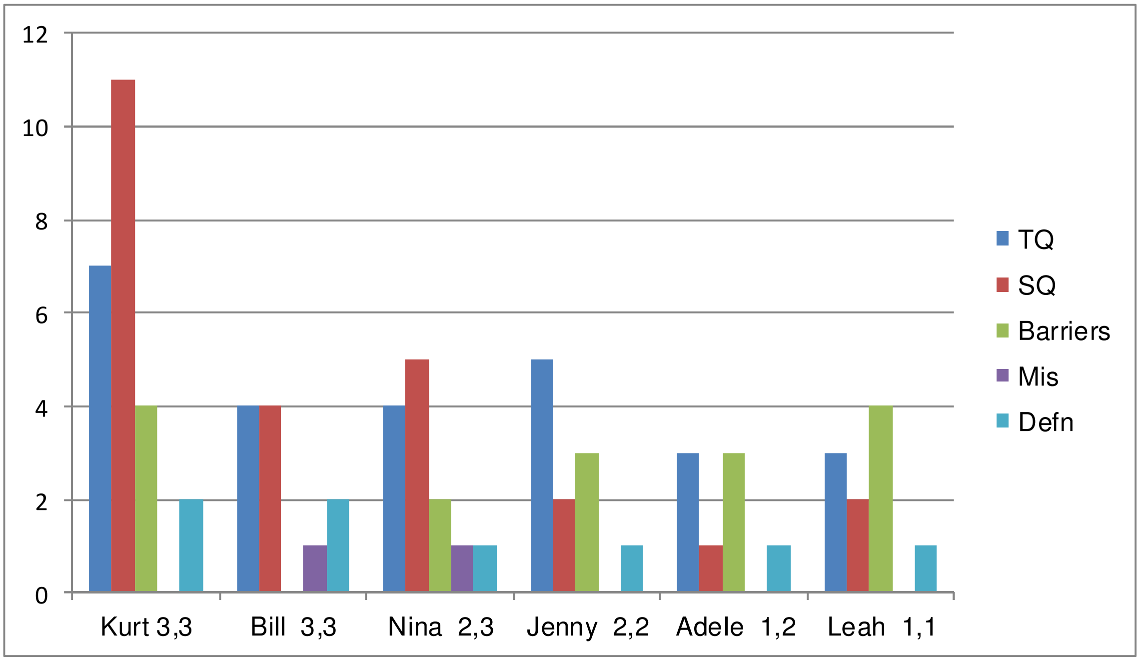


Figure 4.3 Frequency of Codes in Reflective Journal Postings; Teacher Qualities, Student Qualities, Barriers, Misunderstandings, Definition of Inquiry.

Interviews. The interviews were conducted individually and were framed by the prepared questions. (See Chapter III). The intent was to allow the candidates to reflect on their TPA assignment regarding the content they taught, their implementation of the lesson, their current understanding of inquiry, and any barriers they may have encountered when preparing to video record a class of high school science students. The six interviews were transcribed, and then coded using the five earlier codes that came out of the analysis of the twenty-six cohort members' reflective journal postings*: teacher qualities for inquiry, student qualities for inquiry, definition of inquiry, barriers to inquiry* and *misunderstandings.* Figure 4.4 reveals the frequency that each of the five codes appeared for each case in their interviews. Note

Adele reflected on the most barriers, and Kurt reflected on teacher and student qualities required for inquiry more often than the other cases. Bill, Adele, and Leah were the three cases that revealed misunderstandings of inquiry.

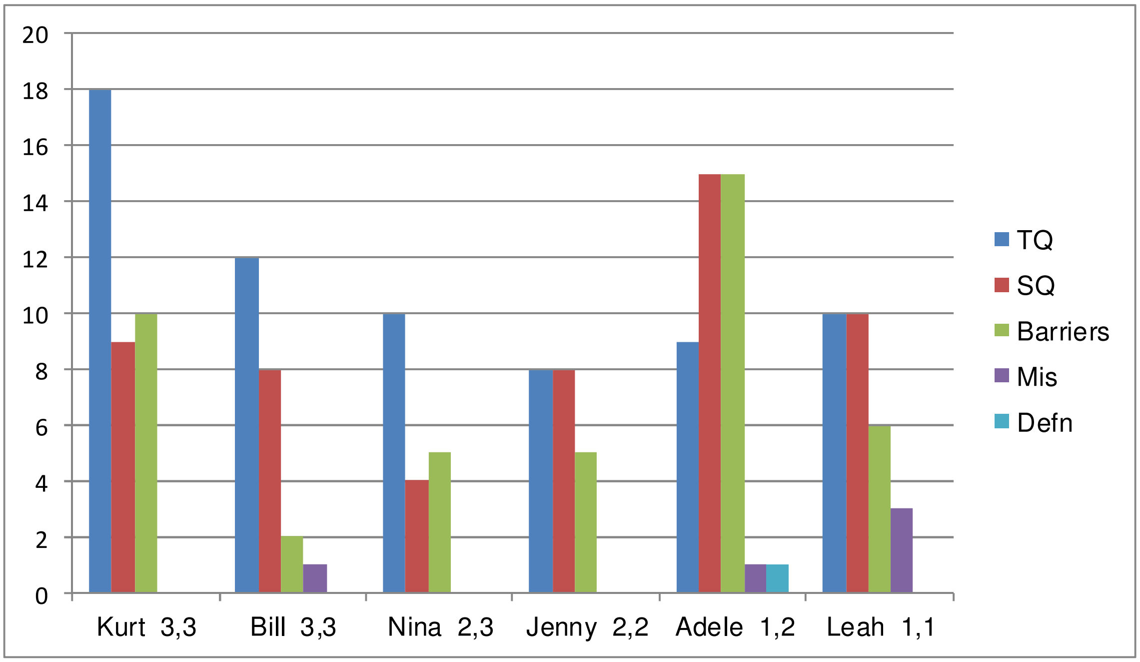


Figure 4.4 Frequency of Codes in Interviews; Teacher Qualities, Student Qualities, Barriers, Misunderstandings, Definition of Inquiry.

Care was taken to allow for new codes to emerge as well, and, as a result, one new code emerged during Phase Two analysis: *personal experiences*. The sixth (new) theme that arose out of the data, the teacher candidates' *personal experiences,* with inquiry-based instruction in their own classroom or in their experience as students, helped to lend an on-going narrative for each of the interviewed TCs. However, these *personal experiences* were coded far more frequently in the interview than in the reflective journal postings as a way for each TC to relate a narrative of their classroom teaching experiences. Embedded within some of these personal experiences codes are examples of teacher and student qualities required for inquiry, or definitions of inquiry. For example, Jenny stated,

> Secondly, although I'm still sold on the many rewards of teaching with inquiry, I recognize that my lessons will most realistically range between full-blown inquiry, activities that are completely teacher directed and everything in between. (Jenny, Journal 042811)

Here Jenny is defining the range of possible inquiry activities reflecting more teacher-led to more student-led. Due to the fact that each narrative that was coded for *personal experiences* was also coded by another code, (i.e. *definitions of inquiry*, or *qualities for inquiry*) each statement was revisited and each of the personal experience codes were re-coded into one or more of the other four themes during the cross case analysis. Thus, four themes were the focus for the case studies and the analysis that follows.

In addition, four new codes emerged from the data while preparing the case narratives. Of these four codes, one was a new theme and three were enhanced existing themes. The new theme was: some TCs *found it to be easy* to implement inquiry. The three codes and the themes they enhanced include: 1) inquiry requires *differentiation*, a sub-theme under *qualities for inquiry*, 2) *frustrations,* a second new sub-theme under *qualities for inquiry* and 3) TCs reflected on *four shared barriers* under the theme *barriers to inquiry.* This theme and the enhancing sub-themes will be described in more detail in the cross case analysis in Chapter V.

In the sections that follow, each case is described in a detailed narrative that includes quotes from their written and verbal reflections as well as their TPA commentary. Most of the reflections presented are representative of Schön's reflection-on-action (Schön, 1987). Each case begins with a quote that typifies the candidates' views of inquiry and the context of this candidates experience, and is then followed by three sections pertaining to the three sources of data collected: TPA commentary and video clips, reflective journal postings, and interviews.

Kurt: *"I knew almost nothing about inquiry-based practices before our summer class. I found the topic very exciting, and continue to feel this way."*

Kurt is a non-traditional male student. He worked for a few years in an industrial science setting in a research and development capacity. He is married with no children. He was pursuing a life science licensure. His practicum experience was in a large urban middle school classroom, and his student teaching experience was in a large urban high school with 34% English learners, 86% students of color, and 81% on free-reduced lunch. However, in his biology class, he had 60% English learners and 20% on IEPs. He also spoke candidly in the methods class about how his middle school cooperating teacher was a firm believer of inquiry-based instruction and used it weekly, while his cooperating teacher in the high school did not use inquiry at all. He received a 3 for both of the TPA Task 2 rubrics. He was considered a top-scoring candidate.

Teacher performance assessment: Task 2. When Kurt's TPA commentary and video were analyzed he received a score of 3 for both rubrics. This ranked him not only as passing this task, but as performing above many of his peers for both the engaging students in learning and deepening student learning during instruction rubrics. While he only referred to inquiry once during his write up, he specifically referred to students and their roles in the activity 46 times.

The video footage he included was one clip 16:51 minutes in length. He was observed during the video engaging the students through a personal story of his research on pet nutrition. This was followed by an overview of the fecal analysis activity that the students completed. The students were asked to use data tables, prepare graphs, interpret the data that was provided, and to justify their explanations of the fecal analysis in terms of the assimilated nutrients of different types of dog foods. Kurt read through the background information and elicited students' responses and posed questions for student feedback. The students worked in small groups to analyze the data and completed the questions on the inquiry activity. The last few minutes of the clip revealed the students interpreting the graphs and offering their explanations for the best foods for different dog breeds. This was done as a large group discussion. To facilitate and guide students, Kurt stated:

> Instead of simply telling them how to figure it out, I tried to lead them to their own understanding through a question. I reiterated that the first column says it is the amount in the food, and the second column is what comes out in the feces. From this many were able to come to their own conclusion about how to determine the amount that was assimilated. (Kurt, TPA commentary, prompt 3)

However, he also referred to this class of students as being "very accustomed to being spoon-fed the answers to worksheets and most lessons are about as far from inquiry as I've seen" (Kurt, TPA commentary, Prompt 1a). Overall, he felt that this lesson had achieved its goals for his students' learning through inquiry-based instruction as well as the content of nutrients and nutrition.

Journal entries. Each week, Kurt's journal entries were longer than most of his peers' entries, and he provided context and evidence to back up his claims and comments. He presented deeply reflective comments each week, and therefore revealed a very thoughtful and introspective look at his teaching practices. His understanding of inquiry and goals for science teaching were apparent from the very first posting in the summer. He described what students would be doing:

> Inquiry provides a way to involve students in the process of their own learning, thereby promoting deeper connections with the material. It also (and I must say I love this part because it touches on my two principle goals in teaching) provides a way to help students develop critical thinking skills and a predilection for continued, lifelong learning... students take on larger roles and responsibilities in their own learning... discovery of answers... increased student participation... see more activity, though again, not disorder or chaos. Students might be involved in hashing out ideas and proposing possible solutions, or perhaps they are making careful observations and drawing conclusions. Students involved in an inquiry-based classroom exercise may be

> more likely to be working in pairs or groups and an emphasis will likely be placed on brainstorming. (Kurt, Journal, 072010)

He also spoke of the teacher as a guide or facilitator for student self-discovery.

Kurt did not reflect much on inquiry during his fall postings. He did, however, discuss the barriers he encountered during his middle school practicum. This school's teachers and textbooks were very supportive of inquiry-based instruction, and yet, "activities often had to be a bit more structured for students to be able to progress. In other words, I found that it is quite difficult to make truly open-ended inquiry practices work," (Kurt, Journal, 121010). At this stage in his teaching, he was wishing for more open-ended inquiry and was struggling to make such inquiry happen.

He returned to the subject of inquiry in multiple journal entries in the spring during his student teaching. During the open response posting, Kurt discussed how inquiry was progressing in his classroom. His students were using a computer program to facilitate their learning and inquiry activities. His narrative flows easily between teacher qualities and student qualities, as well as the barriers that he and his students encountered during one particular lesson. "The lab is fairly inquiry-based, and the program does a good job of providing some structure and required steps, but not giving too much away. The major drawback to the lab was the inflexibility of the program," (Kurt, Journal 031011). He went on to add:

> Despite these frustrations, I think the activity actually helped me take a real step forward in the inquiry department for my students. I stressed that they might want to run the entire experiment once before recording any <u>data</u>, then go

> back and do it again, perhaps making changes as they learned. (Kurt, Journal, 031011)

Kurt noted that his students “were feeling frustrated” with this activity and he told them “not to worry, and that it was okay to feel a little frustrated it means you are learning (or about to hopefully).” (Kurt, Journal, 031011)

When posting his teaching philosophy in the spring, inquiry-based instruction was a large part of his guiding principles of not only planning and teaching, but for student engagement, participation, and learning. “I am a strong believer in the 5E learning cycle, and will attempt to incorporate its principles into many of my classroom activities” (Kurt, Journal, 040711). In particular he spoke of the experience his students had with “brainstorming, generating and implementing their own procedures, and reflecting on their work” as instrumental for “the construction of their own knowledge” and their “intellectual and social growth”.

Unlike some of his peers, Kurt chose to revisit and reflect on inquiry-based instruction, even when not solicited to do so. His passion for inquiry and some of the struggles for implementing inquiry-based instruction were present in his final overview journal for fall, “Mid1” (121010), and open response in the spring, Mid3” (031011). He talked at length about the student qualities required for (or gained through) inquiry-based instruction, including: “curiosity”, “openness to new ideas”, “self-esteem”, “students become active researchers”, “employ scientific methods and strategies”, and “scientific habits of mind” (Kurt, Journal, 040711). His references to what he would be doing as a teacher crossed over into what the students would be doing so that the teacher qualities and student qualities intermingle. "I will also incorporate web based inquiry into my classroom, affording students the opportunity to conduct inquiries in ways that may otherwise be impossible or impractical," (Kurt, Journal, 040711)

He admitted in his "Last" journal entry that he had learned a lot in the summer methods course and this stuck with him throughout his practicum and student teaching.

> I knew almost nothing about inquiry-based practices before our summer class. I found the topic very exciting, and continue to feel this way. In looking back over my initial posts about what I think inquiry looks like, and what issues or disadvantages their might be to inquiry, I basically feel the same now as I did then. (Kurt, Journal, 042811)

He also reflected on the barriers that inquiry presented in terms of the time it takes to prepare a good inquiry lesson.

> Anyway, the point is that I was not able to "make happen" many of the things I really wanted to. Inquiry was not a regular part of my teaching; students were not able to work collaboratively on a regular basis; lots of material was presented in a didactic way; many lessons were not culturally relevant; I cannot say that I established a real classroom community. (Kurt, Journal, 042811)

In this statement, he was clearly laying out a broad list of pedagogical skills; inquiry, cultural relevance, creating a classroom community, collaborative groups, and rating himself low on all.

Interview. Kurt's interview was 59:09 minutes long where he offered a rich picture of his experience with inquiry-based instruction in his fall practicum and spring student teaching placements. "I think you know, and like I said, my student teaching experiences were pretty good, but my middle school was like rock star inquiry and my high school was completely the opposite" (Kurt, Interview, 082611). He also stated that, "My middle school used, national research council [*sic*] book that was designed specifically to help bring inquiry to middle schools, and it was like so awesome you know" (Kurt, Interview, 082611).

Kurt discussed at length some of the barriers that he encountered while student teaching. This assignment came very early in his student teaching and he did not know his students well. Also, there was not a culture of inquiry at the high school where he taught.

> Um, well, I mean overall inquiry, inquiry-wise, you know there wasn't really a lot of that going on. From what I could see…I discussed it mostly with my cooperating teacher, not with the rest of the department. And you know the basic comment I got back was, "well good luck". (Kurt, Interview, 082611)

He also identified his students "discomfort with ambiguity" as a barrier to implementing inquiry-based instruction. "My students would straight up tell me, 'Why don't you just give us the answer?' That kind of thing. So like they definitely didn't, they were not pleased with any sort of ambiguity. Like, these kids were worksheet-aholics" (Kurt, Interview, 082611). He also considered that being a new teacher was a barrier for him, as he did not have the support from his cooperating teacher.

He also encountered barriers in completing the video assignment. While completing the assignment, he did not feel this teaching event was a good example of inquiry-based instruction and therefore some of the prompts were difficult to reflect on in meaningful ways. He also was confronted with difficulty getting the video footage. He at first was offered help by the media specialist from the school, but they backed out. Then, his cooperating teacher told him he would not be willing to help with videotaping. In the end, he had one clip, with a camera in one location in the back of the room, focused mostly on the front of the room (and him) and the few students in between. His university supervisor was observing that day and did one sweep of the class with the camera on the tripod.

Kurt also discussed at length the qualities of teachers and students who are successfully doing inquiry; again he discussed inquiry from both standpoints and often would switch back and forth. Students were “graphing”, “interpreting data”, “working collaboratively in pairs”, engaged in the “scientific ways of knowing”, “coming up with logical arguments”, “drawing”, and “questioning” (Kurt, Interview, 082611). Teacher qualities included “gaining a familiarity of his students’ prior knowledge”, “posing engaging questions”, “linking content back to prior learning”, ”providing relevance”, “promoting discussion”, “provide scaffolding when necessary”, and “teaching vocabulary” (Kurt, Interview, 082611).

While analyzing his video recorded lesson during the interview, he came to realize that his lesson was more student-directed than he initially thought. When he completed the TPA commentary for this assignment, he did not believe this was an example of strong inquiry—in fact, he felt that it wasn't inquiry.

> It [the lesson] didn't follow the 5E model in particular, and certainly not in any strong way, in my mind. Um, because I don't think the students were really exploring the subject before they were basically being given information. It sort of start, like to me they, the two, you either start with the information and then you do something with it. Or you kind of get into the thing a little bit first, to develop some engagement and some desire for the information. Then you get to the information part, and then maybe you give more details after that. And I don't feel like that that's really the sequence that I did it. So I failed at that. (Kurt, Interview, 082611)

However, after analyzing the lesson with the "Essential Features of Classroom Inquiry and their Variations" chart (NRC, 2000) during the interview he came to realize his students were engaged in a question provided by him and asked to analyze the data given, both indicating more teacher direction but inquiry-based (see Appendix B).They were guided in the process of formulating explanations, and were directed toward areas and sources of scientific knowledge, while some of his students were forming their own reasonable arguments others he coached, each one indicating a more student directed level inquiry. While this was coded as a misunderstanding of inquiry, he was able to adjust this thinking and affirm his understanding that his TPA video activity for Task 2 was indeed an inquiry activity. Therefore, this was a corrected misunderstanding.

Bill: *"I'm going to do a lot of class discussions."*

Bill is a traditional male student, having completed his undergraduate degree in chemistry and beginning his initial licensure program immediately upon graduation. He is married with no children. He was pursuing a chemistry licensure. His practicum experience was in a large urban junior high school classroom, and his student teaching experience was in a large urban high school with a strong IB program. His students were pre-IB tenth graders in chemistry. He received a score of 3 for both rubrics for TPA Task 2. He was considered a top-scoring candidate.

Teacher performance assessment: Task 2. When Bill's TPA commentary and video were analyzed, he received a score of 3 for both rubrics. This ranked him as passing this task, and as performing above many of his peers for both the engaging students in learning and deepening student learning during instruction rubrics. He did not mention inquiry once during his write up, whereas he specifically referred to students and their roles in the activity 15 times. His lab was more "cookbook" by design; however, the way he implemented this activity revealed that he guided students to a deeper understanding to analyze their data, and asked them to justify their answers as he rotated to each lab station.

The video footage he included was one edited clip 16:11 minutes in length, and he edited out the transition from introduction to lab stations. The lab portion began at 4:10 into the video clip. The students were combining magnesium and hydrochloric acid, boiling off the remaining water to isolate the product. He guided the students through the process of calculating the empirical formula of the product ($MgCl_2$). He expressed, “To my surprise, a good number of students were unsure of what exactly was left in the evaporating dish” (Bill, Video Annotations, 022811). The students also had trouble connecting the concept of the conservation of mass with the procedure they were following. “A good number of students were able to connect the law of conservation of mass with what we were doing without being aware they were doing it. Interesting” (Bill, Video Annotations, 022811).

As Bill visited each lab station during his teaching event, he guided the students to connecting the law of conservation of mass with the procedure they were performing to solve the mass of chlorine. While talking with the lab groups, he modeled the equation on a note card as the students discussed their solution, and left his notes at each lab table. He facilitated these conversations well with each group, displaying a clear objective in mind for what he wanted the students to learn (conservation of mass) and the underlying chemistry as well. He also commented on his facilitation of the small group conversations in his write up for the TPA Task 2:

> In the clips I am trying to get them to make the connection explicitly by asking them what concepts they are using to guide their data analysis. Once I mention it, they seem to be able to make the connection, but before it is rather fuzzy. (Bill, TPA commentary, prompt 2)

This lesson followed what he referred to as the ideal form of inquiry, stated earlier in the year in his first “Early” journal posting:

> And I as the instructor would carefully guide the discussion by tailoring some of their ideas until I feel the students have explored the options well enough,

> and have come to the conclusion I intended with a good understanding of the concept. (Bill, Journal, 072010)

The student qualities that he emphasized in his commentary included: “data analysis”, “justifying answers”, “design their own procedure” and “thinking critically”. Whereas his own teacher qualities included: “guiding through calculations”, “modeling”, “facilitating”, and differentiating instruction. Bill specifically discussed differentiating instruction in this inquiry lab as:

> I felt that although I was trying to engage all students in this activity that I was really trying to focus on the bottom and the top students through letting them come up with their own procedure. This let the top students really get detailed with their procedures and creative, while it forced the bottom level students to really think about the subject and think through what they were doing instead of just going through the motions and not really learning anything in lab. (Bill, TPA commentary, Prompt 1b)

Differentiation in inquiry appears again later in his TPA commentary for Task 2, when he is prompted to discuss what he might do differently in the future:

> At this point in the semester I have a pretty good idea of who the students are that require extra time for tasks, or take longer than the average student to understand certain concepts. Given the opportunity, I would have spent more time with these students and made them a more significant part of the group conversation of the data analysis and calculations. (Bill, TPA commentary, prompt 4b)

His knowledge of his students' abilities in chemistry could allow for this type of facilitation of student learning; learning through discussion in small groups.

Journal entries. In Bill's first journal posting in the summer, "Early", he described the teacher's role in inquiry as leading a discussion following a demonstration:

> And I as the instructor would carefully guide the discussion by tailoring some of their ideas until I feel the students have explored the options well enough, and have come to the conclusion I intended with a good understanding of the concept. (Bill, Journal, 072010)

At this very early stage in his methods course work, Bill already had a notion of students building their own knowledge with the scaffolding he provided with his demonstration and discussion. He mentioned inquiry labs as a second form of inquiry instruction. The students' roles would include "sharing ideas", "challenging other's ideas", and "drawing conclusions from data". He refers to inquiry as a backwards approach. "This backwards like approach forces students, through their data analysis and interpretation, to understand the concepts behind their conclusions, rather than simply following instructions on a lab sheet" (Bill, Journal, 072010).

He also revealed a misunderstanding regarding inquiry-based instruction namely; open inquiry is the ideal form of inquiry.

> The ideal form of an inquiry based lab would be entirely open-ended. The experiment would simply explore a concept, without giving any specific instruction. I think that this method would give students too little direction, and

> be counter-productive. It would remove the motivational element that is necessary for inquiry. Since the students would have no set goals except to explore a concept, they would most likely not know where to begin, or care to begin at all. (Bill, Journal, 072010)

While he did see open inquiry as exploration, he did not see exploration as being directed by the instructor at this early stage of his development as a teacher.

Bill's early views of inquiry were quite candid in his "Mid1" posting during the fall. At this point, he had completed two methods courses of the three required at this university and had completed his practicum in the junior high. He stated:

> I am also more aware and convinced that a student centered classroom is the way most students can be reached. When I was doing my observation hours in Iowa, I was skeptical of the way the teacher ran her classroom (highly inquiry/student centered). I preferred learning through lecture, and thought that best for my students. After hearing all her reasons, I became more open to the idea, and after doing this program and my experiences so far I am an avid believer that inquiry is the best way to reach the most amount of students. There will be no foolproof method; some students will always be left behind. But, so far, inquiry seems to me the best way to make knowledge accessible to students. (Bill, Journal, 121010)

This revealed his thinking and some of the challenges he had overcome regarding teaching through inquiry.

Bill included inquiry in his teaching philosophy in the spring. He correctly defined inquiry, using four of the 5Es— engage, explore, explain and elaborate—to elucidate his thinking. He talked explicitly about what the students would be doing in an inquiry classroom.

> Through inquiry students will engage in and take control of their own learning. They will be encouraged to explore their own world, pose their own questions, and discover their own answers. Not only is this method accessible to most students, it also increases meaningful learning the most. Real world concepts and issues are affirmed the most when students are able to directly experience them and come to their own conclusions. (Bill, Journal, 040711)

He considered inquiry to be a strategy that would "reduce socioeconomic inequalities" and would reach "as many students as possible." therefore, a student-centered classroom is important to him (Bill, Journal 040711). Interestingly, he also stated that students in his classroom, "will be encouraged to take control of their own learning and develop their own views about the world which, when guided by the teacher, are in fact the correct factual concepts found in the textbooks and on the exams" (Bill, Journal, 040711). Students would be developing the correct concepts through his guidance in inquiry.

Unfortunately, Bill did not choose to comment on inquiry during his journal entry regarding barriers to teaching, nor in his open response in the spring. Bill chose not to post a final journal at the end of his spring methods courses as well. Therefore, narrative from his interview can help to understand his thinking about inquiry at the end of his licensure coursework.

