Inquiry Education in Science Classrooms: How Teachers Modify Instructional Behaviors

Following the Teaching Science as Inquiry (TSI) Aquatic Science Professional Development Program

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By

Katherine M Degnan

Thesis Committee:

Katherine Ratcliffe, Chairperson

Paul Brandon

ThanhTruc Nguyen
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Abstract

Using a multiple-case study approach, the effects of an inquiry-based professional development program on participants’ use of inquiry strategies in the classroom were investigated. Participants included three teachers from the Oahu cohort of the Teaching Science as Inquiry (TSI) Aquatic Science professional development series. Data sources included the Inquiring into Science Inquiry Observational Protocol (Minner et al., 2010), my own post-observation reflection narrative, teacher post-observation instructional templates, and post-observation survey responses. All participants expressed that their use of inquiry-based instruction increased after the professional development, and observations supported their reports. Each case study participant was observed using a variety of inquiry techniques in his or her classroom including scientific investigations. These findings show that professional development programs can influence the instructional style of educators and help teachers become more familiar with inquiry philosophy, techniques, and behaviors.
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Chapter 1. Introduction

Inquiry Education in Science Classrooms

Professional development courses that specialize in inquiry education are designed to educate and inform teachers about learning, instructional practices, and techniques in an effort to modify existing teaching behaviors. Following professional development courses, teachers are expected to adapt the lessons and instructional methods to their classrooms. Implementing inquiry instruction requires that teachers engage students, guide and facilitate learning, assess the learning of students and their own instruction, create environments that are conducive to learning science, and develop school programs that support inquiry-based science (Luft, 2001; National Research Council, 1996).

Inquiry is defined as a process of learning during which “. . . scientists and students pose questions about the natural world and investigate phenomena . . .” (NRC, 2000, p. 214). Inquiry education supports students’ exploration of science and promotes an understanding of the process of scientific investigation. Schools and institutions promote inquiry instruction as an effective form of teaching; to implement inquiry education teachers must understand the theory of inquiry while also implementing inquiry-based instructional practices (Anderson, 2002).

Researchers have found that teachers have difficulty adapting inquiry instructional practices to their existing teaching styles. To promote inquiry instruction, professional development programs have been designed to help teachers understand the practices of science, the nature of scientific inquiry, and how to translate these understandings into curriculum (Crawford, 2007). In addition, research has shown that
professional development programs need to provide follow-up opportunities to support teachers’ implementation of inquiry during the school year (Wee, Shepardson, Fast, & Harbor, 2007).

Due to the difficulties teachers experience learning and implementing inquiry instruction, some researchers believe that professional development programs should address the practices and beliefs of science teachers (Luft, 2001). According to Luft and Pizzini (1998), change is a process accomplished by individuals, it is a “highly personal experience,” and requires development of skills and feelings. Personal beliefs and educational experience likely influence the instructional practices of educators.

The TSI Aquatic Science professional development project was designed to encourage teachers to understand the phases of inquiry, use new pedagogical techniques, and include relevant science content in their curricula (Seraphin, 2010). The goal is to help teachers facilitate scientific inquiry and to create a community of scientists in their classrooms. A community of scientists is established when students learn science by engaging in the non-linear progression and practice of science. The phases of inquiry are designed to reflect the nature of a scientific investigation. When scientists are working through an experiment they may have to revise steps or repeat procedures; this would be defined as a non-linear process. In the classroom, the phases of inquiry can be experienced as a non-linear progression of learning, meaning that instead of progressing directly from one step in a procedure to the next, students are encouraged to move back and forth between each phase (F. Pottenger, personal communication, November, 2011). The TSI Aquatic Science project provides educators with the opportunity to foster a
scientifically literate population of students (Seraphin, Philippoff, Kaupp, & Laurie, 2012).

This study critically examined the teaching practices of participants involved in the TSI Aquatic Science professional development series to determine the extent that they were able to implement inquiry-based methods in their classrooms. I conducted three qualitative case studies to investigate the influences of the training modules on the participants’ instructional behaviors. I assessed whether participants utilized instructional practices that create an inquiry-based classroom community. Specifically, the research questions were that following the implementation of TSI Aquatic Science module,

1. Will the teacher participants use project-supplied inquiry education techniques in their science classrooms?

2. Are teachers able to identify the phases of inquiry used and will they be able to modify their teaching behaviors to reflect inquiry techniques outside of the project?

The significance of this study is its contribution to the extant knowledge base about teachers’ understanding of inquiry and their abilities to design and implement inquiry-based learning. Specifically, the study provides insight into science teachers’ development of inquiry instructional behaviors and practices through the process of implementing inquiry in their classroom. The findings provide important information about the influence of professional development programs and inquiry instruction.
Chapter 2. Literature Review

This study is an examination of scientific inquiry and inquiry-based instructional practices during a professional development series. The review of literature will address four topics: (a) science education reform, (b) inquiry education, (c) social cognitive theory as it applies to self-efficacy, and (d) the difficulties of altering teacher practices and beliefs.

Science Education Reform

Over a decade ago, education policy makers determined it was necessary to improve scientific literacy among students and provide teachers with a means of creating an effective scientific classroom community. The National Research Council (1996) published the National Science Education Standards [henceforth Standards] that provided a framework for science education reform. Through outlining the means by which educators could foster a scientifically literate population, the Standards emphasized an inquiry-based K-12 classroom environment. However, researchers continue to investigate the difficulties that teachers experience implementing and adapting inquiry-based education in their classrooms (Anderson, 2002; Crawford, 2000; Kang & Wallace, 2005; Luft, 2001).

The Standards were intended to provide a model that education officials could use to establish learning objectives, curriculum instruction, and assessment tools. Researchers have reviewed classroom practices and questioned teacher understanding of inquiry, and found that teachers have difficulty implementing the Standards using an inquiry-based approach (Anderson, 2002; Bodzin & Beerer, 2003; Brown & Melear, 2006; Crawford, 2007; Hume, 2009; Wee, Shepardson, Fast & Harbor, 2007). Hume (2009) suggested that
many teachers have a simplistic view of scientific inquiry and fail to provide students with learning experiences that reflect genuine scientific inquiry. If researchers could help promote the understanding of science inquiry by providing the support necessary to implement and revise teachers’ practices, inquiry education might be more achievable in classrooms. In an attempt to address this issue, the Teaching Science as Inquiry (TSI) Aquatic Science professional development program was designed to help teachers understand the phases of inquiry, adapt the methodology to their classroom, and include relevant science content.