Interview. Bill's interview was 33:38 minutes long and was held in a coffee shop. Therefore, there were times when it was very difficult to transcribe parts of the dialogue. He analyzed his videotaped lesson using the five essential features and indicated variation in the levels of inquiry. Students were engaged in a question he posed and then were given possible connections to scientific concepts as well as steps and procedures for communication—an approach that is more teacher-directed. However, his students were collecting data that they were told to collect and guided in a process of formulating their explanations while he sat with each group. These are examples of more student-directed inquiry. However, despite this assessment using the "Essential Features of Classroom Inquiry and their Variations" chart (NRC, 2000), Bill still did not think this lesson was inquiry-based, revealing a possible misunderstanding (see also Appendix C).

> Um. I think it falls more towards not than as inquiry. Just because they were involved in any design process of the experiment. [questioning voice] Um. I guess I wanted them to all come to the same answer, there was, there was definitely a right answer. And there wasn't any um other interpretation or different interpretation. It was right or wrong. So that in my mind would be a very directed/structured part of it, seems to make it pretty far from inquiry. (Bill, Interview, 082611)

And yet when probed further about his thinking, he contradicted himself and stated that he did redesign this lab to be less “cookbook” and have more student-data collection and data analysis. “So, I purposefully made that a little bit more open but not the other parts I left pretty close [*sic*]” (Bill, Interview, 082611). He later stated this was actually guided inquiry. “The lab as a stand-alone wasn't guided, but when I went around and talked to them, it became more guided” (Bill, Interview, 082611). It was how the lab was implemented that made it inquiry-based in his mind, rather than how it was written.

Bill spoke at some length regarding the barriers he encountered during his student teaching. He identified his students and his cooperating teacher as the biggest barriers. He described his students expecting and wanting lecture, meaning they wanted the correct answers given to them. “Because even with the inquiry thing I tried to do in class, I got a good amount of resistance,” (Bill, Interview, 082611). And in describing his cooperating teacher, he stated, “Yeah, he um, he wasn't explicitly against inquiry, and you could kind of tell by his attitude um, that he thought that the only form of meaningful learning was um, lecture worksheet that's very traditional sorts of things” (Bill, Interview, 082611).

The qualities he wanted to have as a teacher of inquiry included two instructional strategies: leading discussions and discrepant events. Class discussions and small group discussions appeared to be his main focus for inquiry. He did not discuss the *student qualities for inquiry* in any depth. In fact, he questioned whether he would let the students generate their own explanations.

> Yeah. Um, and as far as the explanations go, I'm not sure how much I'll toy with that. Um, because it supposed to be all the of the different features, the right and wrong answers, um, yeah, I'm not sure about that one [*sic*]. (Bill, Interview, 082611)

In general, Bill did feel that he incorporated more inquiry than his cooperating teacher did, however, he did not reveal in-depth or varied levels of inquiry. He definitely wanted students to have a deeper understanding of the concepts. He felt that his method of inquiry through small group discussion would help with this endeavor.

> I'll think they'll have a deeper understanding of the concepts um, since this is a general chemistry course, there's a lot less emphasis on actually working problems. So, um, with all of the extra time I'll have in my classroom not having to teach how to work problems and stuff, the only math we're really gonna do is stoichiometry. Yeah. So all of that extra time I'll have, I'm just gonna was do class discussions exploring concepts further. (Bill, Interview, 082611)

Both of these statements mirrored his thinking of inquiry in his very first posting in the summer.

Nina: *"Inquiry… an area where I will need to continue to grow."*

Nina was a traditional female teacher candidate. She attended the secondary science education graduate program immediately following her undergraduate experience. She is a single woman who also coaches college sports. She was pursuing a physics licensure. Her practicum experience was in a large integrated district middle school classroom, while her student teaching experience was in a large suburban high school. The lesson that she analyzed for her TPA was a 9th grade physical science course. She noted this group had a high number of students for whom science and math were challenging. She received scores of 2 on S4 “Engaging Students in Learning” and a 3 on S5 “Deepening Student Learning during Instruction” of her TPA Task 2. She was considered a mid-level passing student.

Teacher performance assessment: Task 2. When Nina’s TPA commentary and video were analyzed, she received a score of 2 of rubric S4, and a 3 on the S5 rubric. This ranked her as passing this task, and performing above many of her peers for the second video rubric. It is interesting to note that she only referred to inquiry once during her write up, whereas she specifically referred to students and their roles in the activity a total of 56 times.

The video footage she included was two clips (7:34 and 13:21 minutes in length). In the first clip, Nina reviewed data collection from the previous day’s class. She asked for student input as she modeled graphing the data on the board. The second clip showed Nina demonstrating Newton’s First Law of Thermodynamics using different discrepant events. She used a predict-observe-explain (POE) approach for each demonstration that she performed. This teaching strategy consistently allowed students to make their own predictions, observe the discrepant event, and explain to the class what they observed and justify their explanations.

When reflecting on this lesson, Nina commented on the fact that she wished she had asked students to write down their predictions and explanations so that she could be sure that every student was actively participating:

> If I could do this demonstration over, I would incorporate time to have the students write what the terms that were introduced to them mean in their own words. I also might have students write down a hypothesis on what will happen to the egg once the tray is hit. This will introduce students to make a hypothesis / prediction and then after the demonstration, I would have the students write down what happened and if their hypothesis was correct. I would also have a discussion with the students about making a hypothesis / prediction and analyzing the results and letting them know that if their hypothesis / prediction was incorrect that they should not quickly erase and write in a different hypothesis to match the results. (Nina, TPA commentary, prompt 4b)

Her description of what she would change if she were to teach this lesson again clearly showed the level of scaffolding she wished she included for this class of students.

She mentioned both the *teacher qualities* and *student qualities required* for these two days of teaching/learning. *Teacher qualities* included discrepant events coupled with POE, asking questions, modeling data analysis through graphing and student engagement. She had decided to model data analysis because, "[m]any of the students are unable to make the connection between gathering data and how to analyze it" (Nina, TPA commentary, prompt 1a); this could also be considered a *barrier* to more open inquiry. *Student qualities* included POE, active participation, and relating examples in class to their lives. "In the clips with the demonstrations, I think I do a better job asking students to think about other examples they have seen and how it relates to their lives" (Nina, TPA commentary, prompt 3). Overall, she felt the lesson went well. She stated:

> I thought the students were very engaged in the demonstration and seemed enthusiastic about it. I was surprised at how many students did not think the egg would fall into the smaller beaker after they had seen the demonstration two times before. I was also impressed with one of the students who mentioned that what happened to the egg would depend on how hard the tray was pushed / tapped. This showed me that she was really thinking about all factors of this. (Nina, TPA commentary, prompt 1a)

Nina considered important nuances of student learning and engagement such as the many factors that her students were considering that could influence the results of her egg drop demonstration.

Reflective journal postings. In Nina's first reflective journal posting "Early" (072010) she described inquiry from the teacher's role as well as what the students would be doing. She described her role as a "resource", a "devil's advocate", and to provide questions that promoted engagement and challenge student thinking. In turn, her students would have more, "leeway to determine their own methods on how to obtain the information they need" (Nina, Journal, 072010). They would be engaged in hands-on activities, collaborating in small groups, and relying on “each other as resources” of ideas and information. A tension between theory and practice was revealed when she stated, “It also challenges students as most have been programmed to rely on teachers for every little instruction for each activity” (Nina, Journal, 072010). She defined inquiry as, “finding information that might be in unknown or unfamiliar territory or building on previous knowledge. It can consist of asking meaningful questions to get a deeper knowledge and understanding of a certain subject,” (Nina, Journal, 072010). However, she also described inquiry as an opportunity for students to develop and create an “unstructured lab” (Nina, Journal, 072010).

She did not comment on inquiry during her fall open response overview, or in her open response during the spring. However, in the spring during the second journal posting “Mid2” (020311), which asked the candidates to consider barriers to teaching and learning at their placements, she expressed hopes to use some of the discrepant events that her peers had demonstrated during the summer, thus revealing a desire for prepared materials.

However, she commented broadly about inquiry in her teaching philosophy journal posting “Late” near the end of the spring (040711). She referred to herself as a coach and a teacher, and considered the complexities of being able to teach and reach all individual learning needs in her class. She expressed her classroom as being one of gradual implementation of inquiry:

> Guided by the state standards, students will learn the concepts of Physics in a fun, interactive, welcoming and safe environment through conducting inquiry-based experiments, hands-on learning and group work. The beginning of the school year will require activities with more direction from me with a gradual shift to student-directed activities... I will help guide the students to better understand the scientific concept and will also assist with making connections to real world situations. (Nina, Journal, 040711)

She realized that the potential barriers to achieving inquiry-based instruction were time and patience.

When reflecting back upon the entire year, she stated in her final posting in the spring that inquiry-based instruction was not something that she would be able to implement immediately in her classroom. She also admitted a need for continued growth in her development as a teacher:

> Inquiry-based instruction and planning is an area where I will need to continue to grow. One of my observations with [my university supervisor] he asked how and where inquiry could be implemented. That question took me by surprised and I was not really sure. I think keeping inquiry in the back of my mind as I plan and teach will be helpful. (Nina, Journal, 042811)

She reflected on the importance of inquiry in her planning and teaching and her current limitations of being able to accomplish it. Overall, Nina did not comment on inquiry very often in her yearlong reflective journal postings.

Interview. Nina's interview was 40:33 minutes long. Nina revealed that she chose to video record the 9^{th} grade class of general physical science students, a more challenging class for her. She felt she would learn more from reflecting on her instruction for this class than she would for the 12^{th} grade physics students. "So I definitely wanted the assignment that was challenging for me, and something like that. So I chose the 9th grade class" (Nina, Interview, 072111). She described this class of 9^{th} graders as:

> It was kind of hard with that group because they were thirty kids in that class that were um, students ranging from very low level science and math to average performing, and this was a lower level physical science class. So, it's kind of hard to get everyone focused on the one same thing." (Nina, Interview, 072111)

She also reflected on the fact that this was an assignment she did very early in her student teaching, before she knew her students as well and before they were comfortable with more student-centered activity in class.

When asked, she did provide details of how inquiry-based instruction changed later in the semester, she stated:

> …[W]ell, I think one of my last two weeks they were ending a unit working on, I think it was simple machines. And so, the students pretty much designed their own lab activities so they picked a tool they were interested in, and they made their own questions, they made their own lab, like how they collect data and everything. So they were a lot more student-centered. But, again there were

> also some students who needed a little bit more help. Like, how do I make a lab to test the wedge or whatever their tool was. (Nina, Interview, 072111)

The students also presented their findings to the class. It became clear during the reflection that she (like others) noticed that inquiry-based instruction required a nuanced and differentiated implementation, and that her students demonstrated the qualities of inquiry.

Nina rated the activity that was video recorded for the TPA task as more teacher-directed. Learners were sharpening and clarifying questions and some of her higher performing students were posing new questions. Learners were given data to analyze—and possibly ways to use the evidence to formulate an explanation—while some learners were guided rather than given ways. Learners were given possible connections as well as directed toward areas of and sources of scientific knowledge. For communicating and justifying explanations, learners were given steps and procedures as well as provided guidelines to sharpen their communication. (See her analysis of the "Essential Features of Classroom Inquiry and their Variations" chart in Appendix D.) Nina detailed why this activity was more teacher-focused, and she related it back to her time in this classroom, and both her familiarity with the students and the students' discomfort with student-directed work.

> So um I think the activity that I video recorded, it is a little bit inquiry-based, but it's not um, as student-centered as, um, I would have like it to be. I guess. Um. But again, with the class that I was working with I didn't feel comfortable doing it completely student-centered at that time. (Nina, Interview, 072111)

While this statement was coded as a *barrier*, it could also be interpreted as indicating an awareness of students' prior knowledge and abilities in science and math.

Nina admitted that her thinking of inquiry has changed sharply since the beginning of the summer science methods course, thus revealing her own misunderstandings have changed. She thought initially, "I guess when I first started this program I thought inquiry-based instruction was, 'ok, here's your supplies, go, and now think of something.'" (Nina, Interview, 072111). However, now she had a more nuanced view of inquiry and an understanding of the complexity of implementing inquiry from the teacher's perspective as well as from the students' perspective that includes all five essential features of inquiry.

She talked at length about *barriers* to implementing inquiry that she encountered. She felt that physical science itself did not lead easily to inquiry, the context of the "class of students", "lack of materials", working with and through frustration, and her knowledge of the students all could be barriers to inquiry. "Um, I think too that sometimes the students can be barriers. Because they are not used, they might not be used to this type of instruction, you know" (Nina, Interview, 072111). She felt she still had some more to learn and therefore needed more practice implementing inquiry. An additional barrier relating to completing this assignment includes how some of the students reacted to the camera. One student in particular refused to participate while the camera was on.

> There was one girl, who she would raise her hand all the time, talk all the time, answer all of the questions, ask me questions about everything. But, as soon as

> she found out we were recording, she just shut down. (Nina, Interview, 072111)

This student was previously very active during class discussions and often raised her hand, but changed her level of participation during the videotaped lesson—thus changing the activity level of this student as well as the context of the class discussions on a typical day.

In addition, Nina spoke about the comments she received from her students and her goals for teaching science.

> Hopefully they will um, appreciate science more, and become interested in maybe even pursuing in a career in science. Um, I remember a lot of the students were was there on my last day, they were, saying you know, “I didn't realize that I really liked science. You know you really helped me. It was really good having you there.” And also, um, my cooperating teacher, because we had two different perspectives. And then a lot of the girls mentioned, it's really nice seeing a woman or female working with science. And they really liked that. Um, I'm hoping that they would be more interested in science—not necessarily physics, but just science in general. (Nina, Interview, 7/21/2011)

With increased student engagement and her modeling of good science practices she hoped students would gain more than science knowledge but also an appreciation for science as well. This could be identified as a *student quality*, “liking science”.

Another *student quality* she included was maintaining an open mind and dealing with frustration. Nina stated:

> So just making sure the students have an open mind for this type of instruction and to help them know that getting frustrated is alright. And I think if, over the time, hopefully you start to implement more inquiry-based instruction, you'll know your students and you'll see like when they getting beyond the point of frustration where it's not learning.

Frustration could be considered a barrier for students to accomplish inquiry. It is clear, however, from her comment that some frustration is okay for students to endure. Therefore, a teacher explicitly telling students that frustration is normal is important, and watching for student levels of frustration and facilitating as necessary to promote learning.

Jenny: *"Inquiry denotes asking questions and seeking answers."*

Jenny was a non-traditional female teacher candidate. She attended the secondary science education graduate program after deciding to make a career change. She was a single mom of a high school-aged son. She was pursuing a life science licensure. Her practicum experience was in a large suburban middle school classroom, while her student teaching experience was in a large urban high school. The lesson that she analyzed for her TPA was during a modern biology course for tenth graders. She noted this group had a high level of students IEPs through the school's special education services. She received scores of 2 on both rubrics of her TPA Task 2. She was considered a mid-level passing student.

Teacher performance assessment: Task 2. When Jenny's TPA commentary and video were analyzed she received two scores of 2 (out of a 4 point scale) on the S4 and S5 rubrics for this video performance assessment. This ranked her as passing this task, with a mid-range score but not exceptional. It is interesting to note that she only referred to inquiry once during her write up, whereas she specifically referred to students and their roles in the activity 45 times.

The video footage she included was three clips (4:06, 5:05, and 2:06 minutes in length) instead of the required two. In her clips she introduced an altered reality goggle tossing activity. Students were getting started with the activity and students were collecting data in the final clip. This activity had students wearing lab goggles with their lenses replaced with Fresnel lenses. Their task was to toss a beanbag into a five-gallon bucket placed 15-feet away. The goggles altered the students' perception, with their sense of where the bucket was located was inaccurate.

No data analysis was observed in the clips. Her written responses to the TPA commentary, however, were rich in detail, referring to all five essential features of inquiry, and including information relating to the larger lesson and unit. For example, she related this activity to the students' prior knowledge on brain development and neurobiology as well as offering scaffolding for data collection and analysis. She stated, "The application of the activity is hands-on and meaningful, is linked to both learning and language objectives, and clearly promotes engagement". In regards to her students and *student qualities* seen in the activity, Jenny mentioned that:

> These students have not participated in extensive labs and many do not like having to make predictions, record data, or analyze results. They also do not like to read procedures preferring instead to be told exactly what they need to

> do…most groups managed to collect and record data that allowed them to analyze and interpret their results and make sense of the follow- up questions. I wish we had captured more of the hour on video as there were many moments when students were clearly having fun and enjoying the activity immensely. (Jenny, TPA commentary, prompt 1a)

She focused specifically on student thinking and strategies for eliciting student thinking through questions and guidance. Jenny described her frustration that the clips did not include examples of students analyzing data, although the students had been doing this already. She commented on the poor sound quality at points in the video, with students' conversations not being audible regarding their depth of knowledge of scientific concepts.

Reflective journal postings. Overall, Jenny included written reflections that included four of the five themes, only *misunderstandings* were absent from her postings. *Teacher qualities* and *barriers to inquiry* were mentioned more often (5 and 3 times respectively). (See the Frequency Counts Chart, Figure 4.3.) In her first reflective journal posting "Early" Jenny defined inquiry as this: "From a very general perspective, I think inquiry denotes asking questions and seeking answers" (072010). She followed this with a definition of inquiry that included the qualities that students could gain.

> Inquiry based learning promotes critical thinking, the development of problem solving skills, and self-confidence in one's ability to learn about and understand science... The key, I think, to truly establishing these skills and abilities in

> students is to provide them with the "hands on" opportunities to experience for themselves the excitement and personal rewards that accompany genuine scientific inquiry. (Jenny, 072010)

She even included the need for adaptation:

> I realize that designing lessons to include inquiry based learning requires a great deal of organization, planning, preparation, and adaptation but I'm actually quite eager to create exactly that sort of curriculum and am excited at the thought of watching my students experience the joy of self-discovery and perhaps developing a passion for investigating the world around them and the confidence to know that they can. (Jenny, 072010)

She revealed a rich early concept of inquiry-based instruction. She also described the qualities that students should have including: the ability to "distinguish questions", "design and implement their own scientific inquiries", "recognize and resolve problems", "revise and rework procedures", and "defend a scientific argument."

Jenny did not choose to reflect on inquiry-based instruction during her fall journal postings; however, she revisited inquiry in the spring during an open-response posting. She described in detail the *student qualities* that were present during the inquiry activity she implemented in a DNA unit. Namely, that the students had some "frustration" which later transformed to "light bulbs started to go off". Here, she allowed her students the opportunity to engage in inquiry and let them struggle a little bit in hopes of greater personal gains in learning. She did not elaborate on *teacher qualities* or a *definition of inquiry*, nor did she elucidate the *barriers to inquiry*.

In her teaching philosophy journal posting, “Late” (040711), Jenny elaborated in great detail the types of *qualities* she has, and anticipates having, as a teacher; that of an expert facilitator.

> As a teacher I see my role as that of facilitator, one who simplifies the student’s task by passing along suggestions for tried and true methods of investigation and encourages them to experiment and explore. I relish the idea of being the kind of teacher that sparks impassioned discussions and elicits deep critical thought, but I also experience a little thrill each time I witness a group of students unwittingly immersed and passionately engaged in a cooperative problem solving activity... I’m confident at this point that my use of those educational tools and dedication to implementing an inquiry-based curriculum in my classroom will allow me to develop into an expert teacher one day. (Jenny, 040711)

One can see her hopes and her confidence in implementing inquiry-based instruction in her classroom. In her “Last” journal posting for the year (042811), she reflected back over her year, realizing that she initially thought inquiry-based instruction would be difficult to implement, but realized with experience that it can be easy. In fact, she stated:

> I found myself integrating inquiry without even realizing it. I used a lot of questioning and student-centered learning without even trying. This probably comes from learning so much about it. It seemed to really stick for me and it

> ended up not being as difficult to implement as I thought it was going to be. (Jenny, 042811)

Here again she returned to her earlier theme of inquiry as questioning.

She also explained the *teacher* and *student qualities* in some detail in her "Last" journal posting for the year (042811). Her qualities of a strong teacher of inquiry-based instruction included: time, patience, discrepant events, and planning student-directed activities. She described students as "naturally curious" and wanting engagement in science. But she spent far more of her time and space reflecting on the *barriers* and challenges of implementing inquiry-based instruction. These *barriers* included: the school, the district and local administration, the students themselves, the type and extent of collaboration among colleagues, time, her skill at developing interpersonal relationships with her students, and personal desire.

> Although we did discuss some of the challenges involved in creating an inquiry-based classroom when we first learned about the concepts last summer, I think it took my sometimes exhilarating, occasionally exasperating and always challenging classroom experience (in two VERY different schools) for me to truly recognize the extent of the teaching-with-inquiry hurdles that I will encounter… "Explore, explain, and elaborate" can present more challenges and, depending on your student's previous experience with inquiry, can take some time and practice to successfully implement. (Jenny, 042811)

Jenny's comments in her final journal posting revealed a rich and complex view of teaching science, one that included the impact of many stakeholders, in addition to patience and interpersonal skills.

Interview. Jenny's interview was 41:01 minutes long. She detailed her inquiry-based activity and the frustration she felt in her interview, as well as the *barriers* she encountered while attempting to complete the TPA assignment. She talked at length about the *qualities* teachers and students would need for inquiry-based instruction, each coded in eight long stretches of text. In her interview her discussion of inquiry was always in relation to *teacher qualities* and *student qualities*; she did not offer a general *definition*. She had no obvious *misunderstandings*.

The video footage of her TPA activity, albeit inquiry-based, was "not her first choice" to use as evidence of her inquiry-based instruction. However, the realities of her busy schedule led her to use this video as her evidence for this second task of the TPA. She felt that the portion of the lesson that turned up on the video footage was the "least inquiry-based" of all of the possible moments that could have been recorded. Her cooperating teacher was behind the camera, making the choices of what to tape and what to skip. She stated the camera was a "distraction"; when reflecting on the use of the video camera in her classroom she said that "I was awkward" and "it's a matter of getting the kids to forget about the camera."

Jenny considered her students to be one of her biggest *barriers to inquiry*. She stated:

> You know having to with this particular group being a little less um... comfortable with inquiry. So having to pull teeth a little bit to, you know, prompt. It wasn't major, because it was such a fun activity but you know, in order to get people going again, is back to the confidence level thing. In which, they haven't experienced a lot of it. (Jenny, Interview, 072111)

Other barriers that she encountered included the time needed to implement inquiry, the limitations of the video footage she had recorded, and both students and teacher candidate being distracted by the camera.

When looking at the “Essential Features of Classroom Inquiry and their Variations” chart, she scored her lesson as more learner-centered, with all five essential features, including the most student-centered variation, down the left-hand side (see her analysis of the “Essential Features of Classroom Inquiry and their Variations” chart in Appendix E). However, she did discuss the need to implement her plan somewhat differently, in that she planned to have the students pose the question. Instead, she had them select among questions. Also, she brought up the importance of scaffolding essential feature 4, learner connects explanations to scientific knowledge for the different students in her class, thereby differentiating inquiry-based instruction during implementation.

Jenny described *teacher qualities* and *student qualities for inquiry* in rich detail during her interview. *Teacher qualities* included checking for “prior knowledge”, “hands-on activity”, “organization”, “flexibility”, facilitation, “questioning”, and making “adaptations for individuals”. *Student qualities* included making "predictions", "questioning", "curiosity", "debate", and "argumentation." Three of the five essential features were present in the interview before she was prompted to look at the five essential features chart, questioning, data collection, and communication. But she added the qualities of engagement and collaboration as well. Her students were having fun, working together, and when reviewing the chart, staying on task,. She admitted that she learns best through inquiry and therefore, "When I think full-blown inquiry is the stuff that I'd really like to be doing. I would love to have a classroom with just, it's just got discovery labs with kids non-stop um, and how they are learning, is primarily this first category of inquiry." (Jenny, Interview, 072111)

Adele: *"A quiet class is a 'boring' class."*

Adele was a non-traditional student. She worked in both science and non-science related jobs before attending graduate school to pursue her physics teaching license. She is married with two high school aged children. She completed her middle school practicum in a large urban middle school and her student teaching in a large suburban high school. She started the program in the fall, rather than the summer, and therefore took the inquiry-methods course after she had completed both her fall practicum and spring student teaching. This sequence was not preferred but was necessary in her case as she was completing coursework for her undergraduate physics degree during the summer. She received a 1 on the S4 rubric and a 2 on the S5 rubric. Her video revealed the issues she dealt with in regards to classroom management in this ninth grade classroom, which in part led to her low score. She was considered a low scoring student.

Teacher performance assessment: Task 2. When Adele's TPA commentary and video were analyzed, she received a score of 1 for S4 (engaging students) rubric and a 2 on the S5 (deepening student learning) rubric. When regarding the engaging students in learning rubric, Adele ranked as not passing this task. She did not mention inquiry once during her write up, but specifically referred to students and their roles in the activity 31 times. The students' lab handout was not included in her assignment, and therefore it was difficult to determine whether the students were required to formulate explanations, make connections with physical science content, or communicate their findings. Her videotaped lesson was of her 9th grade physical science students.

Adele included two clips from her instruction during a friction lab activity, which she defined as being a cookbook lab. Students were to be completing the lab and writing up their analysis of what happened during the "rough and smooth" lab. The first clip was 10:27 minutes long. There was some evidence in it of Adele addressing students questions regarding their interpretation of the lab activity and of the terms of roughness and smoothness.

> They are performing a lab activity where they use probeware to measure the force produced by friction on a block of wood, moving across various surfaces. In many of the clips I am circulating within the groups to first, ensure that they have understood the instructions; second, to ensure that the equipment they are using is working properly; and third, to question them about the data and/ or results they have obtained. (Adele, TPA commentary, prompt 1a)

Much of the video footage and most of the second clip (8:07) showed her attempts at regaining student engagement and maintaining classroom management. She can be heard in the clips requesting individual students to “have a seat”, “work on their reading packets”, and asking “where’s your group?”, all in an attempt to gain control of the classroom and get the students back on task. There were a few students working in pairs around the periphery of the room. While these students could be on task, we do not hear their conversations, nor does Adele address them either verbally or in her written commentary. In the TPA portion where Adele was asked to reflect on what she would do differently, she attempted to comment on students’ use of academic language. However, she shortchanges even her own attempts to include it.

> In Video Clip part II at 00:31; while this portion of the clip is not concept or academic language oriented, I mark it as an opportunity because the entire lesson was very chaotic. I felt that I was spending more time managing the class, rather than addressing concepts and academic language. (Adele, TPA commentary, prompt 4a)

In her commentary, Adele addressed the *teacher* and *student qualities* present in the video, and linked them to inquiry-based instruction. She was addressing student questions, engaging students in the activity, circulating to check for understanding of process and content, eliciting student thinking, asking questions, and reinforcing and scaffolding student understanding.

> Another example of eliciting thinking happens in Video Clip Part I at 7:07, I am asking the students to explain their reasoning for selecting a particular

> example for the usefulness of friction. By asking the students questions and letting them come to their own conclusions, and then reinforcing those conclusions, it helps them to scaffold their own knowledge. (Adele, TPA commentary, prompt 3)

In turn, the students came to their own conclusions while performing the lab. All in all, this lab, the student management, and her students' misbehavior became the main focus of the video footage. Therefore, it was very difficult to find evidence of student learning and engagement. This negatively affected her scores on the TPA.

Journal entries. Due to her starting the program late, Adele's first journal entry was in the fall, rather than summer. However, she did not reflect on inquiry-based instruction until the open response in the spring ("Mid3", 031011). In it, she reflected on the barriers she had encountered during her spring student teaching while teaching her 9th grade physical science students:

> Inquiry comes and goes in my classroom. With the number of students I have it is difficult to do explore or expand activities. The layout of lab space is not the best, so lab type activities are difficult to manage, and in some cases hard for the students to complete. I am crossing my fingers that next trimester will be different. (Adele, Journal, 031011)

In this posting, she was referring to the same class of students in which she recorded for her TPA Task 2 assignment.

Adele also reflected on how she would like to offer her students guidance in learning science in her teaching philosophy. She talked specifically about using both cookbook labs and student-designed labs to afford students hands-on and inquiry activities.

> Therefore, I plan to use a variety of teaching styles (hands-on, inquiry, etc) in my classroom. I also plan to conduct a variety of experimentation in the classroom, ranging from cook-book labs, where the student follows a specific recipe (of sorts), to designing their own experiment, focusing on a real world situation. (Adele, Journal, 040711)

Interestingly, Adele's *definition of inquiry* and *student qualities* seems to be the limit of her reflections in her journal entries. She talks briefly about *teacher qualities* only in her teaching philosophy. Adele does not include what she would be doing in her reflections before or after this journal entry.

In her last spring posting, when most other teacher candidates are completing their last methods course, and she had the "inquiry" course yet to accomplish, Adele spoke candidly about her earlier *misunderstandings* about inquiry. She talked about inquiry being easier to implement than she previously thought:

> When I first started reading about inquiry, and the idea that kids could learn stuff on their own just by exploring, I thought "I have to see this!" My first posting talked about my insecurity with changes in teaching methods, I indicated that Inquiry was a mystery to me. In a way it still is, not because I don't understand it or don't know how to use it, but because it is not this grandiose thing that I made it out to be. I remember thinking, what am I

> doing? I have no idea how to do this inquiry thing. Now it comes naturally. (Adele, Journal, 042811)

She also mentioned the 5Es in her *definition of inquiry* in her posting. However, it was not until her last semester, her summer methods course, that she included a well-defined view of inquiry.

> Inquiry can be entirely student centered, where the students pose all of the questions, they make all of the assumptions and provide all of the connections (resources) to reach a conclusion. Or, it can be teacher led, where the teacher poses the question, the students make some assumptions with guidance, and the teacher provides some of the connections or resources to help students read conclusions. (Adele, Journal, 071911)

She also discussed the need to scaffold inquiry for more novice students. She provided a very detailed explanation of what students would be doing in class including: exploring, asking questions, observing, making assumptions, making connections, experimenting, and collecting data and learning:

> Since much of inquiry is experiential, I would expect to see a lot of experiments being conducted. I would expect to see students that are sharing their observations with either the full class or with their small groups. .... Most importantly you would hear students asking questions. "I wonder how…?, Why does…? What would happen if…?" (Adele, Journal, 071911)

At this point in her methods courses, Adele understood inquiry as an experience that students have through observation and asking questions.

Interview. Adele's interview was 53:08 minutes long. She had video recorded a few different lessons for her 9th grade students in physical science and her 11th/12th grade physics class. She could not recall which clips she had included for this assignment, so we watched a portion of the video again during the interview to remind her of which one she chose for her TPA Task 2. Her cooperating teacher had been following her with the camera during the lab activity, and handed the camera off to a student when he had to leave the room. In her video, her students were very distracted by the camera.

> Uh, the one thing about the video assignment that I felt was really frustrating, was the fact that, because they know they're being videotaped, they act differently. And then in some cases, they're gonna act better… That particular group, I think acted worse, I mean they did the hammy stuff in front of the camera. (Adele, Interview, 090111)

As stated above, Adele's video revealed her working tirelessly to gain control of a classroom of misbehaving students for all but the first 2 minutes of footage.

Adele described the lesson as a cookbook lab dealing with friction prior to analyzing the Essential Features of Classroom Inquiry and their Variation chart. "Well unfortunately it was a cookbook lab [laughs]. It wasn't, it wasn't greatly inquiry, but um, so yeah, I think that there were some times where they asked them to pose their own question" (Adele, Interview, 090111). However, when she evaluated each of the five essential features of inquiry, she ranked each of them in the middle of the chart between teacher-directed and student-directed (see Appendix F). She circled *learner* *sharpens questions provided by teacher*, *learner directed to collect certain data*, *learner given possible ways to use evidence*, *learner given possible connections*, and *learned coached in development of communication*. When Adele was asked to re-evaluate whether her friction lab was an inquiry lab, she stated, "Where there's definitely some aspects that were inquiry in the lab. Just from looking at the chart…I have a much more broad definition of what inquiry is nowadays" (Adele, Interview, 090111). To be clear, after learning more about inquiry in July and August ,Adele was interviewed in September on an assignment she had completed in February.

When reflecting back on this assignment, she begins to renegotiate her definition of inquiry and explain this activity in terms of her new definition:

> The activity as, as it was, as a cookbook lab, I think that it didn't, I think it could have been done better. You know, I think that it could have been rewritten and approached more from their questioning. Um, so, but I think that there were some things about it that, that they needed the guidance. In that they were used to the guidance. Um, inquiry was something that wasn't, it's really hard to say, because inquiry is so many different things. [laughter] And it can be seen in totally different ways, but what I was going to say, is that inquiry is something that they weren't used to. (Adele, Interview, 090111)

Adele also described at length the barriers she encountered while teaching her 9th grade class for the first five weeks of her student teaching. When prompted to consider how she might have done it differently, with her current knowledge and looking back on her student teaching experience, Adele said she wished she had infused more inquiry-based instruction:

> More inquiry, yeah. More open and going toward a more open-ended inquiry. I think it's something that never really experienced. Um, and in some cases, I kinda feel like they were opposed to it. Maybe because they just developed this dependence over time. (Adele, Interview, 090111)

Her 9th grade students' dispositions toward inquiry seemed to be the biggest barrier in her mind. This was also apparent in their behavior from her video clips. Other barriers included: the curriculum prescribed by her department, her lack of planning (she taught second hour what her cooperating teacher taught first hour), the students discomfort, and her own "confusion" as to what was expected of her at this placement since she arrived halfway through the semester.

For her 12th grade physics class many of these barriers no longer existed; however, she considered one of the textbooks assigned to the students a poor choice for the group of students. That said, she considered the time required to redesign labs to include more inquiry was a barrier in this class.

Adele also felt the assignment was difficult to complete early during her spring student teaching. She had wished she known her students better and that she had more of her own "control" of the class assignments and behavior management. In addition, she related that the TPA prompts were hard for her to interpret. Some of the prompts are in paragraph form, while others were a bulleted list on the SCALE document (2011). This misled her to leave out important information in her commentary:

> There was one part where it asks for four things, four or five things, and I caught most of them, but somehow I missed one part of the question, but it was all in one big block. And so, it was easier to miss parts. Especially when it was, here's this big block and here's these bullets, you think, ok I have to answer the bullets and then totally miss everything that's in that big block of text. (Adele, Interview, 090111)

This could lead to a lower score on the rubrics and will be interpreted in Chapter V.

When considering *teacher qualities for inquiry* Adele mentioned "planning", "classroom management", "academic language", "assessment", and "using higher order thinking questions". Her reference to inquiry as something that requires certain qualities of teachers was very limited compared to her numerous references to student qualities of inquiry. For *student qualities*, she mentioned:

> And understand with each level comes uh, a higher order of thinking where you're comparing things or you're evaluating something or, um, or you're having them apply what their learning in that, applying something that you've learned takes more thought than just describing or reiterating some vocabulary words. (Adele, Interview, 090111)

Here she referred to one of the goals of the 5Es Learning Cycle of inquiry-based learning. She also mentioned "discovery", "graphing" and "interpreting graphs". But as she continued to describe her own students they did not necessarily have these traits:

> They were used to being bottle-fed. They were used to um, being given a cookbook lab, and you follow the directions; well, in most cases, they wanted

> you to walk them through the directions, rather than following the directions themselves. I had a lot of the, "What do I do next?" (Adele, Interview, 090111)

She felt that there was a wide range of abilities in her class which required “more or less scaffolding” of the activities—hinting that his meant more scaffolding for more students more of the time. Adele returned several times to the importance of hands-on activities for student learning:

> And I think that they're gonna understand it a little bit better, because they can touch things and, and you know, when we, with the 6th graders, when we talk about speed, they can actually go out and measure what their speed is. Um, they can, they can do things that relate to their own lives. That they can make their own personal learning, um, and I, I really honestly believe if a person learns from their own personal learning it's, it's something that they learn, they want to learn it, they internalize it. (Adele, Interview, 090111)

Adele’s descriptions of *student qualities* spans the scope of inquiry-based learning, personal relevance, higher order thinking through analysis and evaluation, as well as the skills required to do hands-on science and graphing.

Finally, when Adele was asked to reflect on the TPA as a task to complete for class, she stated, “It was very tiring and a lot of work, but I thought it was a good experience” (Adele, Interview 090111).

Leah: *"Cause non-inquiry just has textbooks."*

Leah was a non-traditional student. She worked in both science and non-science related jobs and returned to graduate school to pursue her chemistry teaching license. She is married with a young child. She completed her middle school practicum in a large suburban middle school and her student teaching in a large suburban high school. She taught both honors and general chemistry students. She received a score of 1 for both TPA Task 2 rubrics, and therefore did not pass this task. She is considered a low scoring student.

Teacher performance assessment: Task 2. When Leah's TPA commentary and video were analyzed, she received a score of 1 for both rubrics. This ranked her as not passing this task, performing below her peers for both the engaging students in learning and deepening student learning during instruction rubrics. She did not mention inquiry once during her write up, but specifically referred to students and their roles in the activity 18 times. In addition, there was no evidence in the lab handout that students were required to formulate explanations, make connections with chemistry content, or communicate their findings. The lab included step-by-step directions for completion and a data table directing students what data to collect. Her videotaped lesson was of her 11th grade honors chemistry students.

Leah included one 3:41 minute video clip of her lesson that included a lab where students were looking at periodic trends, electronegativity, and reactivity. In the video, she gave a brief introduction and made verbal changes to the lab sheet. The students would be using calcium metal, which is toxic, and she informed them she would distribute this to the students. The introduction was 2:34 minutes long, leaving about one minute of the video where the students were working in the lab. Students were setting up their experiments, but made no data collection or analysis was observed in the clip. There was not enough evidence in the video to determine whether this teaching event included an inquiry lab from the short clip and lab handout.

Leah discussed in her TPA commentary that the students were indeed analyzing their data and coming up with the trends of the periodic table using lab-collected data.

> After the lab was done, they answered questions about what they discovered in the lab and had them apply their data to figure out what periodic trends are seen based on reactivity. I never gave them the direct answer I had them try to figure everything out by themselves. (Leah, TPA commentary, prompt 3)

But Leah did not include the questions that students were asked to respond to or any other evidence besides that which is in the written commentary for this task. She had presented the three periodic trends the day before. Therefore, she had already *explained* before the students *explored* with this lab, reversing the order of two of the five Es of inquiry-based instruction. She stated:

> That should have given the students enough background knowledge to figure out the trend of reactivity. There were probably missed opportunities at the end of the lab. Some students may not have fully understood the lab, so perhaps I could have come together as a class and had them discuss their findings... This would allow students who fully understood it to share with the class (this would

> help solidify their understanding by teaching it) and also allow students who were completely lost to get caught up with their classmate by learning from them instead of from a lecture. (Leah, TPA commentary, prompt 4a)

It is not clear from her commentary how many of her students were "completely lost".

From her TPA commentary, Leah appeared to rely on what she intended for students to learn as the basis for the next phase of instruction, rather than checking for students' understanding of what they learned.

> I reminded how we talked about periodic table trends the day before and had them tell me what the three trends were. Then I told them that they would be doing a lab on reactivity and they would be discovering the periodic table trend themselves based on the data they collect. The students use the lab to react chemicals together to see which are more reactive. On their own they then came up with a trend on the periodic table for reactivity. They did this by analyzing their data that they collected during the lab and applied it to what they know about each of the elements. From this analysis they were able to come up with a periodic trend of reactivity [*sic*]. (Leah, TPA commentary, prompt 1a)

Her attention appeared to be on what the students were expected to do, rather than what they were actually learning. However, as mentioned earlier, Leah did not include the portion of her lab handout that asked the students to analyze the data, so evidence was lacking.

Journal entries. In Leah's first journal entry ("Early", 072010), she was asked to reflect on the *definition of inquiry* and describe it. She stated that she didn't remember any classes where she was able to learn through inquiry. She states that, "It relates to the real world. There is more freedom…There will be multiple correct answers while doing inquiry instruction" (Leah, Journal, 072010). In it, she also revealed a *misunderstanding* that inquiry is "more of an opinion based type of learning" (Leah, Journal, 072010). She described *teacher qualities* as "engaging students", "posing questions" and "creating discussions". She also described *student qualities*: gaining a "deeper understanding of a subject matter", and the ability to "think critically" about the subject. However, she also mentioned one potential *barrier to inquiry*, that being student frustration. "However, I think that it is easier for students to get frustrated. If they don't arrive at an exact answer they may just give up" (Leah, Journal, 072010). She did not comment on inquiry in her final posting for the fall, so the next glimpse of her journal entries related to inquiry came in spring during her student teaching experience.

When Leah began her student teaching in the spring, she commented on a potential *barrier* to implementing inquiry in her classroom. She felt the classroom management was going smoothly at the beginning of her student teaching, but her cooperating teacher said that this may change a few weeks into her teaching and that she should be prepared before the students "start to push the boundaries".

> So in the next couple of weeks I will be prepared to hold my ground on the science spiral notebook for example. I hope to add to the classroom by being a

> resource for them. I hope that they are able to learn on their own via inquiry, but I don't want them to be afraid to come ask me questions about anything. (Leah, Journal, 020311)

This reference to students being able to "learn on their own via inquiry" seemed premature so early (two weeks) into her twelve weeks of student teaching. This statement is also unclear as to whether she meant students proceeding to learn through open-inquiry or students' intrinsic motivation to learn.

Leah chose to include an example of how she implemented inquiry in her classroom in her open response in the spring.

> As far as the use of inquiry in the classroom, I think it has been a very important aspect that has been included. I think it definitely needs the use of scaffolding attached to it. Students cannot be thrown in to full out student based inquiry right off the bat… they need a little guidance in the beginning. (Leah, Journal, 031011)

At this point in the semester, about one month after her previous posting where she discussed students being able to "learn on their own via inquiry", she clearly identified scaffolding as important for successful inquiry instruction. Her reference to scaffolding did not refer to differentiation for individual learners; rather, the whole class would require scaffolding to assist them with inquiry.

Leah commented on inquiry in her teaching philosophy journal entry in the spring ("Late", 040711). She described an ideal of a student-centered classroom with a "balanced level of inquiry depending on the students in my classroom" (Leah, Journal, 040711). But she elaborated in great detail as well on *student qualities:*

> Students will use the fundamentals that they have learned to do hands-on work. The students in my classroom will experience an inquiry centered learning environment where they will be able to express their thoughts and ideas while learning the concepts. The students will also be given a lot of choice in their learning, which will help intrinsically motivate the students. There will be group work in which students can build their knowledge together. A cooperative learning environment will be established so they can learn teamwork skills and their learning can be maximized by emphasizing their individual strengths. (Leah, Journal, 040711)

Here she referred to student choice, motivation, cooperative learning and teamwork as all-important aspects of her classroom's culture of inquiry.

In Leah's last posting in the spring when reflecting back across her learning over the three methods courses and two teaching experiences, she stated, "when I first started talking about inquiry-based instruction, I thought it was going to be very hard to implement" (Leah, Journal, 042811). She went on to elaborate later in her posting:

> As I started teaching, I found myself integrating inquiry without even realizing it. I used a lot of questioning and student-centered learning without even trying. This probably comes from learning so much about it. It seemed to really stick for me and it ended up not being as difficult to implement as I thought it was going to be. (Leah, Journal, 042811)

From her written reflections, it seems that she was able to implement inquiry easily; however, with her failure of the TPA, it is not clear whether she understood how to implement inquiry-based instruction. Full analysis of this puzzle will be discussed in Chapter V.

Interview. Leah's interview was 35:08 minutes long. She revealed that the students were in the lab for the videotaped lesson for 45 minutes to an hour, although she had recorded less than 4 minutes of that time. She could not recall which lab she had done for this assignment, so we watched the video again during the interview. In general, she described her teaching strategies during this inquiry lab as providing limited information for the students ahead of time, drawing attention to important safety measures, and reminding students of chemistry concepts recently studied:

> Um, I remember trying to, with all the labs, not just that one, um, kinda give them as little amount of information as possible, but without so little that they were getting lost, that they were able to things on their own. (Leah, Interview, 083111)

The students were expected to work in the lab, record and analyze their data, and write their conclusions:

> Yep, it was 11th graders. So I kinda highlighted the important points and then really relied on them to read the directions, to get the equipment they needed, and you know kind of what we learned in methods classes, the inquiry, having them figure stuff out on their own. And not have everything laid out for them. (Leah, Interview, 083111)

Students were not given much introduction during the video. “And, um, and we haven't talked about reactivity trend at all, this was the way for them to see why that trend is the way it is, without me just telling them here's the order of reactivity of the metals” (Leah, Interview, 083111).

When she analyzed her activity from the TPA task, she indicated that the students were sharpening or clarifying the question, but then she goes on to say that they really did not have a choice on questions. Learners were directed to collect certain data, and yet she indicated that they drew the data tables in their own notebooks and hinted that this means they may have determined what constitutes as evidence. “They kinda made their own” but then she contradicts herself and says that she “gave them pretty much everything to look for” (Leah, Interview, 083111). She included a data table on the back of the set of instructions for the lab. She guided the process of formulating explanations and gave the possible connections, but this comes only from her TPA commentary and her comments in the interview. She also selected the more student-centered, learner coached in development of communication. There was no evidence of these last three essential features in the material she provided for the TPA commentary. (See her analysis of the “Essential Features of Classroom Inquiry and their Variations” chart in Appendix G).

Leah considered this activity as having, “a lot of learner self-direction” (Leah, Interview, 083111).

> So I kinda highlighted the important points and then really relied on them to read the directions, to get the equipment they needed, and you know kind of

> what we learned in methods classes, the inquiry, having them figure stuff out on their own. And not have everything laid out for them. (Leah, Interview, 083111)

When Leah was prompted to consider how she felt the students had done in this activity, she stated:

> I think it went pretty good. I feel like the conclusion could have been a little better. Um, they didn't fully understand why they were doing this order, until the following day, maybe I could have done a little more in the beginning. If I remember correctly, why they were doing this. They were coming to me like, what does this order mean? So then I, you know, focus on what is it supposed to be, you know this is a match, and you just need to figure that out in the lab. I probably should have guided them more in the beginning of figuring out the order, you're going to see if it matches, like that, I kind of just let them do it and showed them afterwards, but I don't think they fully understood. (Leah, Interview, 083111)

Here she focused on whether the students could complete the activity rather than student learning, as an indicator of a "pretty good" lab.

Leah talked about the *teacher qualities* for inquiry-based instruction: planning "hands-on activities", "group work", "collaborating", and "problem-solving". She stated that it's "…really more of an exploration of science, instead of a, explanations" (Leah, Interview, 083111).

She described *student qualities* as “working in teams”, “collaborating”, “problem solving”, and “self-direction”. However, she also stated that students lacked problem-solving skills and abilities for data analysis and that these were areas that she targeted in her teaching.

> I think problem solving skills are what a lot of the students lack. So I want to try to focus on that. And, you know, if they have the problem solving skills in my class they'll be able to apply to any science class really. I think that a lot of data analysis would be good to do. Um, even if it is simple plug it into excel and getting a best fit line or something like that, um. I haven't seen that a lot in high school, so I think that by the time they get to college they should have that down pat. (Leah, Interview, 083111)

Leah described a few of the *barriers* that she encountered while doing inquiry at her student teaching placement. “If I found a lab, I would have to retype it, to make it not [sic] cook-booky” and this took time (Leah, Interview, 083111). Yet she felt there were limited “resources.” Leah then began talking about her new job that would begin in a week, and not her placement in the spring. So it is unclear which school she was referring to, rather that limited resources can be a barrier to inquiry-based instruction.

She also revealed some *misunderstandings* regarding inquiry-based instruction. She felt that chemistry is a hard subject to do “full-blown inquiry”. Leah relates this to the fact that the students don’t have the information they need to do the labs, once again revealing her desire to *explain* before students *explore*, as in her TPA commentary:

> There's so much information that they don't, or never heard of before. Um, and you can't really do a chemical reaction without knowing the mechanisms behind it, so we have to guide them, what kind of what reactions to do, or guidelines, so… (Leah, Interview, 083111)

She also seemed to confuse inquiry as being any hands-on lab activity, "Cause non-inquiry just has textbooks" (Leah, Interview, 083111). She went on to say, "My cooperating teacher did a lot of labs. So he was like pretty good. Um, implementing inquiry, uh, he did a lot of PowerPoints though" (Leah, Interview, 083111). It appears that here she conflates hands-on labs with inquiry-based learning. There is a hint, later in the interview, that she realized that some students may need more scaffolding in inquiry labs, but then she claimed to have "just plowed" ahead with her honors chemistry students anyway.

In the interview Leah was asked to clarify a comment she had written in her first reflective journal posting.

> Um, you know, inquiry, I remember you, I remember the first day you asked us, if you've never had inquiry, and what type of inquiry have you ever done. I remember you had shown us this, and explained it a little bit, and in my mind I thought it had to be full-blown. I remember writing, I don't think I've ever done inquiry. (Leah, Interview, 083111)

She had indeed written that earlier in the year.

In addition, Leah discussed that she did not feel prepared for student teaching, due to limited analysis of her teaching during the fall semester. However, like the cohort; she had taught three mini-units, worked with a peer throughout the planning, and implementation of these lessons. Her cooperating teacher observed her daily, and four times by her university supervisor, who each wrote up evaluations of their observations. Perhaps Leah needed more support during her student teaching.

Chapter V: Analysis

In Chapter IV, Phase One was described and the preliminary analysis of the data of the 26 TCs' scores on the TPA. These scores were considered in selecting interviewees and preparing for Phase Two; two high-scoring, two mid-scoring and two low-scoring TCs were invited for the semi-structured interview. Therefore, Phase Two will be analyzed in this chapter; each of the six cases of the teacher candidates will be analyzed and described in detail.

In Chapter IV, six individual case studies were written to represent the six teacher candidates who were interviewed. Each case was described utilizing the three sources of data collected and analyzed: 1) their analysis of Instructing and Engaging Students in Learning, Task 2 of the Teacher Performance Assessment (TPA), which includes video clips as well as a written commentary; 2) six of the twenty-six reflective journal postings throughout the year the teacher candidates were enrolled in the methods courses; and 3) an interview following the conclusion of their licensure program.

The analysis presented in this chapter was guided by the two research questions:

1. What does the Teacher Performance Assessment reveal about science education teacher candidates' understanding of inquiry-based instruction?
2. How do the candidates represent their knowledge of inquiry in their reflections?

First, the analysis of research question one will be presented. The National Research Council's (2000) five essential features of inquiry as defined in the "Essential Features of Classroom Inquiry and Their Variations" table was the framework that guided this analysis. (See Table 2.1). Second, the analysis of research question two is presented including elaboration on each of the four themes that arose from the analysis of each case. The four themes were *definition of inquiry*, *qualities required for inquiry, barriers to inquiry,* and *misunderstandings of inquiry*. Following the discussion of the original four themes, the cross case analysis will be represented including discussion of the new and enhanced themes that arose from the data and the unique differences for each case. Each teacher candidate's knowledge of inquiry will next be summarized through cross-referencing the two research questions. Finally, a model was constructed to represent the TCs' knowledge of student and teacher *qualities for inquiry*.

RQ1: What Does the Teacher Performance Assessment Reveal about Science Education Teacher Candidates' Understanding of Inquiry-based Instruction?

Analysis of Kurt's TPA. Kurt was a high-scoring candidate and was ready to begin to teach. He scored a 3 on both rubrics of Task 2 of the TPA out of a possible 4. However, the focus of this study is on what evidence the TPA revealed about Kurt's understanding of inquiry. Therefore a closer analysis was required beyond the TPA rubric scores. The TPA revealed Kurt had an understanding of the five essential features of inquiry.