**Inquiry Education**

The National Research Council (1996) released the *Standards* as a means of educational reform to promote a scientifically literate population. To understand the goal of the *Standards*, we must understand scientific literacy, which refers to the knowledge and understanding of the characteristics of science, and the ability to apply that knowledge and understanding to everyday situations (Bodzin & Beerer, 2003). Scientific literacy encompasses the essential features of scientific inquiry, which can be considered as a means of gaining knowledge (Wee et al., 2007). The *Standards* (National Research Council, 2000) defined inquiry as

\[ \ldots \text{[a] set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena;} \]

\[ \text{in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories} \ldots \]

\[ \text{students will learn science in a way that reflects how science actually works. (p. 214)} \]
The information regarding inquiry in the *Standards* is meant to aid teachers in the classroom, however the definition of inquiry in the *Standards* addresses the process of science and is independent of educational practices (Anderson, 2002). Anderson (2002) conducted a review of research regarding science education reform and found that inquiry is used in a variety of ways without distinction as to the differences between a desired form of teaching practice and a certain kind of student activity. Even though the *Standards* include specific teaching examples, teachers are left to create their own interpretations of what constitutes this form of teaching (Anderson, 2002). Scientific inquiry has been defined by scientists, researchers, philosophers, and historians; according to Crawford (2007), “science inquiry in the classroom takes on different forms; and researchers, teachers, and teacher educators all may have very different views” (p. 614). With so many interpretations of inquiry instruction, it is important to help teachers define inquiry in the classroom and assist educators to implement inquiry-based learning. Teachers have to use inquiry instructional techniques with their students and would need opportunities to develop inquiry-based curriculum.

To promote inquiry education, a shared core of norms and practices that emphasize scientific principles must be developed (Feuer, Towne, & Shavelson, 2002). The *Standards* specifically state that inquiry instruction with students should include identifying researchable questions, designing and conducting experiments, developing explanations, thinking critically about the relationship between evidence and explanations, and communicating scientific procedures and explanations (National Research Council, 1996). Feuer et al. (2002) identified these scientific endeavors of inquiry instruction as principles, which are normal behaviors expected in scientific
research. Luft (2001) ascertained that if science teachers are provided with theoretical information and practical concepts of inquiry education then they will be more likely to use inquiry in the classroom and better understand the methodology of inquiry education. The goal and purpose of inquiry instruction is to “promote student understanding of the nature of science” (Bodzin & Beerer, 2003, p.40). Therefore, it is important to provide teachers with professional development programs that support the implementation of inquiry-based instruction in classrooms (Bodzin & Beerer, 2003; Luft, 2001).

Research suggests that inquiry-based instruction can yield positive results, yet, it is unclear how many teachers successfully use inquiry or how many are likely to alter their teaching practices to add inquiry strategies as a result of training (Anderson, 2002; Bozdin & Beerer, 2003; Luft, 2001). Anderson (2002) identified three variables that may inhibit inquiry instruction; (a) technical challenges, (b) political conflicts and (c) cultural differences. Technical difficulties may arise because teachers may have limited in-service education, prior curricular commitments, and the challenges of identifying the teacher and student roles in the classroom. Political challenges may include parental resistance, unresolved conflicts among teachers, and lack of resources. The cultural challenges may be the most important because beliefs and values are factors; there is a tendency for schools to emphasize formal assessment and standardized test preparation rather than scientific investigation experiences.

Crawford (2007) identified some additional factors that may hinder a teacher’s success in teaching science as inquiry; (a) conflicting views of school-based cooperating teachers, (b) school context, (c) student population, (d) subject matter, (e) university teacher requirements, (f) parental pressures, (g) high stakes testing, (h) self-confidence,
and (i) the nature of prior authentic scientific research experiences. Inquiry education has been proven to be an effective means of creating a scientifically literate student population, however, as these factors indicate, initiation and continuation of inquiry in the classroom can be difficult for schools and teachers.

To meet the goals set forth by the National Research Council, science teacher educators must help teachers understand the practices of science, the nature of scientific inquiry, and how to translate these understandings into curriculum (Crawford, 2007). Hume (2009) found that teachers were interested in understanding what literature had to say about scientific inquiry and wanted to discuss how it applied to their classroom practice and how they might promote authentic scientific inquiry in their programs. For teachers to understand the nature of science, Hume suggested that they would benefit from meeting with scientists to understand actual instances of scientific investigations and how scientists go about solving problems. Translating the practices of science into a curriculum that will challenge students to implement inquiry techniques requires training and mastery of inquiry-based instruction.

Wee, Shepardson, Fast, and Harbor (2007) found evidence to suggest that professional development programs provide experiences that help teachers develop their overall knowledge about inquiry and the ability to develop inquiry-based applications in the classroom. However, they determined that a lack of support following a professional development may be the reason teachers do not exhibit higher levels of inquiry in their classroom practices, and suggested that professional development programs need to provide a more intensive follow-up agenda to support teachers’ implementation of inquiry during the academic year. They investigated science teachers’ learning about
inquiry as they implemented inquiry in their classroom, and found that even when inquiry was included in the science curriculum, it was viewed as a body of knowledge, rather than a learning process. Therefore, inquiry must be presented as an instructional technique as well as a non-linear process of learning that models the nature of science.

**Teaching science as inquiry.** At the University of Hawai‘i, the Curriculum Research & Development Group (CRDG) hosted a series of inquiry-based professional development courses. Pottenger, a member of the CRDG faculty, developed a model of Teaching Science as Inquiry (TSI) that focused on the phases and modes of inquiry learning and teaching in a non-linear format (Seraphin, 2010). The TSI Aquatic Science project, a three-year National Science Foundation funded program, provides teachers from the Hawaiian Islands with in-person instruction in inquiry methods, an online learning community, and a cohesive curriculum series. The TSI Aquatic Science professional development modules are based on Pottenger’s theory of inquiry education and curricula from the books: *The Fluid Earth: Physical Science and Technology of the Marine Environment* (Klemm, Pottenger, Speitel, Reed, & Coopersmith, 1990), and *The Living Ocean: Biology and Technology of the Marine Environment* (Klemm, Reed, Pottenger, Porter, & Speitel, 1995). The goal of TSI is to help teachers facilitate scientific inquiry and to create a community of scientists in their classrooms by engaging students in science using non-linear practices and progressions (Seraphin, 2010).

The TSI Aquatic Science professional development program was divided into modules, which were developed as four interrelated workshops providing inquiry-based teaching of physics, chemistry, biology, and ecology in aquatic science. The curriculum content was developed to highlight the nature of scientific investigation and to engage
students in the practice of science (Seraphin, 2010). The curriculum and professional development workshops were designed to allow and encourage teachers to use these new pedagogical techniques to implement inquiry-based education in their classrooms.

**The Teaching Science as Inquiry instructional model.** The TSI model emphasizes the nature of scientific investigation and development of critical thinking skills. The National Research Council (1996) suggested that engaging students in scientific inquiry would promote their understanding of the nature of science and result in a scientifically literate population. For students to understand the nature of scientific investigation, teachers must learn how to implement inquiry-based education in their classrooms. The National Research Council encouraged teachers to display the skills of scientific inquiry so students might assimilate similar attitudes and practices (Brown & Melear, 2006). Through the TSI Aquatic Science professional development program, teachers learn to help students understand basic scientific concepts and guide students’ thinking through the process of scientific investigation.

Pottenger’s model of inquiry, used during the TSI Aquatic Science professional development project, includes five phases: initiation, investigation, invention, interpretation, and during the entire process, instruction (see Appendix A). This model is similar to the 5E instructional model used in the Inquiring into Science Instruction Observation Protocol (ISIOP) (Bybee, 1997; Minner, DeLisi, Karelitz, & Hirsch, 2010). The 5E instructional model is based on a constructivist approach to learning and includes five phases: engage, explore, explain, elaborate, and evaluate. Pottenger’s five phases of inquiry and the 5E instructional model both identify the phases of learning that scientists continually navigate. Scientific endeavors often require revisions to the procedure and
repetition of steps; the investigation proceeds by first reviewing and returning to previous stages in a non-linear process.