Analysis of the essential features. In closely analyzing Kurt's TPA commentary, he clearly included statements that reveal an understanding of all five essential features of inquiry, as detailed by the NRC (2000). For instance, for the first essential feature, "learner engages in scientifically oriented questions" Kurt's TPA commentary and video revealed that questioning guided the inquiry activity from beginning to end. He stated:

> My strategies during the Analysis section (i.e. the questions) were different for the two sections of question. For questions 1, 2 and 3 I wanted to gauge students' ability to read the data table (this activity is actually part of a unit on graphing and data interpretation)… During questions 4, 6 and 7 I really tried to get students to consider and later to explain the thinking behind their choice, not just which food they chose for their answer. This required two main things. First, students needed to understand which nutrient(s) were relevant to the question. Second, it required that students understand that it is usable levels of this relevant nutrient that are important. Many students did make these connections. (Kurt, TPA commentary, prompt 3)

This reflection also provided evidence of Kurt's inclusion of the second and third essential features of inquiry: "learner gives priority to evidence in responding to questions" and "learner formulates explanations from evidence" (NRC, 2000, p. 29). The activity was organized around educating students on data collection and graphing in questions 1, 2, and 3, while he stated that questions 4, 6, and 7 require the students to explain their thinking behind the answers they provided. For more detail on these questions Kurt referred to in his inquiry activity, see Appendix H.

Kurt offered continuous academic language support during his video and in the activity, in an effort for students to achieve the fourth essential feature of inquiry, "learner connects explanations to scientific knowledge" (NRC, 2000, p. 29). Terms that he emphasized and offered support for included: macromolecules (from a unit the students had just completed), assimilate, feces and fecal matter. These terms were a part of the story he introduced at the beginning of the lesson, the required reading, and the terms he used and linked to everyday language for students.

The fifth essential feature of inquiry, "learner communicates and justifies explanations" was present both in his class discussion as well as the 7th question on the activity. Therefore, students were able to verbally communicate their explanations in small groups and as a class, as well as write them. Here, he emphasized the need for students to explain their reasoning in addition to providing the answers to the questions. While this was a highly teacher-guided inquiry, it clearly met the five essential features of inquiry, and Kurt revealed as much in his TPA commentary.

In the final prompt of the TPA commentary, the TCs were required to reflect on the lesson and write about missed opportunities during their instruction of the lesson. It was here that Kurt discussed his frustration with this assignment, the TPA Task 2 as well as his Enzymes and Fecal Analysis lesson. He completed this portion of the TPA during his third day of teaching this class. He stated:

> As a result, there are a lot of things I would change were I doing it again… The point is that I almost look at the entire activity as a missed opportunity. Certainly all activities can be improved, but I believe this activity has real potential that was not fully realized" (Kurt, TPA commentary).

Kurt's reflections here reveal a frustration with the situation many novice teachers feel. Despite the fact, that he felt his students learned data collection and graphing, as well as linking new scientific concepts (assimilation of nutrients) to prior knowledge (macromolecules), Kurt felt this lesson could have been improved to provide greater learning opportunities for his students.

Analysis of Bill's TPA. In Bill's case, he was a high-scoring candidate and was ready to begin to teach. He scored a 3 on both rubrics of Task 2 of the TPA out of a possible 4. However, as with Kurt, the focus turned to what evidence the TPA revealed about Bill's understanding of inquiry. The TPA revealed Bill had an understanding of the five essential features of inquiry, with an emphasis on eliciting student responses in an attempt to assist students to understand the law of the conversation of mass.

Analysis of the essential features. In closely analyzing Bill's TPA commentary, he clearly included statements that reveal an understanding of all five essential features of inquiry. For instance, for the first essential feature, "learner engages in scientifically oriented questions" Bill's TPA commentary and video revealed that questioning guided the inquiry activity from beginning to end (p.29). He stated:

> This [eliciting student thinking through questioning] is basically all I was doing in the video clips. I went around to every single group and guided them with questions to critically think about the data they were collecting, what they needed to calculate, and how to calculate it. I did not give them the answers outright, unless it seemed that they were already at that point, just slightly fuzzy about how/why. (Bill, TPA commentary, prompt 3)

Evidence of the second and third essential features, “learner gives priority to evidence in responding to questions” and “learner formulates explanations from evidence” was also present in Bill’s TPA Commentary and video clips. He stated:

> In addition to basic lab skills and technique, asking students to critically examine their data and figure out how to arrive at the solution helps them to understand the process of data collection and analysis, as well as problem solving. These skills are important for any student to succeed academically. (Bill, TPA Commentary, prompt 1b)

Note in his commentary his emphasis on these two essential features is skill development, rather than including ways of knowing or nature of science.

Evidence of Bill’s understanding of the fourth essential feature “learner connects explanations to scientific knowledge” appeared twice in his short two page commentary. Bill provided the very minimum of what was expected. He did not lack understanding or clarity; rather, he was brief in his commentary and reflections. He stated:

> In the clips I am trying to get them to make the connection explicitly by asking them what concepts they are using to guide their data analysis. Once I mention it, they seem to be able to make the connection, but before it is rather fuzzy. The more explicitly they make this connection, the more able they will be to use the academic language to justify their process. (Bill, TPA commentary, prompt 2)

And the last essential feature, “learner communicates and justifies explanations”, he stated:

> I asked individual groups after they were done explaining their process what concepts they had used to come to those conclusions. This allowed for each level of student to express themselves at their own level, and once I mentioned the law of the conservation of mass, to be able to make the connection between the process and that concept in their own way. (Bill, TPA commentary, prompt 2a)

This analysis of his TPA commentary for Task 2 revealed a strong understanding of the five essential features of inquiry, which is also supported by his high scores on this task.

Analysis of Nina’s TPA. Nina was a mid-scoring candidate and was considered ready to begin to teach. She scored a 2 on rubric S4 and a 3 on S5 of Task 2 of the TPA out of a possible 4. Upon closer analysis, the TPA revealed Nina had an understanding of the five essential features of inquiry, with an emphasis on eliciting student responses before and after an egg drop demonstration in an attempt to engage students in predict-observe-explain (POE) and using their new vocabulary meaningfully with the lesson's content, Newton's Laws of Motion.

Analysis of the essential features. Nina's video and Task 2 commentary revealed that she attended to the first essential feature of inquiry, "learner engages in scientifically oriented questions", in the questions that she poses to the class.

> With the students in this class, the questions that I ask in the first clip are lower order on Bloom's Taxonomy. It is not until the demonstration where I start asking the students to think critically and start asking questions with higher order thinking skills. (Nina, TPA Commentary, prompt 3)

When addressing the second and third essential features of inquiry respectively: "learner gives priority to evidence in responding to questions", and "learner formulates explanations from evidence", Nina reflected in her commentary:

> The instruction given in video clip 1 seems to be that the learner is given data and told how to analyze, but it was my goal and intention to provide students with data similar to what they saw in the prior class period and all together see how to analyze the data. Many of the students are unable to make the connection between gathering data and how to analyze it. As the previous class period's homework, I asked the students to really examine their data and to see if they could bring meaning from it. (Nina, TPA commentary, prompt 1)

She had chosen her 9th grade physical science students for this TPA assignment, knowing that it would be more challenging for her instructionally. This class struggled with inquiry-based instruction, but she worked with them during this teaching event to scaffold each POE for them so that the students could gain some comfort with it.

For the fourth essential feature of inquiry, "learner connects explanations to scientific knowledge" Nina provided scaffolding in the form of a POE during each demonstration Nina completed. She also provided scaffolding for their use of new vocabulary in an effort to allow students to construct correct scientific explanations.

> I think relating the terms back to things they were familiar with helped show them that science is all around us. Also, being able to relate it to their lives shows that science is important and we are not selecting lab activities for them to do just to waste their time. (Nina, TPA commentary, prompt 2a)

And finally, evidence that Nina attended to the fifth essential feature of inquiry, "learner communicates and justifies explanations" was present in the class discussion that accompanied each demonstration. Nina reflected on this in her final prompt of the TPA commentary for Task 2 that asked the candidates to reflect on what they would do differently next time:

> I would also have a discussion with the students about making a hypothesis / prediction and analyzing the results and letting them know that if their hypothesis / prediction was incorrect that they should not quickly erase and write in a different hypothesis to match the results. (Nina, TPA commentary, prompt 3b)

This analysis of his TPA commentary for Task 2 revealed a strong understanding of the five essential features of inquiry, which was also supported by her passing scores on this task.

Analysis of Jenny's TPA. Jenny was a mid-scoring candidate and was considered ready to begin to teach. She scored a 2 on both rubric S4 and S5 of Task 2 of the TPA out of a possible 4. Upon closer analysis, the TPA revealed Jenny had an understanding of the five essential features of inquiry, with an emphasis on introducing inquiry to her students through a question she posed: can you change your brain? Students were collecting data, discussing the topic, and arguing about whether your brain can change or not using the evidence from their activity.

Analysis of the essential features. Jenny's video and Task 2 commentary revealed that she attended to the first essential feature of inquiry, "learner engages in scientifically oriented questions", in the questions that she poses to the class both at the beginning as stated above, and throughout her lesson. She also discussed that this class had "not participated in extensive labs and many do not like having to make predictions, record data, or analyze results" (Jenny, TPA commentary, prompt 1a). Therefore she stated she needed to be careful in setting up the lab groups.

She described the second, third and fourth essential features, where her students were asked to give evidence when responding, they articulated explanations from their evidence, and they connected these explanations to science content in the following reflection:

> I had just changed the seating chart and wanted to encourage students to work with different people from those with whom they preferred to work. By getting students laughing about their changed perceptions when wearing the goggles I got a number of them to let go of their frustrations at having to work with new people and, by the end of the hour, all groups were working together successfully. After clarifying a bit of initial confusion regarding methods of data collection, most groups managed to collect and record data that allowed them to analyze and interpret their results and make sense of the follow- up questions. (Jenny, TPA commentary, prompt 1a)

The fifth essential feature was also reflected upon in this first portion of the TPA:

> This led to an interesting discussion in which some students said that we can absolutely change our brains while others were adamant that you can change the way you think but you cannot change your brain. A productive argument ensued as students debated that changing the way you think is indeed changing your brain. (Jenny, TPA commentary, prompt 1a)

While her students may not have participated in many hands-on labs during her time at her school, her implementation of this lesson, the subsequent video clips of the teaching event, and her commentary revealed a clear comprehension of the five essential features of inquiry. This comprehension was also supported through her passing scores on this task.

Analysis of Adele's TPA. Adele was a low-scoring candidate and she may not have been ready to teach, according to the criteria for the TPA. Out of a possible 4, she scored a 1 for S4 (engaging students) rubric and a 2 on the S5 (deepening student learning) rubric of Task 2 of the TPA. She would have passed the TPA if she had received passing scores on the rest of the 11 rubrics. Adele's case was unique, in that she did not complete the summer science methods course that introduced inquiry-based instruction until after the completion of her spring student teaching and of the TPA. The analysis that follows attempts to uncover the evidence the TPA revealed about Adele's understanding of inquiry.

Analysis of the essential features. The TPA revealed Adele had an understanding of two of the five essential features of inquiry. She reflected on the activity (friction lab) and student management more frequently than the features of inquiry. In closely analyzing Adele's TPA commentary, she clearly included statements that reveal an understanding of only the first and third essential features of inquiry, as detailed by the NRC. For instance, for the first essential feature, "learner engages in scientifically oriented questions" Adele's TPA commentary and video revealed that questioning guided the activity from beginning to end (p.29). She stated:

> I am asking a group of students a higher order questions, asking why they think the floor is going to have more friction than the table. Individually, I question the students as they are completing the lab worksheet; Asking leading and high order questions to challenge their understanding of the concept. (Adele, TPA commentary, prompt 1a)

Adele did not include the student handout for the lab activity, and, therefore, it is not clear how much of the activity was prompted by questions, or whether there was an essential question driving the activity at the start. However, questioning is present at the beginning of clip 1.

The other essential feature that is present in Adele's TPA commentary is the third, "learner formulates explanations from evidence". She stated:

> I am asking the students to explain their reasoning for selecting a particular example for the usefulness of friction. By asking the students questions and letting them come to their own conclusions, and then reinforcing those conclusions, it helps them to scaffold their own knowledge. (Adele, TPA commentary, prompt 3)

The tone of her commentary hinted that, if this activity was inquiry-based, it would be ranked as teacher-directed. Rather than focusing on the students in the TPA commentary, as she was prompted, she focused on what she was doing. "I am circulating within the groups to first, ensure they have understood the instructions… to ensure that the equipment they are using is working properly; and third, to question them about the data and/ or results they have obtained" (Adele, TPA commentary, prompt 1a).

Students in first video clip may have been collecting data; however, it was not evident in the video. This class had many management issues during the video clip; they needed redirection, reminders, and repeated visits, and yet some students remained unengaged in the lesson. In the second clip, management issues continued. Not only was it hard to tell from these clips the overall class' level of engagement, it also appeared very few students were engaged. While Adele attended to students' questions simultaneously with students who were off task, her wait times were short. She requested numerous times for students to, "Sit down and work on your reading packet." This lesson and selection of video clip evidence did not enhance Adele's TPA Task 2, instead these clips prevented her from passing rubric S4 "student engagement".

Some clarity was provided through the analysis of her interview narrative. When asked to reflect on her teaching event, Adele first stated: "Well unfortunately it was a cookbook lab [laughs]. It wasn't, it wasn't greatly inquiry, but um, so yeah, I think that there were some times where they asked them to pose their own question" (Adele, Interview, 090111). However, when she looked at the "Essential Features of Classroom Inquiry and their Variations chart" in her interview, she ranked each of them in the middle of the chart between teacher-directed and student-directed. Adele completed this TPA Task 2 assignment in February 2011, completed the summer inquiry methods course in August 2011, and sat for the interview in September 2011. During the intervening time, Adele has learned more of the nuances of the levels of inquiry; therefore this is not considered a *misunderstanding of inquiry*.

In concluding Adele's case, there was no evidence of student engagement or opportunities to collect, analyze, and interpret data in the video clips. The lab activity handouts were not included, nor were the objectives for the lab. Considering these issues in concert: the teacher-directed tone in commentary, the poor video clips, the lack of evidence of student engagement, the confusion as to whether this was an inquiry activity, and the lack of handouts or lessons plans; it is difficult to validate the accuracy of her statements or to conclude whether this activity was indeed representative of inquiry-based instruction. However, she appeared to understand inquiry-based instruction and the difference between it and cookbook labs in her interview.

Analysis of Leah's TPA. Leah was a low-scoring candidate, and she was not ready to teach according to the criteria for the TPA. She scored a 1 for both S4 (engaging students) rubric and S5 (deepening student learning) rubric of Task 2 of the TPA out of a possible 4. Therefore, she did not pass the TPA. The analysis that follows attempts to uncover the evidence the TPA revealed about Leah's understanding of inquiry.

Analysis of the essential features. In her TPA commentary, Leah hinted at three of the five essential features of inquiry. In closely analyzing Leah's TPA commentary, she did not include statements that revealed an in-depth understanding of all five of the essential features of inquiry. For instance, for the first essential feature, "learner engages in scientifically oriented questions," Leah's TPA commentary and video revealed that questioning may not have guided the activity (p.29). She stated: "Then I told them they would be doing a lab on reactivity and they would be discovering the period trend themselves based on the data they collect" (Leah, TPA commentary, prompt 1). The lab handout she included does not include an essential question at the beginning, it simply stated the purpose of the lab, "Purpose: to study trends of reactivity in a period and group of the periodic table" (Leah, TPA commentary). She claimed that students would do the analysis of the reactivity trends after completing their data tables, but she did not include the part of the lab that included the questions that would have prompted their discovery. There is not enough evidence to support a claim that Leah utilized the first essential feature of inquiry.

While the first essential feature was missing, Leah did hint at the second, third and fourth essential features in one statement where she described the activity:

> One their own they then came up with a trend on the periodic table for reactivity. They did this by analyzing their data that they collected during the lab and applied it to what they know about each of the elements. (Leah, TPA commentary, prompt 1)

For the second essential feature, "learner gives priority to evidence in responding to questions," the students were collecting data of the reactivity they observed, she had provided a data table for the students and included it in her TPA commentary. But when she reflected on this in her interview, she contradicted herself. Learners were directed to collect certain data, and yet she indicated that they drew the data tables in their own notebooks and hinted that this means they may have determined what constitutes as evidence. "They kinda made their own [data table]" but then later she stated that she "gave them pretty much everything to look for" (Leah, Interview, 083111). Her video did not show any footage of students collecting data, so there was no evidence to provide support for her claims. This does not provide substantiation that Leah's understanding of the second essential feature of inquiry is fully developed.

For the third essential, Leah again hints at "learner formulates explanations from evidence" by stating students were "analyzing their data." Yet she did not provide the scientific explanations that she expected students to discover through their analysis of the data they collected. Another prompt in the TPA asked, “How did these strategies reflect students’ varying language proficiencies and promote their language development?” (SCALE, 2011, p. 14). Leah offered another hint that learners were formulating explanations. “Some students started ‘teaching’ each other concepts, which not only helps the students who is learning, but also helps the students who is teaching” (Leah, TPA commentary, prompt 2a). Here the students might be teaching one another, but she did not specify what scientific concepts they were learning. Leah clearly expected the students could discover the reactivity trends on their own.

> After the lab was done, they answered questions about what they discovered in the lab and had them apply their data to figure out what periodic trends are seen based on reacitivity [*sic*]. I never gave them the direct answer I had them try to figure everything out by themselves. (Leah, TPA commentary, prompt 3)

In addition, when she reflected on missed opportunities in her lesson Leah stated, “Some students may not have fully understood the lab, so perhaps I could have come together as a class and had them discuss their findings… and also allow students who were completely lost to get caught up with their classmates” (TPA commentary, prompt 4). Here, she stated the students were not afforded the opportunity to communicate their findings and justifications; therefore, the third essential feature was lacking and the fifth was absent.

When reflecting on these two essential features in her interview, the third and fifth, Leah stated: “They were coming to me like, what does this order mean...I probably should have guided them more in the beginning …I kind of just let them do it and showed them afterwards, but I don't think they fully understood" (Leah, Interview, 083111). Rather than focusing on students learning, she focused on whether the students had completed the activity as an indication of a "pretty good" lab. Finally, for the fourth essential feature, "learner connects explanations to scientific knowledge", Leah offered only a brief comment that the students were directed to apply their analysis of the data "to what they know about each of the elements" (Leah, Interview, 083111).

Due to the limited video footage—one clip of 3:41 minutes—there was no evidence in the video to corroborate her statements. Her verbal reflections in the interview offered some insight that Leah was attempting to implement an inquiry activity for students. By providing little scaffolding, though, she overlooked the need to support student learning the scientific concepts. Her idea of inquiry may be that she would offer no support to students, ask no questions of clarification, and just let the students discover it for themselves. The TPA Task 2 revealed that Leah had a limited understanding of implementing inquiry-based instruction. Unlike some of the other cases, Leah only mentioned that she would be *guiding* student learning one time in all of her written (reflective journal postings) and verbal (interview) reflections. Limited frequency of this sub-theme of *qualities for inquiry* may represent limited understanding of the importance of teacher-led levels of inquiry for student learning.

RQ2: How do the Candidates Represent their Knowledge of Inquiry in their Reflections?

Analysis of Kurt's case. Both reflective data sources were used for this analysis; written (reflective journal postings) and verbal (interview). Kurt wrote lengthy and thorough reflective journal postings and participated in the longest interview (59 minutes) of all of the TCs. He had a lot to say when it came to discussing his teaching and his reflections on teaching. Kurt represented his understanding in multiple ways, using a variety of descriptive words to elaborate on his thinking, revealing a rich and highly nuanced view of inquiry-based instruction. Each theme, *definition of inquiry, qualities for inquiry,* and *barriers to inquiry*, will be elaborated using Kurt's narrative in this section. Note that Kurt did not reveal misunderstandings about inquiry and, therefore, this theme is absent for this case.

Kurt's definition of inquiry. The "Early" reflective journal posting (702010) requested that the TCs define inquiry and Kurt's first opportunity to talk about inquiry. Note the bolded sections represent the presence of two of the five essential features in his early definition.

> I think of inquiry as a process of learning about the world around us by **posing questions** about things we observe or detect, and then seeking answers to those questions. These questions can come from any number or sources, and pertain to any topic or field. We might think of an idea ourselves, or we might have an idea proposed to us. Within the field of science questions or ideas might come from suggestions for further research in professional journals, or we might stumble upon a new question while attempting to solve an entirely different one. The methods of seeking answers are also diverse, but generally follow the

> pattern of proposing a hypothesis, then testing that hypothesis and **drawing conclusions based on the data collected**. This all sounds a bit like the scientific method, and I believe that is no coincidence. Inquiry does rely in part on aspects of the scientific method, but it goes beyond it as well. (Kurt, Journal, 072010)

Kurt's partial definition here reveals his early understanding of inquiry in the first week of the summer methods course. As described above in his TPA commentary, and again below, by the end of the initial licensure program, Kurt developed a robust definition of inquiry that includes all five essential features. Kurt's definition of inquiry included both teacher and student qualities required for inquiry later in his reflections, and his narrative appears in the next section.

Kurt's qualities for inquiry. As in his TPA commentary, Kurt consistently included the five essential features of inquiry throughout his written and verbal reflections: students are engaged in scientifically-oriented *questions*, they are asked to *give evidence* when responding, they *articulate explanations* from their evidence, they *connect* these explanations *to science content*, and they *communicate and justify* their explanations. These appeared in his reflections both as teacher qualities (something the teacher is doing and promoting) and student qualities (something the students are actively engaged in) of inquiry-based instruction. Thus Kurt revealed a clear understanding of the continuum and balance between teacher-directed inquiry and student-driven inquiry. He stated in his reflective journal postings that students would be "involved in the process of their own learning", "discovering answers" to questions, increasing their “participation through more activities which require them to employ scientific methods and strategies”, “collaborating”, and “reflecting” on their learning. Quite often it was difficult to code his reflections as either a *teacher* or *student quality for inquiry* because there was implied teacher-student interplay and overlap in his statements. For example:

> Their activity must be carefully overseen and directed by the instructor, but students engaged in inquiry are not being explicitly told what they are supposed to be learning. In a way, they are being facilitated or guided on a journey of self-discovery. Not so much a discovery of themselves, though interpersonal growth is also afforded by the process, but a discovery of answers to questions by way of their own thinking and experimentation. (Kurt, Journal, 072010)

It was during the analysis of Kurt’s reflections that it became evident that the *qualities for inquiry* of both teachers and students needed to be analyzed as one theme, rather than two separate themes.

In Kurt’s reflective journal postings (written) and interview (verbal), he frequently described *teacher qualities* of inquiry-based instruction as *teacher as facilitator* and providing scaffolding for students. He provided many reflections and therefore a rich description of this one facet of *teacher qualities required for inquiry*. He used seven different words to describe this one aspect of a teacher’s qualities: “overseen”, “directed”, “facilitated”, “guided”, “reassured”, “assisted” and “coached”. This is a richer and more nuanced view of *teacher as facilitator* than any of the other six cases. In addition, he stated as a teacher he needed to be familiar with students’ prior knowledge, posing engaging questions, providing relevance, promoting discussion, and emphasizing vocabulary. He also discussed the need to use the "5E learning cycle" method of planning to ensure that inquiry-based instruction was implemented in the classroom.

Kurt also provided a rich description of qualities that teachers and students must have for inquiry's *scientific habits of mind*. This sub-theme persisted throughout the ten months, as it was present in his "Early" reflective journal posting (072010) in the summer, and he returned to it in his teaching philosophy in the spring, and his interview. Examples of scientific habits of mind appeared twenty times in his written and verbal reflections for *teacher and student qualities for inquiry*. Examples of approaches of promoting scientific habits of mind according to Kurt include: "critical thinking skills", "life-long learning", "thinking outside the box", "brainstorming", "developing better solutions", "employing scientific methods and strategies", "scientific ways of knowing", "the process of science", "intellectual habits", "higher order thinking skills", "hashing out ideas and proposing possible solutions", and students would be "active researchers". Here again, Kurt revealed a nuanced and rich description of an important sub-theme (scientific habits of mind) of *qualities for inquiry*.

Other *qualities for inquiry* that were coded for Kurt are numerous. What follows is a list of written and verbal reflections by Kurt and sub-codes under this larger theme: "increased participation", "variety of instructional techniques", use of "vocabulary", "relevance", "curiosity", "frustrations" both for him and his students, "introduce the topic [inquiry] slowly", and "fundamentals". For example, Kurt discussed the importance of students learning fundamentals in his biology class: "If they come out here knowing anything, I'm just trying to get them to know some of the fundamentals" (Kurt, Interview, 082611). To Kurt this was vital; however, his tone and choice of words sounded hopeful rather than certain that his students would learn the fundamental concepts of life science. Refer to Figure 4.3 *Frequency of Codes in Reflective Journal Postings* to note that Kurt's frequencies were high for *qualities for inquiry*, higher than his five peers.

5 E learning cycle. During the analysis of Kurt's teaching philosophy "Late", he stated: "I am a strong believer in the 5E learning cycle, and will attempt to incorporate its principles into many of my classroom activities" (Kurt, Journal, 040711). This had been a topic of instruction in the summer methods course, revisited in the fall and spring. As Stake (1995) stated, "the case researcher plays different roles and has options as to how they will be played. The roles may include teacher, participant observer, interviewer, reader, storyteller, advocate, artist, counselor, evaluator, consultant, and others" (p. 91). As the instructor for these methods courses, I was pleased to see this positive statement regarding the 5 Es in his teaching philosophy, and this sub-theme emerge from the data. Therefore, I made a choice to begin looking for his use of the 5 (sometimes 7) Es in his data: elicit, engage, explore, explain, elaborate, evaluate, and extend. However, he rarely used the pedagogical terms of the 5Es in his postings. He stated both "engage" and "evaluate" in his teaching philosophy (Kurt, Journal, 040711), but he did not use the Es in any other reflective journal postings. The TPA commentary prompted the TCs to specifically reflect on two of the five Es, engage and elicit. However, Kurt used both "engage" and "explain" in his TPA commentary. He only used one term, "engage", in his interview. So while he intends to implement a 5 E learning cycle method of teaching and learning inquiry, he did not use the academic language of the learning cycle with any frequency.