The TSI instructional model, Pottenger’s five phases of inquiry, represent a learning process and an instructional cycle. The general philosophy of the TSI instructional approach involves a non-linear process that is integrated with instruction. As in scientific investigations, the TSI instructional model most often begins with initiation. Initiation occurs when a student identifies a problem to be solved or asks a question about his or her environment (Seraphin, 2010). Initiation may begin with the student or teacher, following a demonstration, presentation, or classroom experience. Following initiation, students engage in the invention of a hypothesis to solve their problem or answer their questions. Seraphin suggested that when students engage in this critical thinking, they develop inquiry skills and increase their understanding of scientific concepts.

Investigation is the phase of the TSI learning model that involves the gathering of information and knowledge (Seraphin, 2010). Investigation often requires observations, experiments, and the collection of data. Investigation may lead to the initiation of new questions that can become part of the current investigation or used later as a new investigation. The TSI learning model emphasizes the importance for students move back and forth between the phases of inquiry as they proceed through an investigation.

As students complete the investigation, they must then evaluate and interpret the data and develop conclusions about their study. Interpretation is considered “both a reflective, internal process and an objective external process” (Seraphin, 2010, p. 1). The information gathered and analyzed is then presented to the classroom community for evaluation and review. The process of interpreting data and communicating findings is a
fundamental skill that prepares students to “engage in civil discourse about issues, clearly communicate and defend their conclusions, and to consider and incorporate alternative points of view” (Seraphin, p. 1). Throughout the learning process, instruction is integrated into each phase of the sequence. Instruction is a reciprocal act; it might take place between teacher and student, student and teacher, or between the students.

*The modes of Teaching Science as Inquiry.* The TSI instructional model includes ten modes of inquiry that illustrate the ways in which new knowledge is developed, and are an important component. Most models of inquiry-based science focus on experiments while many of the other nine modes are ignored (Seraphin, 2010). Teachers are often overwhelmed by re-designing lesson plans to be inquiry-based and may associate inquiry education with extensive experiments or unmanageable classrooms. Inquiry instruction is less intimidating to teachers when they realize that there are many ways in which they and their students can legitimately do scientific inquiry (Brandon, 2010). When incorporating a variety of inquiry modes into an existing lesson, teachers are able to utilize more styles of learning, involving more students, and meeting the *Standards’* recommendations for good teaching practices (Seraphin).

The modes of inquiry addressed by the TSI Aquatic Science professional development program are *curiosity, replicative, technology, authoritative, inductive, product evaluation, descriptive, deductive, experimental,* and *transitive.* These multiple modes represent the variety of ways that knowledge is generated and acquired. Most educators are familiar with experimental inquiry, the search for knowledge through the testing of predictions derived from hypotheses. Curiosity often occurs during the initiation phase of inquiry education and represents the search for new knowledge in
external environments. Searching for knowledge by validating inquiry through testing the repeatability of an investigation that has been seen or described is replicative inquiry. Authoritative inquiry, the evaluation of information provided by an established source, is an example of scientific inquiry that is not hands-on. Inductive inquiry is a hypothesis-finding process that is achieved by examining the relationship between data patterns. Deductive inquiry is a similar hypothesis-creating process but is achieved through the synthesis of ideas or evidence. Transitive inquiry is accomplished through testing predictions that were derived from hypotheses. Creating accurate representation of things or events is descriptive inquiry. Product evaluation inquiry is when the products of technology are examined.

Seraphin (2010) described the importance of using multiple modes; “... science is practiced in many ways, and investigating the nature of science in its various aspects supports student learning through conceptual change” (p. 2). The emphasis on inquiry modes can help students connect classroom science experiences to life experiences, enables students to develop critical thinking skills, and produces a community of scientists within the classroom and a scientifically literate population of learners.

Social Cognitive Theory

Social cognitive views of learning lend theoretical support to the learning progression experienced by teachers during an inquiry-based professional development workshop series. The TSI Aquatic Science program aims to promote the development of cognitive ability and critical thinking skills through the interactions of cognition with behavior and the environment. Bandura (1989) developed a model of reciprocal causation, based in social cognitive theory, that includes factors that influence each other
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bidirectionally: behavior, environmental influences, and personal factors including cognition. Hirst and Manier (1995) described cognitive behaviors as influenced by “content, intentions, context, the external world, and social and cultural scenarios” (p. 116). Cognition occurs due to the interaction between these variables and how an individual responds to the task (Hirst & Manier). During an inquiry-based investigation, learning is influenced by the classroom environment, prior knowledge, motivation, and self-efficacy.

Bandura (1989) identified self-efficacy as the most central or pervasive thought; it is the ability for people’s judgments of their capabilities to exercise control over events that affect their lives. Efficacy provides people with insight into future events and how to manage those events. Prior experience, and physiological and emotional states can all influence self-efficacy (Bandura, 1995). Self-efficacy can also be influenced by social interactions, and vicarious experiences and persuasion can either inhibit or develop a person’s efficacy. An individual’s perception of his or her ability to accomplish tasks will directly affect academic performance. According to the social cognitive theory, people develop skills that regulate “the motivational, affective, and social determinants of their intellectual functioning” (Bandura). People’s feelings of self-efficacy affect their choices of activities, the goals they set for themselves, the effort and persistence toward a task, and ultimately their learning and achievement (Omrod, 2004). Behaviors associated with an individual’s sense of self-efficacy can go beyond the individual to directly influence the entire classroom community.

The TSI Aquatic Science professional development program was designed to help teachers broaden their understanding of scientific inquiry and learn how to apply inquiry
techniques in the classroom. During this workshop series, the teacher participants had to understand the TSI instructional model, learn science content, and develop their own inquiry instructional techniques. Mastery of these tasks required the participants to experience scientific investigations, question the effectiveness, and then use the lessons in their own classrooms; these experiences influenced their sense of self-efficacy.

**Self-efficacy in the classroom.** The self-efficacy of the teacher, as well as that of the student, has the potential to influence classroom instruction, perception of student achievement, and relationships with students. Brown (1993) described the ethos of the classroom as an “atmosphere of individual responsibility coupled with communal sharing” (p. 199) and where students establish an environment where ideas and concepts are shared within the community through discussion, questioning and negotiation. If a community of learners is developed, Bandura (1995) ascertained that there will be a group effort to achieve their shared goals and cope with external obstacles.

Bandura (1995) identified three ways in which efficacy beliefs contribute to academic development; (a) students’ beliefs in their efficacy to regulate their own learning and master academic subjects; (b) teachers’ beliefs in their personal efficacy to motivate and promote learning in their students; and (c) faculties’ collective sense of efficacy that their schools can accomplish academic progress. Students with a high sense of self-efficacy are more likely to learn and achieve more because they will exert more effort in accomplishing a task (Omrod, 2004). Bandura (1995) suggested that teachers who lack instructional efficacy tend to not be committed to teaching and will spend less time covering subjects that they have not taught or previously learned. If students observe a teacher avoiding subjects that may be more difficult, they could potentially acquire this
behavior themselves. The learning outcomes of students within a class could reflect the influence of the teacher’s self-efficacy.

When a teacher is expected to implement new instructional techniques or behaviors, the result will directly affect the class. While inquiry education is often introduced during professional development programs, teachers may be expected modify their instructional practices, lesson plans, activities, and classroom management behaviors. However, for a teacher to alter those variables, the individual must also reflect on his or her beliefs regarding learning, the nature science, and the purposes of education. This has led researchers to investigate the difficulties that teachers experience implementing and adapting inquiry instruction in their classrooms.

**Instructional Beliefs and Practices**

Factors that could limit the success of inquiry education include a complex set of personal beliefs about instruction and views of science formed by each teacher (Crawford, 2007). To alter teacher beliefs or practices regarding scientific inquiry, educational psychologists and researchers must first identify conceptions and help teachers examine their classroom practices. According to Luft and Pizzini (1998), change is a process accomplished by individuals. It is a “highly personal experience,” and requires the development of specific skills and feelings.

Many authors noted the difficulty of significantly altering teachers’ beliefs, and consequently their practices. Brown and Melear (2006) used multiple tools of analysis to investigate the relationship between teacher beliefs and practices of inquiry instruction, and then examined how that relationship evolved with teacher experience. Crawford (2007) examined the beliefs, knowledge, intentions, and practices of five prospective
high school science teachers as they learned to teach science in the Science Professional Development School (SPDS). Wee et al. (2007) used an inductive approach to create case records for teachers involved with a professional development program. Kang and Wallace (2004) investigated how “teachers synthesized their beliefs and goals to produce their unique teaching practices” (p. 143) during a workshop where they could develop their own definitions of inquiry. These researchers all determined that there was little or no change in teachers’ individual perception of inquiry following an inquiry-based science course. However, Wee et al. discovered that teacher participation in the professional development program resulted in an increase of teachers’ abilities to design inquiry-based activities and increase their understanding of inquiry in the classroom.

Also, Luft, Roehric, and Patterson (2003) found that the beliefs and practices of beginning science teachers were subject to change following induction programs that focused on inquiry education.

Brown and Melear (2006) determined that teachers expressed beliefs about inquiry that were not always consistent with their actions. They suggested that first year teachers remain mostly teacher-centered in their beliefs and classroom behaviors. Crawford (2007) reflected on the difficulty that novice teachers experienced integrating scientific inquiry education in their classrooms due to conflicts with existing science curricula, school goals, and instructional tasks. She suggested that some teachers may not feel confident or equipped with strategies or techniques to conduct inquiry-based instruction in their class. Therefore, teacher educators must provide support to teachers when they are learning how to facilitate student learning about scientific habits and the nature of scientific inquiry.
Kang and Wallace (2004) found that teachers may have sophisticated views of science but do not always apply it to their teaching practices. A teacher’s instructional practices develop from the teacher’s perceptions of student needs, instructional goals, and his or her beliefs about knowledge development. Anderson (2002) suggested that teacher educators should focus on creating a community of collaboration among teachers and provide an environment in which educators can reflect on their values and beliefs. For teachers to adapt an inquiry approach to their instructional practices, educators must situate inquiry in a practical context and allow teachers to reflect upon the theory, their beliefs, values, and understanding of inquiry education and the scientific process (Anderson, 2002). Kang and Wallace (2004) ascertained that educational research should focus on teachers’ instructional goals and teaching context since they influence teachers’ “commitment to putting their epistemological beliefs into practice” (p.160).

Luft (2001) investigated how an Inquiry-Based Demonstration Classroom (IBDC) in-service program impacted the extended inquiry instruction of secondary science teachers. During the program they introduced a model of inquiry that teachers were to use in their classrooms, examine, and then reflect upon their lessons. Luft (2001) found that allowing the participants opportunities to explore their own behaviors and beliefs regarding inquiry instruction led to the development of behaviors and beliefs conducive to inquiry instruction. Although research has proven that inquiry implementation can be a difficult and complex process, Luft determined that professional development programs should be constructed to address the practices and beliefs of science teacher.

Later, Luft et al. (2003) conducted a study to understand the impact of induction programs on the teaching beliefs, practices, and experiences of beginning secondary
science teachers. They found a relation between beliefs and practices. Therefore, induction programs in science may reinforce beliefs and practices that reflect the inquiry-based instructional models, if follow-up support is available.

Using a case study model, Adams and Crockover (1999) found that the transition to a student-centered model of teaching is difficult, since teachers may not have appropriate models from which to develop inquiry-based instructional techniques and behaviors. Their results further support the importance of longitudinal research for investigating the effect of science teacher education programs.

Researchers have found the relationship between a teacher’s beliefs in their efficacy, the nature of science, and inquiry is reflected in their instructional techniques. In order to implement an effective professional development program the prior knowledge and beliefs of the participants should be acknowledged and respected. Teachers require practical examples of inquiry education to further their understanding of inquiry-based instruction. Retention and instructional effectiveness relies on adequate follow-up opportunities and a supportive community for teachers to reflect on their instructional practices.

The TSI Aquatic Science professional development series was developed to encourage teachers to understand the phases of inquiry, include relevant science content in their curricula, and implement inquiry-based methods in their classrooms. This study examined the teaching practices of three TSI Aquatic participants to determine the extent that they were able to implement inquiry-based methods in their classrooms after instruction in inquiry-based science education. I conducted three mixed methods case studies to investigate the influences of the professional development series on the
participants’ instructional behaviors. Specifically, I was interested if teachers were able to identify the phases of inquiry used, and if they were able to modify their teaching behaviors to reflect inquiry techniques outside of the project. I also wanted to investigate their use of project-supplied inquiry education techniques in their science classroom.
Chapter 3. Method

Approach

This study used a multiple case study design and a qualitative approach to analyze the instructional practices and use of inquiry education in the classrooms of three teacher participants. The purpose of the case study research was to assess whether the participants utilized inquiry instructional practices in their classrooms, identified the phases of inquiry and modified teaching behaviors to reflect inquiry-based instructional techniques. I used the Inquiring Into Science Instruction Observation Protocol (ISIOP) (Minner et al., 2010) to facilitate classroom observations and made four classroom observations for each case study participant. In addition to the ISIOP data collection, I wrote post-observation narratives about what I witnessed during the lessons and the teachers completed post-observation instructional templates regarding their classroom instruction of the target lesson. I compared teachers’ perceptions of their instruction and my own classroom observation to address the research question. Qualitative sources of data included ISIOP pre-observation teacher questionnaires, my own post-observation reflection narrative, teacher post-observation instructional templates, and post-observation survey responses. The classroom observations were captured using the ISIOP protocol and were described quantitatively.

A case study approach was used for this research in order to develop a comprehensive story about each teacher’s instructional style, inquiry implementation and classroom management behaviors. A case study method was most appropriate for this study because the goal was to gather a depth of information to determine the teachers’ uses of the inquiry methods they were taught. Stake (1995) suggested that “qualitative
researchers have pressed for understanding the complex interrelationships” (p. 37) among the phenomena studied. Observational data along with the post-observation narrative and surveys were necessary to understand the classroom environment and determine if the teacher participants were able to use scientific inquiry in their classroom. Stake explained that teaching is “not just lecturing . . . it is arranging access to information regularly . . . and recognition of conditions that will facilitate learning for learners” (p. 92). The qualitative methods used allowed multiple sources of data to be collected, compared, and described, which contributed to rich descriptions of the teaching that occurred in the classroom.