Kurt's barriers to inquiry. Kurt discussed *barriers to inquiry* in three of his reflective journal postings; "Mid1" (fall posting reflecting on growth, 121010), "Mid3" (open response, 031011), and Last (spring posting reflecting on growth, 042811). Kurt's fall practicum and spring student teaching experiences varied considerably in the students' familiarity with inquiry, as well as the cooperating teacher's willingness to support inquiry. His fall practicum teacher modeled inquiry-based instruction, used an inquiry-based textbook and supported inquiry for Kurt's teaching. His cooperating teacher in the spring, however, did not support inquiry. When Kurt asked for support, his teacher responded, "well, good luck" (Kurt, Interview, 082611).

In addition to his cooperating teacher acting as a barrier, Kurt encountered other barriers including: "students", "difficult to make truly open-ended inquiry practices work", "instructor needs to be very deliberate in working students toward that goal", "I wasn't comfortable with what I was doing [inquiry]", "limited amount of time", and the "culture just wasn't there". He reflected at length in his interview on each of these barriers, having also addressed them in earlier reflective journal postings. Like many new teachers, his sentiment was, "And it's hard as a new teacher to like think up, inquiry like lessons, so to have some support for that is awesome" (Kurt, Interview, 082611).

Kurt also discussed some of the struggles or *barriers* to completing the TPA. He felt students were not analyzing data and scientific concepts, which is one of the prompts to reflect upon as well as part of the rubrics for scoring the TPA.

> So I wasn't able to fully analyze. Like you first question was like, "what are the things that we talked about, or that you've learned that you're now analyzing in your video." Well if I'm not doing those things then I'm not having the opportunity to analyze those things, which is sort of what we want to be doing. (Kurt, Interview, 082611)

He also struggled with recording good video clips. The student conversations were inaudible. He had been offered assistance from the audio-visual department at his school early on, but they ultimately offered no support. His camera was placed in the back of the room, and captured his directions and storytelling, but not the students' conversations as they worked through the assignment. However, because he addressed examples of student conversations in his reflections in the TPA commentary, the absence of student voices did not negatively impact his score on the TPA.

Summary of Kurt's views of inquiry. Kurt had a rich and highly nuanced understanding of inquiry-based instruction. He was able to discuss many facets of students and teachers qualities required for inquiry, and set it into perspective with the barriers he encountered when attempting to implement inquiry in his classroom. He did not reveal misconceptions or misunderstandings about inquiry. Kurt's statement in his final reflective journal posting in some ways sum up his reflections on his experience over the ten-months, “I knew almost nothing about inquiry-based practices before our summer class. I found the topic very exciting, and continue to feel this way” (Kurt, Journal, 042811). His high scores on the TPA Task 2 also reflect a strong understanding of inquiry and the strategies to engage students and deepen their understanding in inquiry-based learning. The TPA Task 2 and Kurt’s reflections in Task 2 of the TPA revealed he understood the five essential features of inquiry.

Analysis of Bill’s case. Unlike Kurt, Bill’s written (reflection journal postings) and verbal (interview) reflections were concise and brief. His interview was the shortest, at 33:38 minutes. While his reflections were shorter than most other cases, he expressed his thoughts in a variety of ways, as opposed to repeating the same response. He did not reflect on inquiry though in either the “Mid2” (reflect on barriers, 020311) or the “Mid3” (open response, 031011) reflective journal postings. He also did not post any reflections in the “Last” reflection on his growth as a teacher (042811). So this left three reflective journal postings and his interview as data sources to analyze this research question.

Bill’s definition of inquiry. Bill defined inquiry both in his “Early” summer (072010) and his “Late” teaching philosophy (040711) reflective journal postings. In his first attempt to reflect in the summer Bill’s definition lacks detail, “Inquiry to me is learning through exploration with motivation. Exploration is the principle behind learning by inquiry” (Bill, Journal, 072010). In this definition he includes none of the five essential features of inquiry. His growth in his understanding of inquiry, as well as his view of social justice, is apparent in his teaching philosophy.

> One way in which I will try to reduce socioeconomic inequalities is to teach in a method that reaches as many students as possible: inquiry. Through inquiry students will engage in and take control of their own learning. They will be encouraged to explore their own world, **pose their own questions**, and **discover their own answers**. Not only is this method accessible to most students, it also increases meaningful learning the most. Real world concepts and issues are affirmed the most when students are able to directly experience them and come to their own conclusions. In addition to making the content accessible to the highest percentage of students, inquiry also makes the classroom setting more interactive and welcoming. Traditional methods tend to have a "right, right now" mantra to their methods. Conversely, inquiry lets students know it is alright to be incorrect now, as long as they explore their misconceptions and eventually **come to the right conclusion**. Student involvement and student-teacher interactions not only increase but become more meaningful. Inquiry also mimics the real-world **problem solving** process much closer than traditional methods. This style of engagement, exploration, explanation, and elaboration, most adequately prepares students for the problems they will encounter both in life and work-related settings. (Bill, Journal, 040711)

Bill provides a rich description of inquiry-based instruction as it might appear in his classroom. He has included the first, third, and fourth essential feature of inquiry. (See bolded statements above). However, he is lacking "learner gives priority to evidence in responding to questions" and "learner communicates and justifies explanations". While his teaching philosophy here is lacking two essential features, Bill had included all five essential features of inquiry in the lesson he analyzed for TPA Task 2 and his commentary, revealing an understanding of inquiry. His definition is more general; he discusses "student-teacher interactions", "problem solving", and four of the 5 Es of the Inquiry Cycle. In addition, Bill interpreted inquiry as bringing relevance and equity to his classroom.

Bill's qualities for inquiry. Throughout his written and verbal reflections, Bill consistently included four of the five essential features of inquiry: students are engaged in scientifically-oriented *questions*, they are asked to *give evidence* when responding, they *articulate explanations* from their evidence, and they *connect* these explanations *to science content.* However, he only mentioned the fifth essential feature in his TPA commentary; the learners *communicate and justify* their explanations. This fifth essential feature was lacking in his definition of inquiry and all reflective journal postings. He may have understood the importance of communicating ideas in reflecting on a lesson, but he did not emphasize it with any consistency.

Bill discussed inquiry in terms of *teacher qualities required for inquiry* and *student qualities required for inquiry*. In his "Early" (072010) reflective journal posting, the *teacher qualities* were focused solely on teaching strategies, "inquiry discussion followed by a demo", "inquiry lab", and "tailoring some of their ideas". However, he had a more nuanced understanding of *student qualities*. Students would: "develop stronger comprehension than direct forms of instruction", share their own and challenge each other's ideas", "analysis would be rather open ended", and "to understand the concepts behind their conclusions". This focus on what the students are doing continued in his teaching philosophy (040711). Bill's comments regarding qualities for inquiry focus on *student qualities*: "explore their own world", "pose their own questions", "discover their own answers" "directly experience", "come to their own conclusions", and "engage in and take control of their own learning". Like Kurt's case, there were several instances of a blurring of the students' and teacher's qualities in statements such as, "students should be the center of any classroom", "encouraged to take control of their own learning" and "guided" (Bill, Journal, 040711).

Bill's firm understanding of the qualities of both teachers and students for inquiry were more evident in his TPA commentary and his interview. In these two data sources Bill was more effusive and he continued to blur the lines between teacher and student *qualities for inquiry;* these were coded, 12 and 20 times respectively. Some of the sub-codes included: facilitate, explore, explain, variety of instructional techniques, "relevance", "motivation", "think of prior conceptions", and "meaningful learning".

5 E learning cycle. Like Kurt, Bill rarely used the pedagogical terms of the 5Es in his postings. He stated both "engage" and "explore" in his reflective journal postings. Bill used the term "engage" after being prompted to consider student engagement in his TPA commentary, and he used "explain". However, he did not use the term "elicit" despite being encouraged to consider it in prompt 3, "Describe your strategies for eliciting student thinking and how your ongoing responses further their learning. Cite examples from the clip(s)" (SCALE, 2011). He did not mention any of the 5 Es during his interview. So while he intends to implement inquiry-based instruction, he did not use the academic language of the Learning Cycle with any frequency.

Bill's barriers to inquiry. Bill did not reflect on *barriers to inquiry* in any of his reflective journal postings, therefore his only reflections on barriers occurred in his interview. He stated, "a lot of those students just wanted me to lecture at them, the inquiry thing I tried to do in class, I got a good amount of resistance… they hated inquiry and they just wanted the right answer" (Bill, Interview, 082611). His spring student teaching placement was in a very traditional classroom. He reflected on the fact that the culture of the classroom was the barrier he encountered when implementing inquiry. He stated:

> He [my cooperating teacher] wasn't explicitly against inquiry, and you could kind of tell by his attitude um, that he thought that the only form of meaningful learning was um, lecture/worksheet that very traditional sorts of things…Um, and yeah, he was more of a barrier, and then the students' attitude towards it. (Bill, Interview, 082611)

Regardless of his students and his cooperating teacher expecting a traditional, didactic style of instruction, Bill incorporated inquiry-based instruction into his classroom, on more than one occasion, and successfully completed the TPA Task 2 with an inquiry activity.

Bill's misunderstandings. Early in his first reflective journal posting Bill revealed a misunderstanding of inquiry; namely that inquiry must be open with little to no guidance from the teacher.

> The ideal form of an inquiry based lab would be entirely open-ended. The experiment would simply explore a concept, without giving any specific instruction. I think that this method would give students too little direction, and be counter-productive. It would remove the motivational element that is necessary for inquiry. Since the students would have no set goals except to explore a concept, they would most likely not know where to begin, or care to begin at all. (Bill, Journal, 072010)

His reflection revealed that students would be unmotivated to complete this "ideal" form or "open inquiry" activity and this would lead to an unproductive learning environment. Later in the year, however, when he analyzed the teaching event for his TPA, Bill coached students and provided scaffolding for the inquiry activity to assist in their learning about the conservation of mass.

Since he was a high-scoring candidate, it was surprising that during his interview it became clear that Bill was questioning whether his lab activity for the TPA was inquiry-based instruction. Despite the fact that he evaluated his lesson using the five essential features of inquiry during the interview with two features (first and fifth) ranked as teacher-directed, and three features ranked in the middle, more student-directed, he stated the following:

> I guess I wanted them to all come to the same answer, there was, there was definitely a right answer. And there wasn't any um other interpretation or different interpretation. It was right or wrong. So that in my mind would be a very directed/structured part of it. Seems to make it pretty far from inquiry. (Bill, Interview, 082611)

This could mean that his definition of inquiry does not include teacher-directed forms of inquiry. But, when considering the qualities of inquiry he included in his written and verbal reflections, it seems that he did understand the nuances between the four variations of teacher-directed and student-directed inquiry, and the blurring of the teacher-student line in the qualities that are required for inquiry (refer to Appendix C for the Essential Features of Classroom Inquiry and their Variations chart, the four variations and his analysis).

Summary of Bill's views of inquiry. Bill demonstrated varied and nuanced understandings of inquiry-based instruction. By the end of the ten-months he was able to discuss many facets of student and teacher *qualities required for inquiry*, and focus on his students learning meaningful and relevant scientific content. Bill's statement in his interview in some ways sum up his reflections on his views of inquiry, "I'm going to do a lot of class discussions." (Bill, Interview, 082611). Bill's preferred mode of teaching was discrepant events followed by discussion.

His high scores on the TPA Task 2 also reflect a strong understanding of inquiry and the strategies to engage students in inquiry-based learning. The TPA Task 2 and Bill's reflections in Task 2 of the TPA revealed he understands the five essential features of inquiry. He also revealed misunderstandings about inquiry during his interview. He ranked his lesson as somewhat student-driven according to the Essential Features of Classroom Inquiry and their Variations published by the NRC in 2000 (see Appendix C), however, he questioned whether the activity was inquiry-based or not.

Analysis of Nina's case. Nina wrote thorough reflective journal postings and participated in a 40-minute interview. She did not reflect on inquiry-based instruction in her "Mid1" posting (121010) or in the open response ("Mid3", 031011). Therefore, four of the six reflective journal postings were used for this analysis. Note that Nina did not reveal misunderstandings about inquiry and, thus, this theme is absent from her case. A single statement indicated Nina had a realization of an early misunderstanding of inquiry was: "Um... I guess when I first started this program I thought inquiry-based instruction was, "ok, here's your supplies, go, and now think of something" (Nina, Interview, 072111). Evident in this reflection is Nina's growth, rather than a persistent misunderstanding.

Nina's definition of inquiry. Nina provided a definition for inquiry in her "Early" posting. She stated: "To me, inquiry means finding information that might be in unknown or unfamiliar territory or building on previous knowledge. It can consist of asking meaningful questions to get a deeper knowledge and understanding of a certain subject" (Nina, Journal, 072010). Note that this early definition is a more general description of inquiry, one of asking questions. This early definition of Nina's represents the first essential feature, but only alludes to others. A general definition of inquiry was not coded in any other data sources for her case. However, as in Kurt and Bill's cases, her understanding of inquiry can be revealed in her reflections coded as *qualities required for inquiry*.

Nina's qualities for inquiry. As in Nina's TPA commentary, her written and verbal reflections included the five essential features of inquiry: students are engaged in scientifically-oriented *questions*, they are asked to *give evidence* when responding, they *articulate explanations* from their evidence, they *connect* these explanations *to science content*, and they *communicate and justify* their explanations. Like other cases, Nina's *teacher qualities required for inquiry* and *student qualities required for inquiry* had a lot of overlap. For instance, while she expected to be engaging the students, "checking in on each group making sure they are on task and ask them questions to engage them further in their inquiry", and the students should also be engaged, "This type of learning [inquiry] would require hands-on techniques with students working in groups to collaborate their ideas and using each other as resources" (Nina, Journal, 072010). Nina revealed a clear understanding of the continuum and balance between teacher-directed inquiry and student-driven inquiry. Therefore, *qualities for inquiry* will be discussed as an overlapping theme.

Nina described *qualities for inquiry* in her reflective journal postings as: "self-learning", "playing devil's advocate", "challenging students", and "coaching". In her teaching philosophy, Nina revealed a rich description of instructional goals for her classroom that included student-directed inquiry:

> Being a good coach and teacher requires the ability to encounter and motivate each person as an individual. It will be important to meet the needs of the various learners I will encounter. As I have discovered from my student teaching and practicum experiences, this is easier said than done. In the end, not *all* students' learning styles will be met at the same time, but I hope to develop units that vary the learning environment to engage as many students as possible. Guided by the state standards, students will learn the concepts of Physics in a fun, interactive, welcoming and safe environment through conducting inquiry-based experiments, hands-on learning and group work. The beginning of the school year will require activities with more direction from me with a gradual shift to student-directed activities. ..... I will help guide the students to better understand the scientific concept and will also assist with making connections to real world situations. (Nina, Journal, 040711)

In this paragraph, she included teacher-as-coach and teacher-as-motivator—clearly setting up her own role as a *facilitator* of learning. She began her reflection on the teacher qualities for inquiry and at the end of her statement discussed the student qualities. This is different from Kurt's easy back-and-forth, or intermingled, teacher and student qualities.

Nina also addressed the need for *differentiation* of inquiry-based instruction for various learners. Her students were working on an inquiry unit where they were learning about simple machines. She stated:

> So the students pretty much designed their own lab activities so they, picked a tool they were interested in, and they made their own questions, they made their own lab, like how they collect data and everything. So they were a lot more student-centered. But, again there were also some students who needed a little bit more help. Like, how do I make a lab to test the wedge or whatever their tool was [*sic*]. (Nina, Interview, 072111)

In the example she described, Nina revealed the need to offer more scaffolding for some students working on an inquiry activity. This varied amount of scaffolding can be interpreted as the need for *differentiation* of instruction.

She also reflected on the sub-theme of *introducing inquiry slowly*, where students are heavily coached at the beginning of the year and more student-directed work at the end of the year. In her first reflective journal posting in the summer ("Early", 072010), her spring teaching philosophy ("Late", 040711), her final spring posting ("Last", 042811), and in her interview. Her definition of the *qualities required for inquiry* starts out teacher-centered and shifts slowly over the course of the ten months to one that is more student-centered.

Nina emphasized that physics is fun and she wanted a welcoming classroom, with hands-on learning, group work, and relevance—all with a gradual shift from teacher-directed to student-directed inquiry. Nina's was one of three cases where the importance of a welcoming classroom environment was revealed. Evidence of this appeared in her teaching philosophy, as quoted above, and also in her interview:

> Hopefully they will um, appreciate science more, and become interested in maybe even pursuing in a career in science. Um, I remember a lot of the students were was there on my last day, they were, saying you know, “I didn't realize that I really liked science. You know you really helped me. It was really good having you there.” And also, um, my cooperating teacher, because we had two different perspectives. And then a lot of the girls mentioned, “it's really nice seeing a woman or female working with science”. And they really liked that. Um, I'm hoping that they would be more interested in science, not necessarily physics. But, just science in general. (Nina, Interview, 072111)

Here she reflected on her last day of student teaching and that some of her students appreciated having a female physics teacher, this made science more accessible and Nina had created a classroom culture where students felt they could discuss this with their teacher.

5 E learning cycle. Unlike Kurt, while Nina used the term “engage” in her written reflections and TPA commentary, and “explore” and “explain” in her interview, she did not reveal a prevalence of using the other 5 Es from the Learning Cycle.

Nina’s barriers to inquiry. The theme *barriers to inquiry* appeared in Nina’s TPA commentary, her reflective journal postings, and in her interview. These barriers included aspects of her teaching that prevented her from implemented inquiry, as well as the students' struggles with inquiry activities. In her journal postings she reflected on "time" and "patience" for inquiry as well as a hope for her future. "I hope to use some of the discrepant events that some of my colleagues demonstrated during the summer semester" (Nina, Journal, 020311). In her interview, she revealed the need to know the "context" of her teaching to be able to implement inquiry; her limited knowledge of the students, the wide-range of learners, the lack of materials, and "student frustration" and discomfort with inquiry all led her to struggle somewhat in her student teaching placement, despite the support from her cooperating teacher. However, she also noted that students' *frustration* is beneficial. She stated: "So just making sure the students have an open mind for this type of instruction and to help them know that getting frustrated is alright" (Nina, Interview, 072111). So while frustration can be a barrier, it can also be helpful for student learning.

Nina also commented in her interview on the barrier to student participation during her video recording of the teaching event for the TPA. She stated:

> There was one girl, who she would raise her hand all the time, talk all the time, answer all of the questions, ask me questions about everything. But, as soon as she found out we were recording. She just shut down. And she was just like, and she was like, "don't call on me, please don't call on me, I don't want to be on camera." She would ask me, "did you turn it off then? Is it still on? Is it off?" (Nina, Interview, 072111)

In her case, implementing this lesson with the camera on revealed a different dynamic than what she was expecting or used to experiencing in her classroom.

Summary of Nina's views of inquiry. Nina demonstrated a varied and nuanced understanding of inquiry-based instruction. By the end of the ten months, she was able to discuss many facets of student and teacher qualities required for inquiry, setting it into perspective of differentiation required for various student learning needs and relevant scientific content. Nina's statement in her "Last" spring reflective journal posting in some ways sum up her reflections on her views of inquiry, "Inquiry-based instruction and planning is an area where I will need to continue to grow." (Nina, Journal, 042811). She continued to work on inquiry, and was hopeful that she would be able to continue to perfect her skills. Her mid-level scores on the TPA Task 2 also reflect a strong understanding of inquiry and the strategies to engage students in inquiry-based learning. The TPA Task 2 and Nina's reflections in Task 2 of the TPA reveal she understands the five essential features of inquiry.

Analysis of Jenny's case. Jenny's written (reflection journal postings) and verbal (interview) reflections were concise and brief. Jenny's interview was 41:01 minutes long. In her interview she detailed her inquiry-based activity and the frustrations she felt, as well as the *barriers* she encountered, while attempting to complete this assignment. She talked at length about the qualities teachers and students would need for inquiry-based instruction, each coded in eight long stretches of text. However, she did not choose to reflect on inquiry in either the "Mid1" (final fall reflections on practicum, 121010) or "Mid2" (reflect on barriers, 020311) reflective journal postings. Therefore, four reflective journal postings and her interview are the available data sources used to analyze this research question.

Jenny's definition of inquiry and qualities for inquiry. Jenny's statement in her first reflective journal posting ("Early", 072010) was coded almost entirely as specific *teacher qualities for inquiry* or *student qualities for inquiry*. She did not write very much about inquiry using generalities. Only the first sentence was a general statement of inquiry. The following was her response to the journal prompt, "In your own words describe what inquiry means to you":

> From a very general perspective, I think inquiry denotes **asking questions** and seeking answers. The best questions, in my experience, originate from genuine curiosity and creativity. So inquiry based education would involve planning and organizing activities to intrigue students and raise their curiosity while providing them with the opportunity to utilize their creativity to **formulate interesting questions** and **pursue the answers**. As we've discussed in class, the **question(s)** could also be posed by the teacher but his/her role would be that of facilitator while the **students devised methods to find the answers** and tested those methods. Inquiry based learning promotes critical thinking, the development of **problem solving skills**, and self-confidence in ones [*sic*] ability to **learn about and understand science**. I think it's critical that students at the high school level be able to **distinguish questions** and **interpretations that guide scientific investigation**, **design and implement their own scientific inquiries**, **recognize and resolve problems** as they apply to those investigations, **revise and rework** the procedures if necessary, **recognize alternative explanations**, and ultimately to reasonably **communicate and**

> **defend a scientific argument**. The key, I think, to truly establishing these skills and abilities in students is to provide them with the "hands on" opportunities to experience for themselves the excitement and personal rewards that accompany genuine scientific inquiry. (Jenny, Journal, 072010)

Note that she weaves back and forth, creating a definition of inquiry that reveals the teacher qualities and how these are required both for student engagement in inquiry and the qualities that the students must have as well. The teacher is "planning", "organizing", attempting to "intrigue students", facilitating, and providing "hands on opportunities." While the students in an inquiry-based classroom are expected to "distinguish questions and interpretations", "design and implement their own scientific inquiries", "recognize and resolve problems", "recognize alternative explanations", "revise and rework procedures", and "reasonably communicate and defend a scientific argument". In this comprehensive definition, Jenny captured all five essential features of inquiry within the first week of her science methods course work.

As the year progressed, Jenny reflected on these and other *qualities for inquiry* in her written (reflective journal postings) and verbal (interview) reflections. They included: students are "action-oriented", "being scientists"; teachers need "flexibility", and be willing to "make adaptations". She anticipated that students would gain independence and to "think for themselves", but she returned her comments to "anticipating and knowing her students" as important aspects for her successful implementation of inquiry-based instruction.

5 E learning cycle. Jenny used the terms “elicit”, “engage”, and “explore”, in her written reflections and both “elicit” and “engage” after being prompted by the TPA commentary. She also used “explain” in her TPA. However, despite including more of the 5 Es in these data sources, she only used the term “engage” in her interview, after being prompted to consider it. Jenny also did not reveal a prevalence of using the 5 Es from the Learning Cycle.

Jenny’s barriers to inquiry. Jenny reflected on some of the barriers to inquiry that she encountered in her practicum and her student teaching experiences in her interview. She struggled with the dichotomy of being flexible and completing the lessons in a timely manner.

> I enjoy doing organization and thinking, about you know, and flexibility, that's an area that I've improved drastically but, probably have a ways to go. I'm not as flexible as I think I am. Again, I get stuck on I have to get through this, I have to time-wise, the clock is ticking, you just have to be able to be flexible. Inquiry demands it…every class is going to be different. (Jenny, Interview, 072111)

She felt a lot of pressure to complete activities and lessons in a certain period of time, even though her cooperating teacher emphasized student learning as the most important element to consider when planning the next day’s lesson. Her critique of her inflexibility may be one that resonated with her. She was the oldest of the TCs to participate in the interviews and had reflected on this in class discussions; that as an older teacher she might be prone to inflexibility, unlike the younger TCs in the program.

She considered her students as *barriers* to successful inquiry based instruction. They were not used to inquiry instruction, they did not like making predictions, recording data or analyzing results; they preferred to be told what to do (Jenny, TPA Commentary & Jenny, Interview, 072111). But to counter her self-critique of being "not as flexible as I think I am", when she considered the *teacher quality of inquiry* of adaptability (flexibility), she reconsidered the idea:

> I think every group is going to be different. And you can't necessarily do one activity that is inquiry with one group and with that group as you can with another. So, and I mean beyond the maturity level the students have, and that sort of thing, and just understanding who those kids. And even every class might be a bit different; you might have to make adaptations. (Jenny, Interview, 072111)

She also countered this with the caveat that some frustration is good and can promote student learning.

Recording her teaching event of the TPA was a big barrier for Jenny. She felt like she and the students were "distracted" during the teaching event. She felt it was a useful exercise however frustrating: "but the results when you actually look at yourself on video. It's phenomenal. I mean, it's, it's a worthy um, assignment, it's a frustrating assignment. But it's very worthy. And there's just gotta be away around the distraction that it causes" (Jenny, Interview, 072111). Her cooperating teacher was in charge of making the recording and he did not capture some of the moments of the lesson that Jenny had hoped he would. Therefore, her reflections on the lesson were limited somewhat by what was recorded in the video clips.

Summary of Jenny's views of inquiry. Jenny's case is an interesting one, as she spoke and wrote eloquently about her understandings of inquiry and, yet, her scores on the TPA were mid-range. She passed the TPA but her scores do not reveal her rich understanding of the nuances of implementing inquiry in diverse classrooms and contexts. In this case, her poor video/audio quality and lack of evidence in rubric S5, level 3, "Candidates and/or other students build on what students are saying and/or doing to improve understanding of science concepts, explanations, and the quality of data," (SCALE, 2011, p. 17) negatively affected her score for this rubric. Her students' conversations could not be heard, due to this lack of evidence she scored a 2 for rubric S5. She received a passing score and therefore the TPA would recommend that she was ready to teach, however, a score of 2 is not reflective of her nuanced knowledge of inquiry. From Jenny's first posting she stated, "Inquiry denotes asking questions and seeking answers" (Journal, 072010). I felt this quote typified Jenny's sense of inquiry. She showed a deep knowledge of inquiry, however, throughout her reflections she continued to return to the essence of inquiry as asking questions and finding answers.

Analysis of Adele's case. Adele wrote brief reflective journal postings and participated in a 53-minute interview. She did not reflect on inquiry-based instruction in her last fall posting "Mid1" (121010) or "Mid2" reflecting on barriers to inquiry

(020311). Therefore, four of the six reflective journal postings were used for this analysis. Note that Adele did reveal confusion or perhaps a misunderstanding about inquiry in her interview.

Adele's definition of inquiry. Adele's definition of inquiry was coded in her third term of science methods course, after she had completed her student teaching in the spring. Like other cases, Adele's definition includes teacher and student qualities of inquiry. Therefore, this was also coded as teacher and student *qualities for inquiry*:

> Inquiry to me means that students are using their own experiences both previous experience and current experiences to learn content. An inquiry lesson allows
>
> students to explore the world around them, **ask questions**, **make assumptions**, and **make connections to concepts**. In some (most) cases the teacher is directing the experience to keep the students attention on the concept that the teacher wishes the students to learn, but he path taken throughout that learning belongs to the student. If used properly, the cycle of inquiry would be never ending, because the discovery of one outcome would spark yet more questions, more assumptions and more connections to that concept. Inquiry can be entirely student centered, where the students pose all of the questions, they make all of the assumptions and provide all of the connections (resources) to reach a conclusion. Or, it can be teacher led, where the teacher poses the question, the students make some assumptions with guidance, and the teacher

> provides some of the connections or resources to help students read conclusions. (Adele, Journal, 071911)

Note her definition lacks the clarity of the previous cases and represents three of the five essential features (bolded above). Instead, she reflected on who is leading the inquiry; that is, the teacher or the student. She does, however, include the 5E learning cycle in part of her definition here and in her final spring posting, “I don’t have to make a big thing to make it inquiry, I just have to include certain elements, like engaging, exploring, explaining, expand, and evaluate” (Adele, Journal, 042811). She did not write a generalized definition of inquiry like those that were present in other cases; hers clearly has the teacher and student inserted into the definition. Perhaps this was due to her taking the science methods courses out of sequence.

Adele’s qualities for inquiry. Adele reflected on qualities for inquiry in her written reflections for “Mid3” open response, “Late” teaching philosophy and her “Last” final posting in the summer as well as in her interview. *Teacher qualities* included several examples of instructional strategies: “classroom management”, “academic language”, “higher order thinking questions”, “variety of teaching styles”, “plan to conduct a variety of experimentation in the classroom”, and “lecture”. *Student qualities* also represented instructional (or learning) strategies: “exploring”, “expanding”, “higher order thinking”, “comparing things”, “discover” and “touch things”. Among examples of non-instructional strategies, Adele included: “real-world situations” and “what does that mean scientifically.” Perhaps this listing of instructional strategies is a limited view of *qualities for inquiry*. Note she does not include non-instructional aspects that are found in other cases, such as a *welcoming/safe community* nor the *foundational* knowledge required to learn science in her reflections.

When prompted to consider what aspects of the methods courses she used in her classroom, Adele stated, among examples of instructional strategies: “Um, making sure that, that they're not just doing the lab for the sake of doing a lab. That they're actually getting something out of it” (Adele, Interview, 090111). This statement was important. While she did not say it in so many words, Adele realized that hands-on activities for the sake of getting your hands on science equipment are not enough to guarantee student learning. The students need to also connect their activity to the scientific concepts that are being revealed or demonstrated in the activity.

5 E learning cycle. In her written reflections, Adele used the terms “explore” and “expand” which may refer to “elaborate” of the 5 E Learning Cycle. She used “elicit” after being prompted and “explain” in her TPA commentary. However, despite including these 5 Es previously, she only used the terms “engage” and “explain” in her interview. Adele also did not reveal a prevalence of using the pedagogical terms of the 5 Es from the Learning Cycle.

Adele’s barriers to inquiry. Adele encountered many *barriers to inquiry* in her student teaching experience. The biggest barriers she reported were large class sizes, the students’ inexperience with inquiry, and her own lack of knowledge of inquiry; she was the only TC who took the summer introductory inquiry course after she had completed her student teaching. Adele discussed her attempts to incorporate inquiry for the TPA teaching event:

> More inquiry yeah. More open and going toward a more open-ended inquiry. I think it's something that never really experienced. Um, and in some cases, I kinda feel like they were opposed to it. Maybe because they just developed this dependence over time. (Adele, Interview, 090111)

Her students' misbehavior and her attempts to regain control were very apparent in her video clips. Taking these comments into consideration, perhaps Adele tried to implement inquiry without the scaffolding that the students needed and depended upon. Of her 9^{th} grade physical science students, she stated:

> They were used to being bottle-fed. They were used to um, being given a cookbook lab, and you follow the directions; well, in most cases, they wanted you to walk them through the directions, rather than following the directions themselves. (Interview, Adele, 090111)

In addition to the students, Adele also mentioned lack of equipment, limited time to alter cookbook labs, and limited lab space as other barriers.

Like some of the other TCs, Adele struggled to get good video clips for this assignment. Her students were clearly distracted by the camera, making faces and play-fighting. But, the video clips were not the only weak aspect of her TPA. She was confused by the prompts of the TPA Commentary as well. She stated:

> And then for me, as a some of the prompts were kind of hard to understand …There was one part where it asks for four things, four or five things, and I

> caught most of them, but somehow I missed one part of the question, but it was all in one big block. (Adele, Interview, 090111)

She also felt rushed to get this assignment done and out of the way, so she could just focus on her teaching.

Adele's misunderstandings. Adele revealed one area of confusion, or a *misunderstanding of inquiry*. Initially, when she began to talk about her TPA Task 2 activity, she stated, "Well unfortunately it was a cookbook lab [laughs]" (Adele, Interview, 090111). But, when she proceeded to evaluate her teaching event, using the NRC's (2000) Essential Features of Classroom Inquiry and Their Variations chart, she ranked the activity as being in the middle of the continuum of teacher-directed and student-led inquiry (see Appendix F). When asked to reconsider whether the lab recorded for the TPA was inquiry-based or not, she stated: "Where there's [sic] definitely some aspects that were inquiry in the lab. Just from looking at the chart…Um, you know I, I have a much more broad definition of what inquiry is nowadays, than I did when I first started [laughter]" (Adele, Interview, 090111). So while the misunderstanding was present in the interview, she altered her thinking, with the help of the NRC's Essential Features of Classroom Inquiry and Their Variations table.

Summary of Adele's views of inquiry. When all of Adele's data is analyzed, she did not include all aspects of the five essential features in her written reflections of the *definition* or *qualities for inquiry*. It was not until her interview, after her licensure program was complete, that she talked about all five essential features. By using the

Essential Features of Classroom Inquiry and Their Variations chart published by the NRC (2000) the TCs were asked to reflect on their teaching event they recorded for their TPA. It was at this juncture that Adele reflected on all five essential features.

Adele stated in one of her last reflective journal postings, “A quiet class is a ‘boring’ class” (Adele, Journal, 071911). This statement typified her TPA video clips, as well as some of the more simplistic views she related in her journal postings and interview. Adele believed that inquiry-based instruction was important, and that the labs should be meaningfully connected to the science concepts that students were learning. In practice, however, she was still working on making this happen. She admitted her room was chaotic, and, when she implemented the lesson for her TPA teaching event, her understanding of inquiry was limited and confused. She encountered many barriers to inquiry during this teaching event; unwilling students, lack of equipment, lack of knowledge, video camera distraction, and time. Perhaps if she had implemented this lesson later in her student teaching experience, things would have gone more smoothly. Perhaps it was important for her to have the inquiry methods summer course before her student teaching, as it was intended. This may have given her the knowledge and confidence to better handle the barriers as she encountered them.

Analysis of Leah’s case. Leah wrote brief reflective journal postings and participated in a 35 minute interview. She did not reflect on inquiry-based instruction in her last fall posting “Mid1” (121010). Therefore, five of the six reflective journal postings were used for this analysis. Note that Leah did reveal misunderstandings about inquiry in all three of her data sources—TPA commentary, reflective journal postings, and interview.

Leah's definition of inquiry. Leah's *definition of inquiry* from her first reflective journal posting ("Early", 072010) revealed a fuzzy conception of inquiry:

> What inquiry means to me is for a teacher to engage the students in learning. They take a more active role than just sitting in a lecture and listening to a teacher recite facts and explanations. When a **question is either presented by the teacher or presented by the student**, there is usually more than one answer. It seems more of an opinion based type of learning and it seems very different to me the traditional way of teaching, especially in science. There were not many chances in my life where I had inquiry based teaching. I can't remember any classes where I was able to do that. (Leah, Journal, 072010)

This statement is the one and only time in her reflective journal postings where Leah mentioned the first essential feature of inquiry, "learner engages in scientifically oriented questions". She did not refer to teachers or students posing questions again. However, she followed this up with "it seems more of an opinion based type of learning" a fuzzy conception of inquiry. While students are able to express their opinions during inquiry based instruction, the goal is for students to be active players in their knowledge construction, and that their lived experiences will allow them to learn the scientific concepts that they are testing—not necessarily that it is based on opinions.

She also stated: "There will be multiple correct answers while doing inquiry [*sic*] instruction" (Leah, Journal, 072010). It is not the goal that every student can have their own opinion about a scientific concept; this would challenge the very nature of standards of science education adopted by the NRC and most states. Finally, this quote revealed that Leah had not experienced inquiry-based instruction before taking this methods course. The hands-on inquiry-based activities that she and her peers completed and analyzed in class were her first exposure to inquiry. This is not uncommon for TCs in science education (Windschitl, 2004). Further examples of Leah's reflections to define inquiry include the specific *qualities for inquiry* of teachers and students, and can be found in the next section. She did not reflect on inquiry in generalities.

Leah's qualities for inquiry. Throughout her written and verbal reflections, Leah included only three of the five essential features of inquiry: students are engaged in scientifically oriented *questions* (stated only once in her first summer reflective journal posting), they *articulate explanations* from their evidence, and they *connect* these explanations *to science content* (stated twice in the interview). She lacked evidence of essential feature two, *gives priority to evidence,* and five, *communicates and justifies explanations*. Recall that she also lacked two of the essential features in her TPA, one and five.

In her interview, when she was prompted to reflect on her TPA Task 2 activity, Leah briefly talked about each of the five essential features. For the two features that were missing from her TPA, one and five, she ranked the first as somewhat student-led, “learner sharpens or clarifies question provided by teacher, materials or other source”, however her activity did not include an essential question. There were no questions to sharpen. Instead, she told students the purpose that was also included on their handouts. For the fifth essential feature, she ranked her activity as in the middle of the spectrum between teacher-directed and student-led, “learner coached in development of communication.” Despite this, no analysis questions were included and no evidence of communication was mentioned in the TPA nor seen in the video. She claimed to have included prompts to allow students the opportunity to communicate in writing; however, there was no evidence of it. Her statements disagreed with her own assessment of the activity in her TPA commentary and in the materials provided for the hands-on laboratory for this lesson. Her limited use of the five essential features of inquiry in her reflections, and the fact that she neglected to reflect on: 1) the questions students would be engaged in and 2) how students would be communicating their explanations, leads one to think that Leah did not have a firm understanding of inquiry-based instruction as defined by the NRC and evaluated by the TPA.

Leah’s written (reflective journal postings and TPA) and verbal (interview) reflections exposed a very teacher-centered stance. Whether Leah was discussing students or teachers, she most often returned to a teacher-centered description of *qualities for inquiry*. For instance, “and I gave them a brief introduction”, “I would let them write their conclusions”, and “I’ll do a lab and start, start small, you know”. Note that in each instance, these could be phrased in student-centered language instead; learners listen to introduction, learners write conclusions, learners do the lab.

Leah's reflections, both written and verbal, bounced back and forth offering a glimpse of what students' qualities are required for inquiry, but then returned quickly to what she would be doing as the teacher. An example of this teacher-centered stance appeared in Leah's teaching philosophy.

> The students will also be given a lot of choice in their learning, which will help intrinsically motivate the students. There will be group work in which students can build their knowledge together. A cooperative learning environment will be established so they can learn teamwork skills and their learning can be maximized by emphasizing their individual strengths. (Leah, Journal, 040711)

Students are "given a lot of choice", "there will be group work", and "a cooperative learning environment will be established" are all examples of a blend of student/teacher qualities, or a bouncing back and forth between a teacher-centered stance and what students will be doing. This blending is perhaps even more apparent in the first sentence in the above quote. Leah offered student choices, which in turn will motivate students intrinsically; in other words, from teacher-centered to student-centered. Many of her written and verbal reflections on *qualities for inquiry* reveal this blending of teacher/student qualities. "Students need a balance of traditional teaching and inquiry teaching so I will implement a variety of teaching and learning methods" (Leah, Journal, 040711).

This consistent blending of *qualities for inquiry* is unique to Leah's case. The other TCs clearly defined roles and qualities for inquiry that teachers or students must exhibit that overlapped at times, but did not blend so completely. In some sense, her statements were so general that it was not clear she had an explicit understanding of inquiry-based instruction. Perhaps it was this blending that prevented Leah from considering student learning. Her strong teacher-centered stance and blurred *qualities for inquiry* did not allow her to look beyond her own tasks and responsibilities.

Despite this blending of teacher and student *qualities for inquiry* Leah offered a variety of examples. As stated above, she included cooperative group work, introduce the topic of inquiry slowly, and a variety of instructional methods. Other examples included: “guidance”, “problem solving”, “team work”, “fundamentals”, “hands-on work”, “critical thinking”, “exploration of science”, “explanations”, and “analysis”.

5 E learning cycle. In her written reflections, Leah used the terms “explore” and “explain” of the 5 E Learning Cycle. She used “elicit” after being prompted in her TPA commentary. However, despite including these 5 Es previously, she did not include any in her interview. Leah, like the other TCs, did not reveal frequent reference to the pedagogical terms of the 5 Es from the Learning Cycle.

Leah’s barriers to inquiry. Leah included some examples of barriers to inquiry-based instruction. However, this was not a frequently coded theme for her. In her “Early” posting, she anticipated that inquiry was “easier for students to get frustrated” (Leah, Journal, 072010). She did not reflect on barriers to implementing inquiry again until her “Last” spring posting and her interview. Therefore, the barriers she experienced were, “I would have to retype it, to make it not cook-booky [*sic*]” and “time”. In fact, Leah thought inquiry was easy to implement.

> When I first started talking about inquiry-based instruction, I thought it was going to be very hard to implement it into teaching. When I actually started teaching, I realized how easy it can be to do inquiry-based instruction, even if it is at a basic level. (Leah, Journal, 042811)

The question remains as to whether she was implementing inquiry in her classroom or whether she was just leaving assignments open for students to make their own interpretations. This topic will be analyzed further in the next section.

Leah's misunderstandings. Some of Leah's misunderstandings or fuzzy conceptions of inquiry have been stated above, and are reiterated here. When defining inquiry in her "Early" reflective journal posting, Leah revealed a fuzzy conception of inquiry "it seems more of an opinion based type of learning" where there are "multiple correct answers" (Journal, 072010). This theme was revealed again in her TPA commentary, where she stated, "I never gave them the direct answer I had them try to figure everything out by themselves" (prompt 3).

Finally, in her interview, Leah's misunderstandings lingered in contradictions. She asserted that chemistry was a subject in which it was difficult to do inquiry activities. This seemed to contradict her earlier desire to "never give them the direct answer" and letting students "figure everything out by themselves." Instead, she insisted on guiding the students:

> …in chemistry especially it's really hard to do full-blown inquiry. I don't think I have gotten there yet. There's so much information that they don't, or never heard of before. Um, and you can't really do a chemical reaction without

> knowing the mechanisms behind it, so we have to guide them, what kind of what reactions to do, or guidelines, so… (Leah, Interview, 083111)

She went on to claim that, "Cause non-inquiry just has textbooks" (Leah, Interview, 083111). This statement contradicts her assertion that there are "cook booky" labs that need modifications to be rewritten as inquiry-based instruction. Her final contradiction comes in her statement about her cooperating teacher's efforts to implement inquiry in his classroom. She seemed to equate doing labs with inquiry. "Um, my cooperating teacher did a lot of labs. So he was like pretty good. Um, implementing inquiry, uh, he did a lot of PowerPoints though [rising voice]" (Leah, Interview, 083111). These contradictions and her generally vague statements make it difficult to claim that Leah has a firm understanding of inquiry.

Summary of Leah's views of inquiry. Leah's limited use of the five essential features of inquiry in her reflections, and the fact that she neglected to reflect on the first and fifth essential features that deal with *questions* students would be engaged in how students would be *communicating their explanations*, leads me to conclude that Leah did not have a firm understanding of inquiry-based instruction as defined by the NRC and evaluated by the TPA.

She did not pass the TPA Task 2, having received two scores of 1 for the rubrics for this task. In her interview, her verbal reflections contradicted each other and what she said in her TPA commentary Leah's *definition of inquiry* early in the year consisted of fuzzy conceptions. The *qualities for inquiry* that she listed throughout the coursework and her student teaching experiences revealed a unique blending of student and teacher qualities that exposed a teacher-centered stance of inquiry and/or her teaching. The TPA scores and the other data sources agree that Leah's understanding of inquiry was sub-par.

Cross Case Analysis

The six case narratives included brief comparisons of one teacher candidate to another, however, in the next section the cases will be formally analyzed across the six cases to elaborate on what was learned from the group as well as the individuals. This section is organized by research question. It should be noted, however, that there is considerable overlap between what the TPA revealed of candidates understanding of inquiry-based instruction as it relates to the NRC's five essential features of inquiry and how candidates represent their knowledge of inquiry in their reflections. Therefore, the data sources will be used across all cases and both research questions.

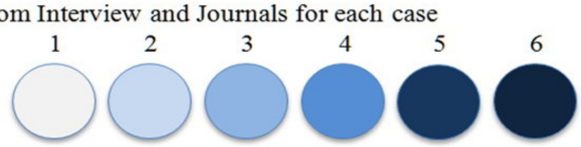
RQ1: What does the teacher performance assessment reveal about science education teacher candidates' understanding of inquiry-based instruction?

Table 5.1 represents the frequency each TC reflected on the five essential features of inquiry, which is the theoretical framework from which their commentary was analyzed here, in their written (reflective journal postings) and verbal (interviews) reflections. Note the darker circles represent coded statements that occurred more frequently. The absence of circles represents a candidate did not mention that essential feature of inquiry in any of their written or verbal reflections. They are listed with Kurt at the top with the most references to the five essential features of inquiry down through the others to Leah, at the bottom, with the least number of references. What is interesting is that there is a correlation between the frequency of references to the five essential features of inquiry and the TCs' TPA scores. The scores appear below each candidate's name on the left. Kurt reflected on the five essential features of inquiry the most often, and he was also a high scoring candidate on the TPA. Leah, the candidate who failed the TPA, did not address two of the five essential features of inquiry in her written or verbal reflections, and for those three that she did reflect upon, she did so only once, twice and three times overall. While she did reflect on all five essential features in her interview, Adele was missing essential features in her reflective journal postings and her TPA. It was not until she was prompted to consider all five with the Essential Features of Classroom Inquiry and their Variations chart that Adele included them. Note, that for the first, second and third essential features were referenced one time each.

Table 5.1
*Frequency of Teacher and Student Qualities representing the 5 Essential Features of Inquiry**

Name TPA Scores	1 – Learner engages in scientifically oriented questions	2 – Learner gives priority to evidence in responding to questions	3 – Learner formulate explanations from evidence	4 – Learner connects explanations to scientific knowledge	5 – Learner communicates and justifies explanations
Kurt 3,3	6	5	6	4	5
Bill 3,3	3	1	5	2	1
Nina 2,3	4	5	2	1	2
Jenny 2,2	4	3	3	3	2
Adele 1,2	1	1	1	3	2
Leah 1,1	1		3	2	

*Data from Interview and Journals for each case



The four TCs who passed the TPA also revealed their understanding of the five essential features of inquiry, both in their TPA and their written and verbal reflections. However, despite the fact that the four TCs (Kurt, Bill, Nina, and Jenny) who passed the TPA can and do address the five essential features of inquiry in their TPAs, they do not use the pedagogical terms for planning and implementing inquiry-based instruction introduced in the methods courses—namely the 5 Es. These five terms are meaningful for preparing and planning to teach inquiry whether it is teacher-directed or student directed; students are **engaged** in a demonstration, they **explore** the science concepts, they **explain** their understandings and **elaborate** on their knowledge, all the while the teacher is **evaluating** them through formative assessments. The four TCs who passed the TPA were not using the pedagogical terminology but they understood the pedagogy of inquiry and have rich definitions and nuanced views of teacher and student *qualities required for inquiry*.

The two low-scoring candidates (Adele and Leah) did not represent all five essential features of inquiry in their TPA, nor did they use all 5 Es for planning and implementing inquiry pedagogy in their reflections and interviews. In their cases, the TPA revealed their limited understanding of inquiry-based instruction. Adele does reference all five essential features of inquiry in her written and verbal reflections, although not with frequency. She may have passed the TPA with a score of (1,2) on Task 2. But, receiving a score of 1 is cautionary. Leah, on the other hand, referenced only the first, third, and fourth essential features of inquiry in her written and verbal reflections and also failed the TPA. In her case, the scores on her TPA revealed her limited understanding of inquiry as did her written and verbal reflections throughout the ten-months of her participation in the licensure program.

RQ2: How do the candidates represent their knowledge of inquiry in their reflections?

Qualities for inquiry. As stated earlier, when analyzing the six cases, it became clear that the *teacher qualities required for inquiry* and *student qualities* *required for inquiry* themes had many overlapping and common sub-themes. It was during the cross-case analysis that these themes were aggregated into one, *qualities for inquiry* and analyzed more closely. In addition to the frequency of reflections on the essential features of inquiry, a model was prepared to represent the TCs' understanding and multi-faceted views of the students and teachers *qualities for inquiry*. There are eleven important sub-themes that are derived from the data and are included in this model, see Figure 5.1. Note that data from all six cases were included in the frequency counts for each sub-theme. Again, Kurt's frequency counts are higher than the other cases, while Leah's are the least frequent. However, perhaps frequency is not as important here as the fact that the candidates discussed these sub-themes in their reflections-on-practice.

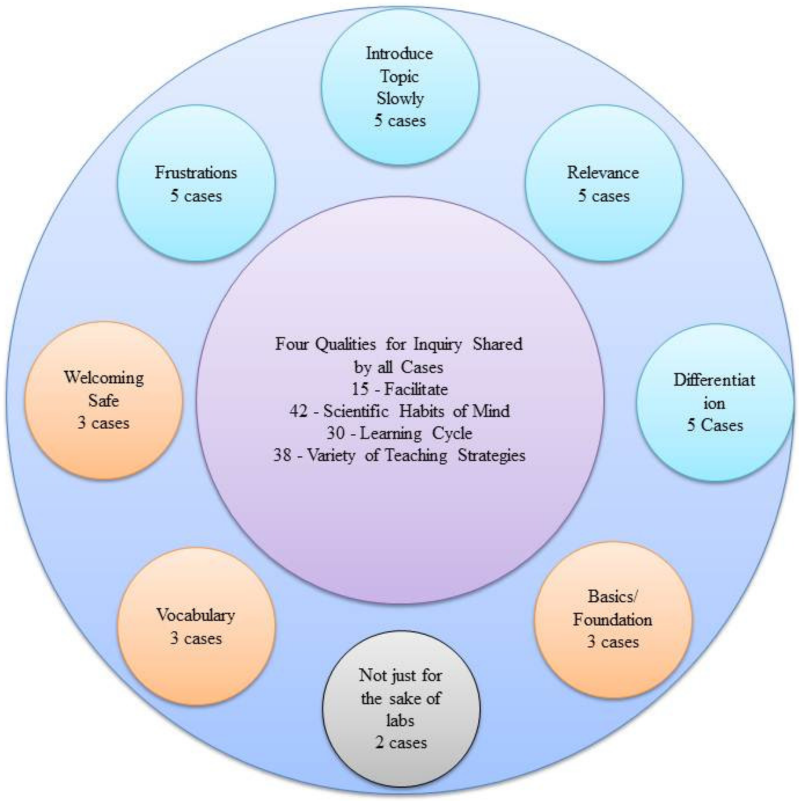


Figure 5.1 Model of Qualities Required for Inquiry

The large blue circle in the model represents the candidates understanding of the *qualities for inquiry*. The purple circle in the middle represents the four sub-themes of *qualities for inquiry* that are shared by all six case narratives and are listed here with their frequencies of appearance: facilitate (15), scientific habits of mind (42), 5E learning cycle (30), and variety of teaching strategies (38). The smaller circles represent sub-themes that are shared by two, three or five of the six candidates' case narratives. The sub-themes of *qualities for inquiry* included here are listed with the number of case narratives that included each: frustrations (5), introduce the topic slowly (5), relevance (5), differentiation (5), basics/foundations (3), welcoming/ safe classroom (3), vocabulary (3), and not just for the sake of labs (2).