Participants

**Professional development context.** Participants in the TSI Aquatic Oahu professional development series included 14 (4 males and 10 females) public, private, and charter middle and high school teachers from Oahu, Maui, and the Big Island of Hawai‘i. The Oahu cohort was composed of six middle school and eight high school teachers with an average of ten years teaching experience. The participants taught a variety of scientific disciplines including chemistry, physics, biology, astronomy, and earth science. Members of the Oahu cohort educated students in urban, suburban, and rural communities.

The TSI Aquatic modules are organized into four topics adapted from the existing Fluid Earth Living Ocean curriculum (Klemm et al., 1990; Klemm et al. 1995): physical, chemical, biological, and ecological aquatic science (Seraphin, 2010). Each of the modules consists of one two-day workshop, one follow-up training, and one Blackboard presentation. Participants were required to attend the workshop and training, participate
in the online learning community, and provide structured feedback to the evaluation team. Teachers received compensation including stipends and course credit, and the participating schools received subsidies.

**Case study participants.** Three participants from the TSI project were purposefully selected for this study based on the diversity in the type of students in their classes, their school settings, and their teaching experiences. Each participant was the subject of an individual case study; however, in cross-case comparisons it was possible to identify common patterns that captured shared experiences of the entire group.

Prior to the third instruction module of the TSI program, I approached the teacher participants to determine if they were interested in participating in this research. These three teachers supported the proposal and were willing to be observed. Although I was an outsider to the classroom, the teacher participants seemed comfortable with my presence in the class and conducted their classroom in a regular manner. The familiarity between the case study participants and I may have minimized their fear of judgment.

*Andrew.* Andrew was a twelfth-grade private school educator in an urban area who had seventeen students in the classroom I observed. His thirty-three years of teaching experience have all been in science education and he has spent all but one year at the same school. Andrew was certified in science education with a Master’s degree in education. The private school where Andrew taught was founded on Christian values, enrolls students from preschool through high school, and implements a college-preparatory curriculum. During the 2009-2010 school year, grades nine through twelve had approximately eight hundred students enrolled. The school has a wide diversity of ethnicities including African-American, Latin-American, Asian-American, Middle
Eastern-American, and European-American (Mid-Pacific Institute, 2012). Almost one-third of the student body was Multiracial-American.

**Patrick.** Patrick, in contrast, had only two years of teaching experience prior to his participation in the TSI Aquatic professional development program. Patrick taught ninth-grade physical science and physics at a public high school that serves seven rural and two military communities. Patrick had his Master’s degree in Education and was certified in secondary education. The public school where Patrick taught, offers comprehensive programs in vocational, technical, academic, and special education, while serving an ethnically diverse student population including Filipinos, Caucasians, part-Hawaiians, Japanese, Hispanics, Indo-Chinese, Samoans, and African-Americans (Campbell High School, 2011). During the 2009-2010 school year, the fall enrollment was approximately 2,650 students; within that population approximately 40% of students received free or reduced-cost lunch, 10% of students were in special education programs, and 7% of students had limited English proficiency (Department of Education State of Hawai‘i, 2012). The average number of students in Patrick’s classroom was twenty-eight students.

**Allison.** Allison is a life science teacher at a public intermediate school located in a suburban residential area. Allison had five years of science education experience during this study, and she had her Master’s degree in mid-level education. Her school focused on mentoring, community service, goal setting, and early college awareness. The intermediate school served approximately six hundred and eighty students; 30% of whom received free or reduced-cost lunch, 12% were in special education programs, and 4% had limited English proficiency (Department of Education State of Hawai‘i, 2012). The
student population is ethnically diverse with a majority of the student population being students of Caucasian and part-Hawaiian decent; there are also students of Chinese, Filipino, Japanese, Hispanic, Portuguese, Samoan, and African-American decent. The average number of students in Allison’s classroom was twenty-four and during her general education class she had ten students with special needs and two students with English as a learned language included in her classroom.

Data Collection

Observational instrument. Permission was obtained to utilize and modify the Inquiring Into Science Instruction Observation Protocol (ISIOP) (Minner et al., 2010). The ISIOP procedure was selected for this study because it provides a quantitative metric of teacher instructional practices and behaviors including inquiry techniques, and because it provides ample resources and training for observers to minimize bias and increase consistency. Minner et al. developed an extensive training procedure that scaffolds learning and requires eight practice sessions prior to entering the classroom setting. The ISIOP protocol consists of a pre-observation questionnaire, scoring forms for classroom observations and a rubric for scoring classroom observations.

The ISIOP was developed as an observational tool to assess the presence of the scientific inquiry process in pedagogical practices and classroom instruction (Minner et al., 2010). The ISIOP reflects the “standards-based, inquiry-oriented, optimal teaching’ indicators that have been theorized or demonstrated to be associated with student learning” (p. 3). Minner et al. identified five independent constructs of science teaching that provide a quantitative metric of “teacher moves’ (curriculum decisions and verbal responses) that provide opportunities for students to learn.(p. 4)”
Minner et al. (2010) determined the validity and reliability for the ISIOP procedure using common psychometric procedures. To achieve content validity, the researchers submitted the ISIOP to multiple cycles of external reviews and instrument revisions. The researchers found that the items and constructs of the ISIOP procedure are a valid way to capture “standards-based, high quality science instruction.” (p. 12). They conducted two pilot studies and studied inter-rater agreement levels and the internal structure of the scoring rubric to determine reliability. The ISIOP scoring rubrics include six independent sections and the researchers found inter-rater agreement levels remained high, greater than 85%, for each section of the protocol.

Minner et al. (2010) identified two forms of bias potentially present when using the ISIOP procedure. To properly use the procedure, a rater must be able to focus on the detail of interaction while tracking the classroom organization (Minner et al.). They determined that each rater creates some bias due to individual background, experience, and personality. The researchers also found that raters with prior experience in schools or who were familiar with science content had a different perspective from naïve observers, and scored accordingly. The eight practice sessions prior to classroom observations are designed to decrease this potential rater bias.

The Secondary Science Teaching Analysis Matrix (STAM), a tool that investigated the relationship between teacher beliefs and practices, was considered for this study (Brown & Melear, 2006; Gallagher & Parker, 1995). The STAM is a matrix that classifies six different teaching styles and measures the behavior of the teacher accordingly. This tool directly measures the relationship between beliefs and practices. However, the STAM is an older instrument that does not provide the same training
resources as the ISIOP. The ISIOP procedure does not classify teachers according to teaching style; instead behaviors and actions of the teacher are recorded and used as data. Unlike the STAM, information collected provides specific information about teacher practices and instruction. For these reasons, the ISIOP was chosen.

**Classroom observation procedure.** Participants of the TSI Aquatic professional development series are required to implement a ‘target’ lesson. The principal investigator and the project manager developed and identified the target lessons for each module. The teachers chose from three different target activities and were required to implement at least two in the classroom. The target lessons were designed to facilitate inquiry instruction and promoted the nature of science. I conducted observations during two non-target and two target lessons for each participant to determine if there was a difference in teacher instruction or behavior. I expected to observe more inquiry instruction during the target lesson and less inquiry instruction during non-target lessons.