These twelve sub-themes and the frequency with which they appeared in the narratives (177 references of the varied *qualities required for inquiry*) represent a highly-nuanced view of inquiry-based instruction and what it takes to implement and participate in inquiry. Differentiation and frustrations are discussed in subsequent sections of this chapter as newly emerged themes. However, the remaining ten requires some more explanation. Table 5.2 reveals which of the sub-themes of *qualities for inquiry* appeared in each case.

Table 5.2
*Twelve Shared Subthemes of Qualities for Inquiry by Case **

	Kurt	Bill	Nina	Jenny	Adele	Leah
Facilitate/ Guide	X	X	X	X	X	X
Scientific Habits of Mind	X	X	X	X	X	X
Learning Cycle (the 5Es)	X	X	X	X	X	X
Variety of Teaching Strategies	X	X	X	X	X	X
Frustrations	X	X	X	X	X	
Introduce the Topic of Inquiry Slowly	X		X	X	X	X
Relevance	X	X	X	X	X	
Differentiation/ Scaffolding	X	X	X	X	X	
Welcoming/ Safe Classroom		X	X	X		
Vocabulary	X		X		X	
Basics/ Foundational Concepts	X	X				X
Not just for the sake of labs	X				X	

* An "x" in the box indicates the candidate shared this sub-theme with others.

Four shared sub-themes. The first four sub-themes of *qualities for inquiry* were shared by all six case narratives and are represented in the Model of Qualities Required for Inquiry (see Figure 5.1). These include: teachers need to *facilitate/guide* students, the importance of teaching and learning the *scientific habits of mind,* the use of the instructional planning model (the *Learning Cycle* or *the 5 Es*), and use of a *variety of teaching strategies.*

Some of the language that appeared in the case narratives to describe teacher *facilitation* or *guidance* included: overseen, guided, directed, reassured, assisted, coached, tailored, encouraged, and act as a resource. This sub-theme appeared numerous times in Kurt's, Bill's and Nina's narratives, and a couple of times each for Jenny, Adele, and Leah. The three top scoring candidates talked about teacher as facilitator more often than the three lower scoring candidates. Gooding and Metz (2012) recommend that the desired level of inquiry is one where the teacher provides the question to guide the inquiry. The question can even be fine-tuned by the students. However, the remained of the inquiry activity is designed and carried out with the students in charge. Guided inquiry is a method of implementation of inquiry-based instruction that is highly recommended in the literature, and the TCs have reflected often on this recommendation (Gooding & Metz, 2012; Eick, Meadows, & Balkcom, 2005; Martin-Hansen, 2002).

Scientific habits of mind, another sub-theme represented in the model, included a wide-range of student and teacher behaviors. All six narratives were included this sub-theme and the TCs reflected on it in various ways. Examples include: critical thinking skills, thinking outside the box, brainstorming, scientific ways of knowing, scientific investigation, expect to find answers, higher order thinking skills, and deep critical thought. While this sub-theme appeared in all case narratives, Kurt spoke about it far more frequently and in more detail than any of the other TCs.

This sub-theme persisted throughout the ten months, as it was present in his first reflective journal posting in the summer. Kurt returned to it in his teaching philosophy in the spring, and his interview. Examples of approaches of promoting scientific habits of mind according to Kurt include: “critical thinking skills”, “life-long learning”, “thinking outside the box”, “brainstorming”, “developing better solutions”, “employing scientific methods and strategies”, “scientific ways of knowing”, “the process of science”, “intellectual habits”, “higher order thinking skills”, “hashing out ideas and proposing possible solutions”, and students would be “active researchers”.

Bill, Nina, Jenny, and Adele each reflected on *scientific habits of mind* a handful of times and with some evidence of a nuanced understanding. Their statements included: “inquiry”, “meaningful learning”, “appreciate science more”, and an awareness that “science is around us”. Although Leah mentioned some aspects of *scientific habits of mind*, her examples were more general: problem solving, inquiry, and critical thinking. These are terms that indicate an understanding of some of the teaching strategies that are important for students to gain a scientific habit of mind. However, she did not link it to aspects outside of the classroom as the other cases did. Examples as mentioned by the TCs of *scientific habits of mind* are similar to those approaches that are endorsed in the literature on teaching the nature of science in science classrooms (Lederman, 1992; McComas & Olson, 1998; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003).

Although the *learning cycle* is one aspect of teaching strategies, it was coded as a separate sub-theme from variety of learning strategies since it was taught and revisited often in the methods courses as a way to incorporate inquiry into their teaching and students' learning. Therefore, all other teaching strategies mentioned in the candidates' narratives were included in *variety of teaching strategies.* Some candidates spoke specifically about different types of strategies: discrepant events (Kurt), visual aids (Leah), and hands-on interactive labs (Nina). They and the others hinted at the need for teachers to use a *variety of teaching strategies*, without explicitly mentioning any strategies. Teachers' use of a variety of teaching strategies was an early recommendation of the Nationals Science Education Standards (NRC, 1996).

In fact, all of the TCs used some of the "E's" from the *Learning Cycle's 5Es*. They talked about eliciting student knowledge, engaging students in activities, explaining scientific concepts, exploring new ideas, and expanding on the students' current thinking. Kurt even stated that he was a strong believer in the 5E learning cycle. This instructional planning tool is one that affords teachers and students the possibility of implementing and participating in inquiry-based instruction (Llewellyn, 2005). It was not surprising to see the TCs using the language they learned in their methods courses; however, it is gratifying to see that they all have integrated the learning cycle's academic language into the ways they talk about both teaching and learning science.

However, despite their use of the 5 Es, none of the TCs actually included all of them. This is even true when all of the data sources, the reflective journal postings, the

TPA commentary, and the interviews, are considered together One candidate, Kurt, mentioned four of the Es at most. Bill and Leah never mention any of the 5 Es during their interviews. The Es that appeared most often were “engage”, “explore” and “explain”. Adele is the only candidate who spoke about “expanding” on content, and Kurt is the only one who addressed “evaluation” of student learning. So while the TCs can talk in detail about inquiry-based instruction and their reflections of using inquiry in their classrooms, they are not consistently using 5E as their language of inquiry-based pedagogy when reflecting on their teaching.

Introduce the topic slowly. Except Leah, all TCs talked about the need to slowly introduce inquiry instruction into their classrooms. While they may not have referred to the NRC’s chart specifically, they all had internalized a need to begin inquiry as a more teacher-directed activity, and slowly shift to activities later in the year that were more student-led. Nina described it as a “gradual shift”. In addition to reflecting on their personal experiences, the TCs were required to read a selected set of articles for the methods courses that presented different ways of introducing inquiry. The article by Eick, Meadows, and Balkcom (2005) “Breaking into inquiry: Scaffolding supports beginning efforts to implement inquiry in the classroom” talked specifically about the types of scaffolding supports teachers should consider when beginning to teach inquiry. It walked through the NRC’s (2000) Essential Features of Classroom Inquiry and Their Variations chart offering both advice and examples of how to “ease” into inquiry. All five candidates who passed the TPA, reflected about this need to *introduce the topic slowly* (see Figure 5.1).

Relevance. All TCs, except Leah, spoke about the need for science to be relevant to students. The candidates did not speak of it in great detail or often, but it was present for all but Leah (see Figure 5.1). While Nina referred to relevance as linking science content to the students' "real world"; Kurt, Bill, Jenny, and Adele spoke of the importance of "relevance" as science in students' daily lives specifically. *Relevance* was an aspect of the TPA Commentary for the Planning Task, (Task One), and although that task was not analyzed for this study, the importance of making the science relevant to the students' lives was assessed by the TPA. The planning commentary asks TCs to reflect on the, "Family/community/cultural assets (e.g., cultural norms, student interests, relevant experiences and resources)" (SCALE, 2011, p. 8). *Relevance* was emphasized in the science methods courses as well, one such reading included the chapter by Gloria Ladson-Billings, "Yes, but how do we do it? Practicing Culturally Relevant Pedagogy" in *White Teachers/ Diverse Classrooms* (Ladson-Billings, 2011).

Welcoming/safe classroom. Three TCs reflected on the importance of creating a classroom culture that emphasized a welcoming atmosphere and a sense of safety (see Figure 5.1). Bill, Nina, and Jenny may have taught in different contexts with very different needs, however, they each found this sub-theme to be important. Bill taught chemistry to college bound students in a Pre-IB program in an urban high school. Nina taught 9^{th} grade physical science, a required course for graduation in a suburban high school. Jenny taught tenth grade biology classroom with a high number of students on IEPs in an urban high school. Nina spoke eloquently about this sub-theme in her interview. She wanted to create a classroom where students felt safe to ask questions and share ideas, a classroom where inquiry can happen by attending to students' need for safety. Although she did not discuss Maslow's hierarchy of needs, it was a topic that was introduced in the general education course work. The TCs may have been considering Maslow's (1943) theory of developmental psychology when considering the desire to create a welcoming and safe classroom.

Vocabulary. Kurt, Nina and Adele all reflected on the importance of the teaching and learning of scientific *vocabulary*. All three TCs were teaching required science courses, where a majority of the student body from the school would be represented in their classrooms. Although Jenny also taught in a similar classroom, this sub-theme did not appear in her reflections. Leah and Bill both taught upper level courses, where perhaps it was assumed the students would be able to keep up with the vocabulary. I'm using the language that the candidates used. Adele is the only one who used the term "academic language" from the TPA.

Adele spoke frequently of her emphasis on the vocabulary and academic language that she presented to students. The TPA has a strong focus on academic language devoting two rubrics (S10 and S11) to the evaluation of the TCs' ability to "identify the language demands of learning tasks and assessments relative to the students' current levels of academic language proficiency and " how the candidate's planning, instruction, and assessment support academic language development" (SCALE, 2011, p. 26-27).

Basics/ foundational concepts. Kurt, Bill and Leah reflected on the need for students learning the science “basics” (Leah), the “fundamentals” (Kurt), or the “practical applications” (Bill) of their knowledge in their science classrooms. It was interpreted that these three TCs were referring to the importance of students learning the “fundamental” scientific content. While this sub-theme did not appear frequently, it was noted as an important part of their reflections as it links the strategy of inquiry to the importance of student learning the relevant scientific concepts (Figure 5.1). Recall that this emphasis on the scientific content is present as the fourth essential feature of the Essential Features of Classroom Inquiry and their Variations chart; learner connects explanations to scientific knowledge (NRC, 2000).

Not just for the sake of labs. Two cases, Adele and Kurt, included this last sub-theme of *qualities for inquiry*. Adele understood the importance of inquiry being based on meaningful questions and activities. She had a clear understanding of the difference between students completing cookbook labs and inquiry-based instruction. She stated, “Um, making sure that, that they're not just doing the lab for the sake of doing a lab. That they're actually getting something out of it” (Adele, Interview, 090111). This distinction that teaching strategies require meaningful connections to content versus having kids complete fun activities or verification labs is elemental to the definition of inquiry. Kurt echoed this sentiment in his “Mid1” reflective journal posting:

> I guess what I’m getting at is that I have seen lengthy activities that really didn’t produce results. I think it’s very important to make sure that students are not just working for the sake of working, but that they have enough information

> (before and/or after) the activity to make it meaningful. (Kurt, Journal, 121010)

The emphasis on child-centered learning and the inherent connection required between content and activity is not new. It has been around for more than a century in the writings of Rousseau, Pestalozzi and Dewey (DeBoer, 1991). However, despite inquiry's long-time presence in the literature, it is not practiced in all, or even most, science classrooms (U.S. Department of Education, 1999). Teacher candidates need to experience inquiry and see the value of inquiry-based instruction to have any hope that they will implement it after they leave their licensure programs (Windschitl, 2002).

Newly emerged themes. In addition, one new and three enhanced sub-themes emerged from the phase 2 analysis. The new theme helps to create a multifaceted view of inquiry: in the summer methods the TCs felt inquiry would be difficult to implement but at the end of their student teaching experiences they *found it to be easy*. In addition to the new theme, three sub-themes arose that enhanced the TCs' understanding. First, inquiry requires scaffolding and *differentiation.* Second, an improved understanding of *shared barriers* to inquiry as revealed by the TCs' interviews and reflective journal postings. Lastly, student *frustrations* can represent a beneficial aspect of *qualities for inquiry*. Student and teacher frustrations were not new codes; however, TCs also additionally reflected that frustrations can lead to student learning.

Found it to be easy. Early in their teacher licensure program the all of the TCs felt that inquiry would be difficult to implement but towards the end of their licensure program they *found it to be easy*. Kurt stated, "I knew almost nothing about inquiry-based practices before our summer class. I found the topic very exciting, and continue to feel this way." Adele stated, "I remember thinking, what am I doing? I have no idea how to do this inquiry thing. Now it comes naturally." Leah's interview also revealed this theme, "I found myself integrating inquiry without even realizing it." However, for Leah one wonders whether her interpretation of what her students were accomplishing in class was inquiry as defined by the NRC, as some of her misunderstandings of inquiry persisted. Her contradictory statements made during the interview did not match the evidence she provided in her TPA commentary and video clip.

Differentiation. The TCs noted that inquiry requires *differentiation* and scaffolding within each class. The TCs noticed that every student in a particular class is not prepared to utilize the five essential features of inquiry at the same level of student-direction. For example, Jenny stated:

> I realize that designing lessons to include inquiry based learning requires a great deal of organization, planning, preparation, and adaptation but I'm actually quite eager to create exactly that sort of curriculum and am excited at the thought of watching my students experience the joy of self-discovery and perhaps developing a passion for investigating the world around them and the confidence to know that they can. (Jenny, Journal, 072010)

Jenny discussed the need for adaptation here. This need appeared again in her interview at the end of the program Jenny elaborated further on this theme:

> I think every group is going to be different. And you can't necessarily do one activity that is inquiry with one group and with that group as you can with

> another. So, and I mean beyond the maturity level the students have, and that sort of thing, and just understanding who those kids. And even every class might be a bit different; you might have to make adaptations. (Jenny, Interview, 072111)

Nina, Bill, Kurt, and Adele also included teacher scaffolding or adaptability as teacher qualities during their interviews. This understanding the need to adapt to the classroom culture, and the students' needs for learning, represents the final stage of concerns for teachers, as stated by Fuller (1969) and represents a TC who is ready to teach and a good example of growth through reflection-on-action. This theme was added to the model as a *quality for inquiry*.

Specific barriers. There were four new, specific *barriers* that three or more TCs shared; time, resources, students' resistance, and novice teaching. Time and resources are two barriers that frequently appear in the literature on inquiry-based instruction (Fogleman et al., 2011; Kimble, Yager, & Yager, 2006; Lotter, Harwood, & Bonner, 2006; Wee, Shepardson, Fast, & Harbor, 2007). However, four of the TCs also referred to their students' resistance to inquiry during their interviews, and upon closer examination these same four TCs completed this task in a non-honors science classroom. It would seem that for these four TCs their students were unprepared for inquiry due to less exposure to it prior to this task. Or perhaps this was what these TCs believed their of students' abilities. In the study of beginning chemistry teachers, Roehrig and Luft reported,

> The most prevalent self-reported constraint among the beginning teachers was low student ability and motivation. If the students were perceived by the beginning teachers as being 'low ability,' they often did not see 'science as inquiry' as an effective instructional strategy. (2004, p. 20)

In addition, Nina, Kurt and Adele all mentioned that this assignment happened early in their student teaching experience; and therefore the task was more difficult as a novice than they predict it would be in the future. While this study found TCs shared *barriers to inquiry* included their students' resistance, perhaps this can be interpreted as novice teacher's perceptions of their students' abilities.

Student frustration. While frustration is not a new theme, student *frustration* with student-directed inquiry was viewed by four of the TCs as both a barrier to, and an asset for, learning. These TCs felt that students can be allowed to struggle a little bit while working through problems, however, not too much. Therefore, *frustration* can be a productive student attitude as well as one that could hinder learning. Whereas, Roehrig and Luft (2004) identified that teachers' in their study believed their 'low ability' students' were not well suited to learn through inquiry; this theme reflected TCs' growth beyond their perceptions of their students' abilities. They were encouraging their students to persist despite frustrations.

Misunderstandings of inquiry. Of the six TCs interviewed, three, Kurt, Nina and Jenny, did not reveal any misunderstandings about inquiry. All three passed the TPA and, more importantly, revealed a rich reflective practice and understanding of inquiry in their TPA commentary. Each one regarded inquiry in terms of accurate definitions of inquiry, varied teacher qualities, and student qualities; and these varied qualities included all five essential features of inquiry for both teachers (posing questions, promoting critical thinking, adaptation) and students (design and implement investigations, hashing out ideas, proposing solutions). On the other hand, three TCs, Bill, Adele and Leah, did reveal one or more misunderstanding in their interviews. Each TC will be described in more detail.

Bill's case. Bill considered the laboratory activity that he selected for the task not inquiry-based at the beginning of his interview. During the interview, he revealed through analysis of the five essential features of inquiry that aspects of the activity were in fact student-directed inquiry. While this misunderstanding appeared during the interview he left the interview still questioning whether the activity truly met his understanding of inquiry or not. He continued to question whether students would ever be able to formulate their own correct conceptions without the assistance from the teacher. Other than this question that remained for him, Bill had no misunderstandings about inquiry-based instruction; rather, it was being able to effectively implement one of the five essential features (formulate correct conceptions) that left him wondering. Like the other candidates who passed the TPA, Bill mentioned all five essential features of inquiry in his TPA and his reflections, and he had an accurate definition of inquiry.

Adele's case. Adele began her interview apologizing for including an activity that was "cookbooky" rather than inquiry. However, following the analysis of the five essential features of inquiry, she was somewhat surprised to see that she had indeed taught an inquiry lesson. It should be noted again that Adele was the candidate who took the inquiry class after she had completed this assignment. Therefore, perhaps she was relying on her previous assumption from the spring that this laboratory was a cookbook lab. Perhaps only after having completed the summer inquiry science methods course could she see the complexity of implementing inquiry. In her interview, she revealed a nuanced view of inquiry, one where some students would need differentiation and scaffolding, while others could perform more student-directed inquiry. Therefore, the misunderstanding that appeared in the interview transcripts was self-corrected during the interview.

Leah's case. Unlike Adele, Leah's misunderstandings persisted throughout the interview. While the activity that she chose did not appear to be inquiry-based according to the evidence that she submitted, the written commentary and video clip, she continued to describe it as if it were student-driven inquiry. When she analyzed her activity that she represented in her TPA video task, she indicated that the students were sharpening or clarifying the question, but then she goes on to say that they really didn't have a choice on questions.

> Yep, it was 11th graders. So I kinda highlighted the important points and then really relied on them to read the directions, to get the equipment they needed, and you know kind of what we learned in methods classes, the inquiry, having them figure stuff out on their own. And not have everything laid out for them.

Learners were directed to collect certain data, and yet she indicated that they drew the data tables in their own notebooks and hinted that this means they may have determined what constitutes as evidence. "They kinda made their own," but then she contradicts herself and says that she "gave them pretty much everything to look for." She guided the process of formulating explanations and gave the possible connections, but this guiding comes only from her TPA commentary and her comments in the interview. She also selected the more student-centered, learner-coached in development of communication. However, there was no evidence of the last three essential features in the material she provided for the assignment. In Leah's case, her TPA scores and the analysis of her reflections-on-action reveal that she lacks an adequate understanding of inquiry. As in Lustick's (2009) study of "The Failure of Inquiry" with preservice teachers, Leah's conceptions of inquiry did not change with her experiences in inquiry in her methods courses and were not accurate at the end of the licensure program.

Conclusions of cross case analysis. It was determined overall that the TPA Task 2 revealed teacher candidates' understanding of inquiry in rich and complex ways, assuming of course that the TC passed the Task. In this sample of six teacher candidates, cross case analysis revealed that those candidates with a passing score had a rich, nuanced, and varied understanding of inquiry including all five essential features; whereas, the student who did not pass the video task (Leah) did not. Leah's understanding was more vague and in some respects contained misunderstandings that persisted across all data sources; her reflective journal postings, her written commentary about the teaching event, the video clip of the lesson; and her interview.

In addition, her own verbal reflections appeared to disagree with the data sources (TPA and written reflections) and she contradicted herself in her interview.

Adele fits in the middle somewhere, she may have passed this task of the TPA; however, she had a low-score (1,2). This may have been largely due to her poor choice of video clips, and that her students were not engaged in the activity for most of the time in the clips. Recall, that she took the methods courses out of the preferred order, completing the summer "introduction to inquiry course" last. She completed her TPA before receiving in-depth instruction on inquiry-based teaching and learning. Her interview occurred after she completed the program and her verbal reflections revealed she had an accurate definition of inquiry, however, her views were less nuanced and her descriptions of *qualities required for inquiry* were not as rich or lengthy.

All six TCs had four shared *qualities required for inquiry*; facilitate, scientific habits of mind, the 5 E Learning Cycle, and use of a variety of teaching strategies. These four sub-themes reveal a highly nuanced view of what it takes to teach and learn in an inquiry-based classroom. As stated earlier, Adele and Leah had fewer codes for each of these sub-themes.

For the other eight sub-themes of *qualities required for inquiry* four are shared by five of the TCs; frustrations in implementing inquiry, relevance, differentiation, and introduce the topic of inquiry slowly. Of these four sub-themes, Leah only shared the last one. Three sub-themes are shared by three TCs; welcoming and safe classroom (Bill, Nina, and Jenny), focus on vocabulary (Kurt, Nina, and Adele), and focus on foundations or the basics. Leah shared the latter sub-theme with Kurt and Bill. Kurt and Adele shared the eighth sub-theme, *not just for the sake of labs.*

Despite her low-score on the TPA, Adele is included in six of these eight sub-themes. This could indicate that she had a nuanced view of the qualities required for inquiry-based instruction that may not have been revealed in her TPA due to the poor choice of lesson and video-clips or the fact that she completed Task 2 of the TPA prior to taking the methods course on inquiry.

On the other hand, Leah only shared two of these eight sub-themes, *introduce the topic slowly* and *the basics*. She considered the slow implementation of inquiry and the need to pay attention to teaching the basics as important *qualities required for inquiry*; perhaps she had a more cautionary view of implementing inquiry or a simpler view.

Differentiation was a sub-theme that emerged from the data that requires more attention because it indicates a highly nuanced view of teaching. The TCs who spoke of differentiation mentioned that they might have to provide more scaffolding during inquiry activities for some students than others, or for some classes than others. This indicates that the candidates were considering more than simply the plans they were implementing during an inquiry activity, but also what each student might require in addition. This also speaks to the many teaching strategies that the TCs mentioned when describing the qualities required for inquiry instruction. This sub-theme was shared by all but Leah.

Chapter VI: Summary, Implications, and Future Research

Summary

TPA scores and codes that arose out of the data were analyzed in an attempt to answer the following research questions:

1. What does the Teacher Performance Assessment reveal about science education teacher candidates' understanding of inquiry-based instruction?
2. How do the candidates represent their knowledge of inquiry in their reflections?

Research question 1. The TPA Task 2 accurately measured these candidates understanding of inquiry-based instruction, even given factors such as their choice of video clips and classroom management issues. When analyzing the twenty-six teacher candidates' TPAs for RQ1, most had accurate views of inquiry-based instruction and revealed strong reflective practice in their written commentary of their teaching event and reflective journal postings. When considering the six detailed cases, the four TCs who passed the TPA also revealed their understanding of the five essential features of inquiry in their TPA commentaries; whereas the two low-scoring candidates did not address all five features in their TPA commentaries. Although one of the low-scoring candidates, Adele, did address the five essential features of inquiry when considering all of her other written and verbal reflections, she did so less often than the four candidates who passed the TPA.

However, the TCs struggled to implement inquiry in meaningful ways, and video record strong examples of inquiry-based instruction and student engagement. Some struggles were due to technical difficulties, others felt constrained by their students or cooperating teachers. In addition, many of the TCs' video clips did not reveal examples of the teachers engaging individuals or specific subgroups, negatively affecting their scores on the TPA rubrics. An added concern was that three teacher candidates completed Task 2 of the TPA utilizing activities with limited opportunities for students to participate in inquiry. In fact, two TCs stated in their TPA commentaries that they did not utilize inquiry-based instruction.

Task 2 of the TPA is an appropriate measure of a teacher candidate's understanding of inquiry-based instruction based on the five essential features of inquiry as presented by the NRC. Since the TPA Task 2 accurately measured science teacher candidates understanding of inquiry, this could also indicate that the full TPA is a valid measure of teacher candidates' understanding of other aspects of teaching (planning instruction and assessment). This would support the decision to adopt the TPA as a statewide assessment to evaluate teacher candidates and teacher education programs. Although the literature reveals the TPA's and PACT's impact on institutions of higher education and the teaching profession (Guaglianone et al., 2009; Mayer, 2005); TPAs as a means to observe teachers through their induction and tenure period (Darling-Hammond, 2010; Newton, 2010); and a review of the TPA's impact on TCs' learning and personal lives (Bunch et al., 2009; Carlile, 2006; Chung, 2008; Hafner & Maxie, 2006; Okhremtchouk et al.; 2009; Pecheone & Chung, 2006; vanEs & Conroy, 2009); none have previously discussed the effectiveness of TPA Task 2 in revealing a candidates understanding of implementing inquiry-based instruction in their classroom. Thus, this study adds to the literature base in addressing the utility of the TPA to accurately assess teachers' pedagogical knowledge with inquiry-based teaching.

Research question 2. The five major themes that arose from the TPA commentary, reflective journal postings, and interviews included: *qualities required for inquiry, definitions of inquiry, barriers to inquiry, misunderstandings of inquiry* and *found inquiry to be easy*. From the case study data, the four teacher candidates who passed the TPA with high- and mid-scores had rich descriptions of the qualities that are required for teachers and students in inquiry-based classrooms. They had accurate or corrected definitions of inquiry, over the course of the program. They included all five essential features of scientific inquiry in their TPAs and in their written and verbal reflections. Analysis of the two low-scoring candidates revealed misunderstandings, TPA commentary lacking two or more essential features, and *definitions of inquiry* and *qualities required for inquiry* that were less detailed and nuanced.