Prior to the classroom observation, each participant completed a modified version of the ISIOP pre-observation questionnaire (Minner et al., 2010) that included the phases and modes of the TSI framework. This modification allowed me to collect information about what phases of inquiry the teacher predicted would occur and which modes they would utilize during the lesson. The questionnaire asked for a brief description of the lesson being taught and how the lesson was situated within the classroom curricula.

During each observation, I made note of the class size, population, layout of the classroom and the topic to be taught. I then recorded information about the lesson events including verbal or physical activity, the types of questions the teacher asked, and the types of comments teachers made. The ISIOP classroom observation protocol included
rubrics to score teacher verbal practices, science content, investigation experiences, and classroom management. Each classroom observation included multiple “lesson events” which are defined as discrete changes in activity.

According to Minner et al. (2010), the ISIOP defines this sampling method as an “event sampling approach, where the observational unit is the lesson event. (p. 4)” Lesson events are differentiated by changes in activity or the organization of the class. Observational data included lesson events for a specific class period. To maintain consistency, I made an effort to schedule multiple observations of the same class period. However, due to the limitations of time and availability I observed four different class periods per teacher.

The ISIOP procedure includes six sections of observation with each section including data of various types including frequency counts of occurrence and ratings on ordinal scales (Minner et al., 2010). These data provided quantitative support for the qualitative trends identified from the post-reflective narratives. For example, I was able to infer whether teacher instruction was inquiry-based, the nature of the verbal practices exhibited by the teacher, and the kinds of investigation-related experiences in which students were engaged. I also identified instructional practices and techniques unique to each teacher participant. Based on these data, I was able to assess whether participants utilized instructional practices that created an inquiry-based classroom community.

**Post-observation reflective narrative.** Following each observation, I wrote a post-observation reflective narrative to add a more subjective appraisal of classroom activities. These narratives included descriptions of (a) specific verbal cues used by the teachers, (b) classroom management techniques, (c) the context of each lesson, and (d)
descriptions of each lesson event. I then used the ISIOP coding rubric to quantify emphasis on science content, investigation-related experiences, and classroom management practices.

**Target lesson post-observation instructional template.** To complete the professional development requirements, teachers were required to complete an instructional template after they taught their target lesson in order to identify teacher perspectives of specific teaching goals, practices of science, and the phases of inquiry that occurred in the classroom. The target instructional template was compared to observational data. A comparison between the teacher’s self-assessment and the actual observation provided further information. Once the classroom observations were completed, I analyzed these observational data to determine if inquiry techniques were incorporated into the participants’ teaching styles.

**Follow-up reflection survey.** Once the classroom observations were completed, each participant completed a written e-mail-based survey. The questions were created to elicit the teachers’ beliefs regarding inquiry education, challenges faced implementing the ‘target’ lesson, and perceptions about whether the TSI Aquatic professional development series had influenced their instructional practices (see Appendix B).

**Validity and Limitations of Data**

Minner et al. (2010) established reliability and validity for the ISIOP procedure and also identified potential sources of bias. To minimize these sources of error, I completed the ISIOP training before entering the classroom environment. During the training, I compared my transcription codes with those of two other graduate assistants.
who were also working with the ISIOP training guide. However, I conducted my classroom observations individually.

The researcher role. I was a member of the TSI Aquatic project as a program development assistant. I worked with educators, learning technology experts, and evaluators at the Curriculum Research & Development Group (CRDG) to develop, conduct, and evaluate the TSI Aquatic Science professional development program. In preparation for each workshop module, I worked with the TSI team to develop and revise the curriculum and align the content with National Science Standards, ocean literacy principles, and Hawai‘i state standards. I assisted in coordinating the professional development modules; including organization of the venue, supplies, and other logistics. During the workshops, I was responsible for setting up the lab materials and facilitating the scientific investigation activities, and I was available to help the teacher participants with supply and content questions. Following the workshops, I provided feedback for revising instructional materials.

My role as a member of the TSI Aquatic Science professional development program could have been a potential source of bias. The teacher participants were member of the TSI Aquatic Science project for a year prior to their involvement in the case study. During this time, I had developed a working relationship with them in a workshop setting. In addition, I wanted the TSI curriculum to succeed in the classroom. Another possible source of bias was the fact that my observations were conducted without an additional observer. Ideally, the ISIOP data would have been collected by two observers so inter-rater reliability could be determined (Minner et al., 2010). Since I did not have an additional observer, I was not able determine inter-rater reliability.
To further minimize bias, I tried to remain an objective observer in the classroom. During classroom observations, I did not participate in the classroom discussions and I was physically located either behind the student tables or in the corner of the classroom, out of the way of instruction.

I also tried to minimize the effects of my relationships with the teachers on the data collected. The ISIOP training methods assisted me to be objective during the observations. In addition, I observed the teachers in the same manner as I had done during the training sessions. Although I had known the teacher participants in a workshop environment, I had not observed the teacher participants implement their instructional practices in the classroom.

To minimize bias due to poor recollection, I completed the post-observation narratives immediately following the classroom observation. Therefore, each of the case studies was developed relying on objective and immediately recorded data rather than researcher memory.

I identified qualitative themes from the data, and compared these with those a second person individually identified from the same data. We compared results to determine the most frequently occurring questions, comments, and physical codes. We also compared the themes to the ISIOP verbal codes when determining if inquiry education was occurring in the classroom.

**Data Analysis**

Each data source was analyzed as described below and compiled to build a case study for each participant. The use of multiple data sources allowed for a rich description, and for comparison and coordination between the cases. As the quantitative
data were insufficient to answer the research questions, quantitative data were used as support for the qualitative trends. Collecting data from multiple sources was intended to provide enough information to develop an adequate assessment of each participant’s instructional practices and use of scientific inquiry in the classroom.

**ISIOP Coding Rubric**

The ISIOP procedure resulted in various types of data that could be quantified. During each observation, verbal cues were enumerated for each lesson event. Prior to the observations, the teachers recorded the scientific content data they intended to cover during the lesson. They also predicted what instructional modes they intended to use along with the phases of inquiry they expected their students to experience. I recorded investigation related experiences, classroom management practices and science content data after each lesson observation. To understand if teachers used inquiry education in the classroom, the science content data were examined to assess the degree of agreement between teacher prediction and researcher observations.

The science content data included a category about “the nature of scientific inquiry” (Minner et al., 2010). This category was used to answer the two research questions; to determine if inquiry education was used in the classroom, and to determine if the teacher participants were able to identify their use of inquiry education. Prior to the classroom observation, as a part of the ISIOP pre-observation questionnaire, each teacher participant selected which measures of inquiry he or she planned to use in the classroom and to what extent inquiry would be used (see Table 1). Following the observation, I recorded which measures of inquiry were observed and to what extent scientific inquiry was used. I recorded these data without knowledge of what the teacher selected on the
pre-observation questionnaire. I investigated the extent of agreement between the
teachers’ prediction of scientific inquiry and the inquiry I observed. I consider my
observation of inquiry in the classroom to be accurate due to the ISIOP training and my
participation as a member of the TSI Aquatic Science professional development staff and
my knowledge of inquiry methods. Due to differences in lesson material, it was important
to consider each observation independently for each of the teacher participants.

**Table 1.** ISIOP Categories Regarding The Nature of Scientific Inquiry (Minner et al.,
2010)

<table>
<thead>
<tr>
<th>The Nature of Scientific Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 The question drives the kind of investigation done</td>
</tr>
<tr>
<td>2 Different scientific domains employ different methods and theories</td>
</tr>
<tr>
<td>3 Mathematics and technological tools are essential to enhance the accuracy of data collection</td>
</tr>
<tr>
<td>4 Scientific explanations have specific characteristics</td>
</tr>
<tr>
<td>5 Science advances through legitimate skepticism by</td>
</tr>
<tr>
<td>6 Scientific investigations produce new ideas or new methods</td>
</tr>
</tbody>
</table>

**Qualitative codes.** The verbal practices rubric included seven categories of
questions and comments that the teachers might make during their lessons. Each question
or comment category had either one or multiple qualifiers; for example, to provide
“signposts” to students, the progression of the lesson, a teacher might make a comment
that is coded as a new or old, itinerary, directions, foreshadow, or situate statement. To
determine the frequency of instructional strategies, the qualifiers within each question
and comment category were combined. To further understand the differences in the
verbal practices used between target lessons and the regular instruction, I analyzed
frequency counts of verbal instructions.
In this study the ISIOP data were coded and compared to the qualitative data that were coded and extracted from the post-observation reflective narrative and the information provided by the teacher in the pre-observation questionnaire (see Table 2). I recorded the number of times each teacher made statements or asked questions categorized by the verbal codes, for each lesson event, then for each lesson in its entirety. Each classroom observation resulted in a different number of lesson events depending on the lesson plan prepared by the instructor. I scaled the total number of comments to the number of lesson events so the lessons could be compared to one another. I compared the frequency of verbal codes from each teacher in the inquiry specific lessons to those that occurred during regular instruction.

Table 2. Qualitative Codes Used for Analysis.

<table>
<thead>
<tr>
<th>Verbal Codes</th>
<th>Inquiring Into Science Instruction Observation Protocol (ISIOP) Verbal Codes</th>
<th>Codes from Post-Observation Narrative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Question</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engage</td>
<td>Ask questions that solicit volunteers for activity</td>
<td></td>
</tr>
<tr>
<td>Gauge and Expand</td>
<td>Ask questions that require students to answer &quot;know that&quot;, &quot;how&quot;, &quot;why&quot;, and &quot;what if&quot; questions.</td>
<td>Ask(ed)</td>
</tr>
<tr>
<td><strong>Comment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signposts</td>
<td>Provide students with information about the progression/order of the lesson</td>
<td>Instruct(ed)</td>
</tr>
<tr>
<td>Feedback</td>
<td>Comments that acknowledge, rephrase, redirect, or correct student contributions</td>
<td>Review (ed)</td>
</tr>
<tr>
<td>Prompt</td>
<td>Comments that further thinking by giving information, hints, suggestions, or thinking aloud.</td>
<td>Introduce(d)</td>
</tr>
<tr>
<td>Reduce Complexity</td>
<td>Using examples, highlighting a specific direction, or summarizing the main points of the lesson</td>
<td>Explain(ed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discuss(ed)</td>
</tr>
</tbody>
</table>
Post-Observation Narrative

The post-observation narratives are the most extensive written data regarding the instructional practices and the execution of the lesson plans exhibited by the participants. After reading through each of the post-observation reflective narratives, I analyzed and coded these narratives according to verbal practices observed. I quantified the common phrases used by the teachers by frequency of occurrence and classified each phrase as a question, comment, or physical action. In these narratives, one phrase was associated with the question category and five phrases occurred most frequently in the comment category (see Table 2).

Listing the verbal instructions most frequently used by each participant allowed me to create a comprehensive review of each of their instructional practices. The five most frequently occurring phrases within the narratives for each teacher were identified and counted. Similar to how I analyzed the ISIOP verbal practice codes, I sub-divided the verbal instruction category into question codes and comment codes. I associated each of the question, comment, or physical action phrases with the related ISIOP question and comment codes to allow for comparisons between them (see Table 2).

Post-Observation Instructional Template

Teacher participants completed the post-observation instructional templates, indicating the overall objectives for the lesson, the logistics required to complete the lesson, and how each phase was addressed. They also indicated the lesson progression between the phases of inquiry on a blank TSI phase diagram (see Appendix A), and included a description of the phase progression. The instructional templates were completed after the observations took place. The template data were compared to the pre-
observation questionnaire to determine if the teachers executed the lesson as planned and how the learning progression occurred or changed.
Chapter 4. Presentation of Findings

Andrew’s Classroom

Andrew is a teacher with thirty-two years experience at a private school in an urban neighborhood. Three of the classes observed were of Andrew’s twelfth grade oceanography class and the fourth observation was of a ninth grade biology class. Andrew encouraged his students to work independently on classroom activities while providing them support and assistance. Andrew described his instructional style in two ways. Depending on the curriculum, he might introduce science content during lessons and use labs to illustrate science principles, but he also uses the scientific investigations to introduce and teach content and process skills simultaneously. Andrew reported that he adjusted his instructional style depending on his students and the lesson being addressed.

Classroom of independent learners. Andrew’s oceanography class was an advanced level science course and he described the curricula as project and research based. Andrew used similar instructional techniques with his ninth grade biology students; however, he spent more time introducing the lesson topic with the younger students. Andrew encouraged students to conduct experiments or activities and then analyze the outcome. He motivated his students to be objective learners and he asked questions to get them to examine how they proceeded through their investigation.

Andrew began class once students were settled, then handed out the activity, and gave students a few minutes to read through the directions. Andrew reviewed the instructions while answering student questions. The investigation began once students were familiar with the procedure and the materials available. During the biology class, Andrew first reviewed cellular respiration with the students, accessing their prior
knowledge; he then introduced photosynthesis and the visible light spectrum produced by the sun. These topics were necessary for the students to understand and begin the lab. Students were instructed to create a procedure, draw a sketch of their set-up, and make a data table to record oxygen readings. Many of the students had difficulty creating a procedure that addressed the research question outlined in the lesson instructions, and Andrew was approached by students requesting clarification and assistance. He worked with each group of students to identify which parts of their procedure needed fixing. When students asked for the answer, Andrew would discuss what they already had and encourage them to think about what was needed to complete the task.

Andrew initiated lessons with the oceanography class with a brief introduction of the topic, an explanation the lab, and information about what type of data or product was expected. The students in the oceanography class often worked in small groups or pairs. Once they were given their task, the students broke off into small groups and began to work through the instructions. Andrew emphasized the importance of examining students’ own work. During a properties of water lab, he asked the students to make predictions, then observations, and then evaluate the result. Andrew allowed the students to be independent learners and would provide limited guidance during their investigations.

**Inquiry instruction in the classroom.** To determine inquiry instruction in the classroom, the qualitative codes obtained from the post-reflective narrative were categorized according to the comparable ISIOP verbal quantitative codes. The frequency of the qualitative codes was then compared to the frequency of the ISIOP verbal codes for both the TSI Aquatic target lessons and the non-target lessons. Andrew most
frequently provided instruction and explanations to his students. According to the ISIOP verbal codes, instructional and reviewing comments are most closely related to “signpost” comments; explanations and discussions could be classified as verbal “prompts.” In Andrew’s case, the frequency of the qualitative data corresponded directly to the frequency of the ISIOP verbal coding. During his TSI Aquatic target lesson, Andrew most frequently used prompting comments to encourage learning, while during non-TSI lessons he often used comments that provided signposts to guide learning.