Kurt, Bill, Nina, and Jenny. The four mid-scoring and high-scoring candidates on the TPA revealed varied and nuanced views of their own teaching practice when considering inquiry-based instruction. They had accurate understandings of the five essential features of inquiry as evidenced in the TPA and their written and verbal reflections throughout the ten-months of the licensure program. Their reflective journal postings and interviews revealed a strong practice of reflection-on-action. They shared many barriers to implementation. They were ready to begin to teach when they completed the initial licensure program based on all measures – knowledge of inquiry and TPA scores.

In addition, it should be noted that Bill struggled a bit with his interpretation of inquiry. He came to understand that his activity was indeed inquiry-based during the interview—in fact more so than he thought to begin with. However, he continued to struggle with the fourth essential feature of inquiry. He stated that his students needed to have the correct answer in the end. In his mind, students could not necessarily be trusted to come up with the correct scientific conception of the content that was being taught. His students were coming to understand the law of the conservation of matter; they were able to define the law, but not necessarily recognize that the experiment they were performing represented that same law. Bill problematized the fourth essential feature of inquiry; revealing the historic concern, among educators and scientists from John Dewey and Jean-Jacques Rousseau to today, the concern of completing a science activity for the sake of doing the activity but not linking it to the scientific content (DeBoer, 1991).

Adele. Both Adele and Leah were low-scoring candidates on the TPA, but that is where their similarities end. Adele did not fail the TPA, but she did score a 1 on rubric S4, engaging students in learning. The guiding question for rubric S4 was, "how does the candidate actively engage students in their own understanding of collecting, analyzing, and interpreting scientific data?' (SCALE, 2011, p. 16). Adele's video and TPA commentary revealed that classroom management issues were predominant during her teaching event. There was minimal evidence that students were collecting data, much less analyzing and interpreting it, as she moved from group to group asking them to get back on task. In Adele's case, it would have been beneficial for her to select a different lesson to analyze for the TPA. In her written and verbal reflections, she had accurate definitions of inquiry however; her definitions lacked some of the richness or clarity of the four TCs with mid and high scores on the TPA. Despite only including two of the essential features in the TPA commentary, Adele provided all five essential features in her written and verbal reflections on inquiry throughout her licensure program. Adele was the teacher candidate who completed the science methods courses out of the preferred order, as she had physics prerequisites to complete prior to starting the licensure program. Therefore, her first methods course was in the fall not summer. This coupled with the fact that the lesson she selected to record was a poor selection, led her to a low score on the TPA Task 2. Despite receiving a low score on her TPA, Adele revealed a strong reflection-on-action in her written and verbal reflections.

Leah. Leah, on the other hand, failed the TPA; she did not reveal a firm understanding of inquiry, she had misunderstandings or misconceptions that persisted throughout her data sources, and she provided contradictions to her own reflections. She had stated in her "Early" reflective journal posting that she had never experienced inquiry-based instruction before the science methods course. This is not uncommon for teacher candidates (Windschitl, 2004). Although the TCs were provided with examples of inquiry during the methods courses, and were coached in writing and implementing inquiry-based lessons, this was not enough for all TCs. Leah, having never experienced inquiry before, needed more opportunities to experience inquiry. This is similar to the findings in the study of science teacher candidates by Windschitl (2002).

> The participants who eventually used guided and open inquiry during their student teaching were not those who had more authentic views of inquiry or reflected most deeply about their own inquiry projects, but rather they were individuals who had significant undergraduate or professional experiences with authentic science research. (p. 112)

Leah had not moved past her teacher-centered view of the classroom to one that is truly constructivist with a focus on student learning and an accurate understanding of inquiry.

This finding is similar to the findings by Roehrig and Luft (2004) and Simmons et al (1999). Roehrig and Luft (2004) noted in their study of chemistry teachers that, "student-centered beliefs held by beginning teachers are crucial in implementing inquiry-based instruction." Simmons et al (1999) also followed beginning teaching into their classrooms. They asserted, "Beginning teachers described their practice as very student centered. Observed teaching practice contrasted starkly with teacher beliefs; while teachers professed student-centered beliefs, they behaved in teacher-centered ways" (p. 947). Leah, unlike the other five TCs, consistently blended the qualities of students and teachers in her descriptions of qualities of inquiry, revealing a unique teacher-centered view of instruction.

There is not enough evidence that Leah's students completed an inquiry-based lab; her video was very short, the lab handout was missing from her TPA, and she contradicted herself during her interview as to the levels or types of inquiry in the lesson. Leah did not have extensive reflections-on-action. But, it was through a deep analysis of the contradictions revealed in her interview, her brief and sometimes simplistic written reflections in her ten-months of reflective journal postings, and her failure of the TPA that this was revealed. She received her teaching license; however, she did not start her first year of teaching where the rest of her peers may have been.

Barriers to implementing inquiry. The candidates revealed several barriers to implementing inquiry-based instruction. Four barriers were shared among more than one TC; time, resources, students' resistance, and novice teaching. Time and resources are two barriers that frequently appear in the literature on inquiry-based instruction (Fogleman et al., 2011; Kimble, Yager, & Yager, 2006; Lotter, Harwood, & Bonner, 2006; Wee, Shepardson, Fast, & Harbor, 2007). While time and resources are difficult to change in a student teaching experience, teacher educators could prepare for the inevitabilities of student resistance to inquiry and limitations due to novice teaching. Roehrig and Luft (2004) might support the view that, like the beginning teachers in their study, teacher candidates' perceptions about inquiry-based instruction as unsuitable for 'low-ability' students should be challenged. While, Windschitl (2002) might promote increasing the number of inquiry-based experiences TCs have prior to beginning teaching thus overcoming the limitations some candidates felt due to their novice status.

Pedagogical language of inquiry. Four candidates had rich and highly nuanced views of inquiry, but they did not necessarily use the language of science pedagogy. In fact all of the teacher candidates in the study did not use the language of inquiry in their reflections-on-action in consistent ways. They did not use the word inquiry often when reflecting on their inquiry activity in their TPA commentary for Task 2. In fact, many (14 of 26) never mentioned inquiry even once. The six TCs in Phase Two also did not use all of the 5 Es in their reflections on their inquiry instruction. While "engage" and "explain appeared the most often, "elaborate" and "evaluate" appeared only once among all six candidates in all of their written and verbal reflections on inquiry teaching.

The consequences of this lack of use of pedagogical language can only be speculated upon. The evidence from the data indicated that five of the candidates had firm and accurate understandings of inquiry. Therefore, their lack of use of the language is not due to a lack of understanding. However, perhaps it could indicate that the candidates are hesitating to fully embrace inquiry. Or this could indicate that they may struggle to implement inquiry in the future.

Teacher candidate growth. There were two teacher candidates who discussed explicitly their own growth over the course of the ten-months of science education methods courses; Kurt and Nina. Kurt had a strong understanding of inquiry when he began the program, and this was reflected in his "Early" reflective journal posting. However, he continued to question his own ability to implement inquiry meaningfully and reflected on his inquiry practice frequently. Nina, stated that she had a misunderstanding about inquiry early on in the program, and came to have a solid understanding over the course of the program.

Implications

There are several implications to these findings for teacher educators, teacher candidates, cooperating teachers, and university supervisors. Six implications from the findings are described in this section indicated by the stakeholders for each. These implications for science teacher education are followed by suggestions for future research.

Teacher educators. First, the Task 2 of the TPA accurately measures a teacher candidates understanding of inquiry-based instruction and student learning, however some teacher candidates will need more support than others. Therefore, teacher educators need to include more opportunities for teacher candidates to experience meaningful inquiry activities; those that represent the different levels of teacher-directed and student-led aspects of the five essential features of inquiry (Lustick, 2009, Windschitl, 2002). The TCs would also need to reflect-on-action for each of these activities as participants in the inquiry as well as potential instructors of a similar activity in order to afford them the opportunities to grow as beginning teachers.

Teacher educators, cooperating teachers and supervisors. Second, teacher educators need to ensure that teacher candidates are placed in classrooms where the students have experience with inquiry or at the very least a cooperating teacher who supports inquiry-based instruction. This could remove some of the perceived student resistance to inquiry, and therefore remove this barrier, as well as offer a supportive student teaching environment. Interviewing cooperating teachers prior to placement, offering training to cooperating teachers and teacher candidates, and potentially promoting co-teaching placements could improve the student teaching experience for teacher candidates (Scantlebury, Gallo-Fox, & Wassell, 2008).

Third, in a working triad of cooperating teacher, university supervisor and teacher candidates, guided reflections can assist TCs to move beyond teacher-centered concerns to student-centered concerns. TCs who attend to student learning and student thinking create classroom cultures where inquiry is not only possible but probable (Roehrig & Luft, 2004).

Teacher educators and teacher candidates. Fourth, the choice of inquiry lesson and the video footage needs to reveal effective inquiry-based instruction. Therefore, teacher educators should encourage teacher candidates to collect video footage from several lessons of instruction. This would allow TCs the choice of "good video". In addition, the opportunity for teacher candidates should be provided by collaborative lesson analysis, as in the professional development studies similar to the video clubs by Borko, Jacobs, Eiteljorg, and Pittman (2008) and Sherin and Han (2003). This could provide TCs with the needed scaffolding for analyzing their teaching practices using the lenses of educational research and reform-based pedagogy in order to encourage the selection of good video clips and meaningful reflection-on-action.

Fifth, science teacher educators should continue to promote the academic language of teaching science with their teacher candidates. As seen in this study, the lack of the use of the "terms" of inquiry does not necessarily indicate a lack of understanding of inquiry-based pedagogy. However, reflecting on one's instructional practices using the language of inquiry—i.e. the five essential features of inquiry, scientific inquiry, engage, explore, explain, elaborate and evaluate—could assist TCs who have fewer inquiry experiences. Using a shared language in any professional can improve communication among the participants.

Finally, teacher educators should watch out for teacher candidates who offer brief reflections that lack the rich and highly nuanced understandings of the *qualities required for inquiry* of teachers and students. vanEs and Conroy (2009) referred to this as "superficial, global claims" (p.97). Teacher candidate growth over the span of their methods courses, practicum, and student teaching experiences should be fostered. Perhaps if this type of reflection-on-action could also be augmented by reflection-in-action, the preparation of teacher candidates could be improved and TCs would have more opportunities to observe their own growth as educators over the course of their initial licensure programs. Taken together, perhaps these findings could inform science teacher educators in assisting students like Leah during the program to achieve a passing TPA and a stronger understanding of scientific inquiry instruction.

Future Research

Some of the above findings and implications lead directly into potential future research. Certainly, as the TPA continues to be developed and evaluated as a tool for authentic assessment of beginning teachers, there is much room for future research. In addition, it appears that science teacher educators need to continue to problematize the five essential features of inquiry, as well as the teacher candidates' use of the language of inquiry in methods courses and student teaching. Observing their teaching and monitoring their reflection-in-action and reflection-on-action, as TCs experience their methods courses and student teaching, could help science teacher educators assist their TCs' growth and future implementation of inquiry-based instruction.

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Appendix A

TPA: Task 2

Task 2. *Instructing & Engaging Students in Learning* Return

Purpose

The Instructing & Engaging Students in Learning task asks you to demonstrate how you facilitate students' developing understanding of scientific inquiry skills and strategies as well as knowledge of science concepts. You will provide evidence of your ability to engage students in meaningful science tasks, monitor their understanding, and use your responses to students to guide their learning.

What Do I Need to Do?

Video your classroom teaching

✓ Examine your plans for the learning segment and identify learning tasks in which you are supporting students as they are actively engaged in collecting and analyzing scientific data. The data may be collected directly by the students or selected from data collected by others.

✓ View the video(s) to check the quality, analyze your teaching, and select the most appropriate video clips to submit.

✓ Provide **two video clips of no more than ten minutes each**. The first clip should illustrate how you facilitated your students' engagement in meaningful scientific thinking while they are collecting data or selecting data collected by others during a scientific inquiry. The second clip should illustrate how you actively engaged students in developing an understanding of how to analyze, interpret, and synthesize the results of an inquiry. The clips should include interactions between and among you and your students and your responses to student comments, questions, and needs.

Video Guidelines

- *A video clip should be continuous and unedited, with no interruption in the events.*
- *The clips can feature either the whole class or a targeted group of students.*
- *Both you and your students should be visible and clearly heard on the video submitted.*
- *Tips for recording your class are available from your program.*
- *Before you video, ensure that you have the appropriate permission from the parents/guardians of your students and from adults that appear on the video.*

- ✓ Provide a copy of any relevant writing on the board, overhead, or walls if it is not clearly visible on the video. Attach this document to the Instruction Commentary.
- ✓ Complete the Video Label Form and either attach it to a videotape or put it in a folder or CD/DVD with the video file(s) in an electronic format. The form is located after the instructions for this task.
- ✓ Respond to each of the prompts in the Instruction Commentary.

Instruction Commentary

Write a commentary of **2-4 single-spaced pages** (including prompts) that addresses the following prompts.

1. In the instruction seen in the clips, describe strategies you used to engage students intellectually while collecting, analyzing, and interpreting data from a scientific inquiry.
    a. Cite examples of strategies aimed at engaging all your students and examples aimed at engaging specific individuals or subgroups. If you described any of these fully in the lesson plans or the planning commentary, just reference the relevant description.
    b. How did these strategies reflect students' academic or language development, social/emotional development, or cultural and lived experiences?
2. Cite examples of language supports seen in the clips to help your students understand the content and/or participate in scientific discourse central to the lesson.
    a. How did these strategies reflect students' varying language proficiencies and promote their language development?
3. Describe your strategies for eliciting student thinking and how your ongoing responses further their learning. Cite examples from the clip(s).
4. **Reflection:**
    a. Reflect on students' learning of concepts and academic language as featured in the video clip(s). Identify both successes and missed opportunities for monitoring all students' learning and for building their own understanding of how to collect, analyze, and interpret data from a scientific inquiry.
    b. If you could do it over, what might you have done to take advantage of missed opportunities or to improve the learning of students with diverse learning needs and characteristics?

Task 2. *Video Label Form*

Candidate ID # ___________________________________

Secondary Science Clips

Clip # 1

Lesson from which clip came: Lesson # _____

Clip # 2

Lesson from which clip came: Lesson # _____

If Electronic, Video Format of Clip(s): (check one)

- ☐ DVD format (no other media player involved)
- ☐ Flash
- ☐ QuickTime
- ☐ Windows Media Player
- ☐ Other (please specify) ___________________________________

Instruction Rubrics Return

INSTRUCTION: ENGAGING STUDENTS IN LEARNING S4: How does the candidate actively engage students in their own understanding of collecting, analyzing, and interpreting scientific data?			
Level 1	**Level 2**	**Level 3**	**Level 4**
• Strategies for intellectual engagement seen in the clips **limit opportunities for students to collect, analyze, and interpret scientific data**. • Candidate accurately **identifies successful and unsuccessful teaching practices.** OR • **Student behavior or candidate's disrespect for one or more students severely limits students' engagement in learning.**	• Strategies for intellectual engagement seen in the clips offer **opportunities for students to collect, analyze, and interpret scientific data**. These strategies reflect **attention to students' academic or language development, social/emotional development, and/or cultural and lived experiences**. • Candidate accurately identifies successful and unsuccessful teaching practices and proposes **reasonable improvements**.	• Strategies for intellectual engagement seen in the clips offer **structured opportunities** for students to collect, analyze, and interpret scientific data. These strategies reflect attention to students' academic or language development, social/emotional development, and/or cultural and lived experiences. • Candidate identifies successful and unsuccessful teaching practices. The proposed improvements are reasonable and address the learning **of a subgroup or individual students.**	• Strategies for intellectual engagement seen in the clips offer structured opportunities for students to collect, analyze, and interpret scientific data. These strategies are **explicit**, and **clearly reflect attention** to students with **diverse** academic or language development, social/emotional development, and/or cultural and lived experiences. • Candidate identifies successful and unsuccessful teaching practices. The proposed improvements are reasonable and **address the learning of diverse students.**

INSTRUCTION: DEEPENING STUDENT LEARNING DURING INSTRUCTION			
S5: How does the candidate elicit and monitor students' responses to deepen their abilities to collect, analyze, and interpret scientific data?			
Level 1	***Level 2***	***Level 3***	***Level 4***
• Candidate primarily asks **surface-level questions** and evaluates student responses as **correct or incorrect**. • **Few connections** are observed being made between and among **science concepts, analyses and interpretations of science data**. OR • Materials or candidate responses include **significant content inaccuracies** that will lead to student misunderstandings.	• The candidate **elicits student responses that require thinking about science concepts, explanations, and the quality of data**. • **Candidate makes connections** between and among science concepts, analyses and interpretations of science data.	• **Candidates and/or other students build on what students are saying and/or doing to improve understanding of science concepts, explanations, and the quality of data**. • Candidate and/or other students **prompt students to make** connections between and among science concepts, analyses and interpretations of science data.	• Candidate's and/or other students' interactions **help develop or reinforce students' abilities to evaluate their own ideas** about concepts, explanations, and the quality of data. • Candidate and/or other students prompt students to make connections between and among science concepts, analyses and interpretations of science data.

Appendix B

Kurt

Essential features of classroom inquiry and their variations.

Inquiry and the National Science Education Standards by the National Academy of Sciences (NRC 2000, p. 29).

Essential Feature	Variations			
1. 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 source
2. 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
3. Learner formulates explanations from evidence	Learner formulates explanations 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
4. 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	
5. 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 sharpen communication	Learner given steps and procedures for communication

More -------------------------------- Amount of Learner Self-Direction ------------------------------------Less

Less ---------------------------- Amount of Direction from Teacher or Material ---------------------- More

Appendix C

Bill

Essential features of classroom inquiry and their variations.

Inquiry and the National Science Education Standards by the National Academy of Sciences (NRC 2000, p. 29).

Essential Feature	Variations			
1. 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 source X
2. Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data X	Learner given data and asked to analyze	Learner given data and told how to analyze
3. Learner formulates explanations from evidence	Learner formulates explanations after summarizing evidence	Learner guided in process of formulating explanations from evidence X	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
4. 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 X	
5. 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 sharpen communication	Learner given steps and procedures for communication X

More -------------------------------- Amount of Learner Self-Direction ------------------------------------Less

Less ---------------------------- Amount of Direction from Teacher or Material ---------------------- More

Appendix D

TEACHER PERFORMANCE ASSESSMENT AND INQUIRY

Nina

Appendix B

Essential features of classroom inquiry and their variations.

Inquiry and the National Science Education Standards by the National Academy of Sciences (NRC 2000, p. 29).

Essential Feature	Variations			
1. 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 source
2. 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
3. Learner formulates explanations from evidence	Learner formulates explanations 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
4. 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	
5. 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 sharpen communication	Learner given steps and procedures for communication

More -------------------------------- Amount of Learner Self-Direction ------------------------------------Less

Less ---------------------------- Amount of Direction from Teacher or Material ---------------------- More

40:33 minutes long interview

Appendix E

Essential features of classroom inquiry and their variations. Jenny

Inquiry and the National Science Education Standards by the National Academy of Sciences (NRC 2000, p. 29).

Essential Feature	Variations			
1. 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 source
2. 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
3. Learner formulates explanations from evidence	Learner formulates explanations 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
4. 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	
5. 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 sharpen communication	Learner given steps and procedures for communication

More ------------------------------ Amount of Learner Self-Direction ----------------------------------Less

Less --------------------------- Amount of Direction from Teacher or Material --------------------- More

Appendix F

Adele

Essential features of classroom inquiry and their variations.

Inquiry and the National Science Education Standards by the National Academy of Sciences (NRC 2000, p. 29).

Essential Feature	Variations			
1. 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 source
2. 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
3. Learner formulates explanations from evidence	Learner formulates explanations 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
4. 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	
5. 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 sharpen communication	Learner given steps and procedures for communication

More -------------------------------- Amount of Learner Self-Direction ------------------------------------Less

Less ---------------------------- Amount of Direction from Teacher or Material ---------------------- More

Appendix G

Leah

Essential features of classroom inquiry and their variations.

Inquiry and the National Science Education Standards by the National Academy of Sciences (NRC 2000, p. 29).

Essential Feature	Variations			
1. 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 source
2. 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
3. Learner formulates explanations from evidence	Learner formulates explanations 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
4. 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	
5. 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 sharpen communication	Learner given steps and procedures for communication

More -------------------------------- Amount of Learner Self-Direction ------------------------------------Less

Less ---------------------------- Amount of Direction from Teacher or Material --------------------- More

Appendix H

Life Science
Lab Activity

Name ____________________

Date ____________ Period ________

Enzymes and Fecal Analyses

Pa . – Enzymes

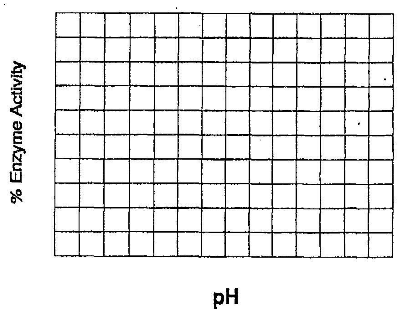
Materials: 3 Colored Pencils

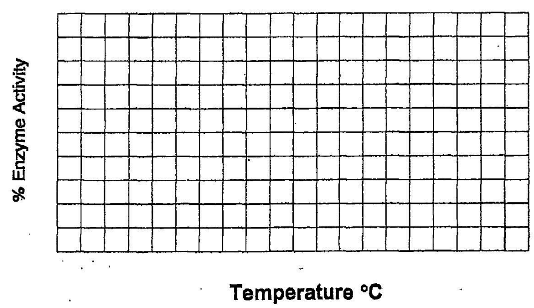
Background
You are the head of a biological research team that has been gathering data about the various life forms living in or near an alkaline* hot spring in Arkansas. You have just returned from having been at the alkaline hot spring site for many weeks. It is now time to get down to some serious research and analyze the data you have collected.

Things seem to be going well when suddenly you discover the labels on three of your collection bottles have come off during shipment. You remember that you collected three different digestive enzymes in these bottles. You also remember collecting one of the enzymes from a group of bacteria that live right in the middle of the alkaline hot spring. The other two enzymes came from the digestive tract of a strange little mammal called a Mondoni, which lives at the edge of the spring.

You realize that if you go ahead and analyze the enzymes, you may find out which enzymes belong to what creature. You relabel the bottles A, B and C and begin your analysis.

Procedure
Using the data table provided, plot graphs of each enzyme on the graph spaces below. Clearly label your graphs with proper titles. Plot all three enzymes on the same graph, using a different colored pencil for each enzyme. There should be two graphs for each enzyme. Use smooth, flowing lines to connect the points on your graphs. When you have finished your graphs, answer the questions in the analysis section.





*The pH is very basic (=12+)

Analysis

1. What is the % activity of Enzyme A at pH 3.5?
2. At what temperature do Enzymes B and C have the same % activity? ______
3. Which enzyme(s) work best in an acidic environment? ______
4. At what pH would Enzyme C probably have 100% activity? ______
5. Which enzymes probably came from the digestive tract of the Mondoni? ______
6. State two reasons why you think this.
   a. ______
   b. ______
7. Which enzyme probably came from the bacteria living in the alkaline hot springs ______
8. State two reasons why you think this.
   a. ______
   b. ______
9. State which enzyme probably came from the stomach of the Mondoni and why you think this.
10. State which enzyme probably came from the intestine of the Mondoni and why you think this.

Part 2 - Fecal Analyses

Background

Pet food companies like Ralston-Purina keep careful records of the nutrients that go into and come out of their experimental animals. They then can tell which of the nutrients in a particular pet food product are actually assimilated by the animal and in what amounts.

You are in charge of the Fecal Analysis Laboratory. Your research centers on analyzing dog feces for various nutrients. You have been really busy lately. (You might say things have really been "piling up!") Anyway, you have just completed the fecal analysis on three groups of dogs that are on three different dog foods. Analysis is done on 1 serving of food and 24 hours of fecal collection from each dog. Your results are as follows:

NUTRIENT	BARKO BITS		ARFY TREATS		WOOFER CHUNKS	
	In Food	In Feces	In Food	In Feces	In Food	In Feces
Protein	40 g	9 g	41 g	8 g	40 g	4 g
Carbohydrates	36 g	30 g	29 g	3 g	40 g	30 g
Fat	14 g	2 g	14 g	8 g	14 g	4 g
Vitamin A	1000 IU	20 IU	1000 IU	800 IU	500 IU	450 IU
Vitamin C	1500 IU	400 IU	1600 IU	200 IU	1400 IU	300 IU
Vitamin D	1000 IU	15 IU	1015 IU	915 IU	850 IU	800 IU
Vitamin B_1	1200 IU	200 IU	900 IU	400 IU	700 IU	200 IU
Vitamin B_{12}	950 IU	250 IU	800 IU	200 IU	1200 IU	600 IU
Calories	800	500	750	100	900	350

ınalysis

. How many grams of fat are in 1 serving of Woofer Chunks? ______________________

:. How many grams of fat in Woofer Chunks are assimilated by a dog? ______________________

ꞁ. ɪɪow many grams of <u>usable</u> protein are in 1 serving of Barko Bits? ______________________

ꜝ. If you wanted to give a dog some quick energy, which food would you recommend and why?

____

____

5. Barko Bits and Arfy Treats have primarily unsaturated fats; while the fat in Woofer Chunks is mostly saturated. Which dog food would you recommend for a dog with a cholesterol problem and why?

____

____

6. Which dog food is potentially toxic if it were eaten exclusively for weeks at a time? Why?

____

____

7. Which food would you recommend for a dog that was recovering from a car accident, which damaged the animal's leg muscles? Why?

____

____

8. Which food would you use to give a dog both quick and sustained energy? Why?

____

____

9. Disregarding any other health risks etc., which food would probably be a good choice for a dog that needs to lose weight? Why?

____

____

10. Overall, discuss which dog food is best for the general health of most dogs and why. (Take plenty of space to explain your answer.)

____

____

____

____

____

____

____