Andrew began his classes by passing out the instructions for the activity to be completed during class. He gave the itinerary for the lesson and provided directions to students for how to complete a specific task. In his ninth grade biology class, Andrew connected previously covered material, cellular respiration and the process mitochondria undergo, to the new topic of photosynthesis. These behaviors reflected comments classified as signposts (Minner et al., 2010). Signposts were established by reviewing previously covered material, providing the itinerary for the lesson, and directions to students for how to complete a specific task (Minner et al. 2010). Establishing expectations provides students with motivation and a product to complete during the class period. It also allows teachers to be clear in their expectations and situate learning within the context of the curriculum.

As students worked independently, Andrew monitored the progress of each group. He prompted student thinking by providing students with minimal cues in order to guide students’ thinking toward a learning target and, instead of providing students with the answer, he encouraged the student to find the answer for him or herself. These practices relate closely to Minner et al.’s (2010) description of the types of prompting comments a
teacher might make. The qualitative codes that most frequently occurred were “explain” and “discuss,” I categorized both as prompting comments. During the TSI target lessons, Andrew often used prompting comments to encourage student learning. For example, during the statement sort activity, each group presented their statement and explained why it was a fact, hypothesis, law, opinion, etc.

If a group answered incorrectly, [Andrew] would try to gauge what the student knew about the definition of the word. [Andrew] might ask students to explain their reasoning for a particular answer and as they worked through the answer he would provide hints if necessary to guide them to the correct definition (Observation, 10.18.11).

Andrew performed a demonstration of gravitational currents. To foster classroom discussion, he had students predict what would happen when he removed a divider between two liquids. Andrew had students evaluate what they saw and explain what was happening. Students were required to use their prior knowledge of density and gravity to explain what they were observing. Andrew used specific prompts to encourage students to critically examine the nature of a scientific principle.

Andrew helped students throughout the learning process. He provided feedback more frequently to students during the TSI target lessons than during the non-TSI lessons. For instance, he articulated a student response more clearly, used more precise scientific language, indicated that some part of a student response was not accurate and pushed for more information, and reinforced persistence. During the TSI fish form and function activity, Andrew monitored his students’ progress through their first series of fish prints.

Once a student had completed a fish print, he would ask them what does
the fish print show them, how could they make it better, and what were some of the problems. Andrew would help them to identify what was needed to enhance the print and students would decide the changes they wanted to make (Observation, 9.29.11).

The conversations between Andrew and his students fostered a creative environment in which students were encouraged to create a better product, the fish print.

**Identification of instructional practices.** Andrew frequently used elements of inquiry instruction in his classroom. When asked what his initial concept of teaching “science as inquiry” was prior to the TSI Aquatic workshop and to compare it to his concept of inquiry presently, Andrew answered. . .

*Before the workshop, I tried to incorporate many inquiry labs into my biology classes. I have always felt (and still do) that having the lesson done by inquiry makes the student a more active learner. Also it probably makes the lesson more meaningful and more likely to be remembered if the lesson is done through inquiry* (Post-observation survey, 1.20.12).

Andrew’s response provides insight into his beliefs regarding the importance of inquiry education in the classroom. Researchers have found that the beliefs of a teacher directly influence their instructional practices (Anderson, 2002; Crawford, 2007; Luft et al., 2003; Kang & Wallace, 2004). Andrew was able to identify the phases of inquiry he intended to use for each of his lessons including what modes he planned to implement.

The science content data was used as an instrument to determine if the teacher participant was able to identify his or her use of scientific inquiry in the classroom. On
the ISIOP pre-observation questionnaire, Andrew identified which of the six domains of
the nature of scientific inquiry category he planned to address during the lesson.
Following the observation, I recorded which of the domains Andrew actually
implemented in his classroom. During the first TSI target lesson observed, Andrew and I
both indicated that he used different scientific domains and scientific investigations that
produce new ideas or new methods (categories two and six, see Table 2). In the second
TSI target lesson, Andrew used questions to drive the investigations students conducted
(category one, Table 2). I observed Andrew promoting mathematics and technological
tools to enhance the accuracy of data collection (category three, Table 2). During non-
TSI lessons, Andrew emphasized that scientific advances often result from skepticism
and making a scientific explanation requires specific characteristics. For three of the
classes observed, Andrew used questions to influence the types of investigations
completed by his students.

Andrew is an experienced educator who used scientific inquiry techniques in his
instructional practices regularly. However, even with thirty-two years of teaching
experience Andrew wrote that he discovered something new regarding his use of inquiry
as a result of the TSI instruction.

_ I believe that I learned to spend more time thinking about how students
think . . . I think I was too focused on the covering of specific content and
not so much on how students learned the content_ (Post-observation
survey, 1.20.12).
Patrick’s Classroom

Patrick was a third year physical science and physics teacher at a rural public high school in Oahu. Three of the classes observed were Patrick’s ninth grade physical science class and for the fourth observation Patrick taught a lesson during a tenth grade biology class of a fellow science teacher. Patrick used specific classroom management techniques regularly and his expectations for behavior were clearly defined. In the pre-observational questionnaire, Patrick identified his teaching style as “focus(ing) on science content in the lesson while using labs to illustrate science principles or phenomena to students” (Pre-observational questionnaire, 10.11.11). This description is an accurate representation of the lesson progressions observed. Patrick challenged his students with self-guided inquiry and provided an environment conducive to learning and the scientific process.

Classroom expectations and behaviors. Patrick began his classes with a ten-minute “catalyst”, which was either a prompt to facilitate student thought or a question that required students to access prior knowledge from a previous lesson. The catalyst provided the initiation into the lesson planned for the day and would begin the first of many discussions. If students were reluctant to offer their opinion or an answer, Patrick pulled out a can that had sticks with the names of each student. When a student’s name was chosen they would participate and then have the opportunity to draw the next person’s name. Using the can to draw names was an effective means of getting a discussion started without students feeling pressured to answer and it gave Patrick a chance to hear from a variety of students. During each of the lessons I observed, students had an opportunity to work in groups. If the students were all working on their individual projects and Patrick needed to get their attention, he would say, “Eyes up here,” then
count down from five. Without having to speak loudly, this was enough to gain their attention. Students who noticed would regulate their classmates getting them to pay attention to Patrick.

After the catalyst discussion, Patrick introduced the topic for the lesson and provided students with an explanation of how it fit into the curriculum. During a target lesson, Patrick explained to students that often during class he provided information and they conducted a lesson or lab based on that information, but that it was important to “. . . step back from the science to observe the bigger picture” (Observation, 10.11.11). Once Patrick introduced the information necessary to proceed with the classroom activity, he often facilitated a discussion with the students to make certain they understood the topic and were ready to continue. Students read the activity directions and asked questions. Patrick engaged students throughout his lessons, from the introduction of the topic to the conclusion of the activity.

During each of the observations, as students began the activities Patrick encouraged them to work together to complete the assignment. He monitored student progress by meeting with each group and answering students’ questions. When working with the students, Patrick asked them to explain their answers or reasoning for proceeding in a certain way. For example, during a lesson on Lewis dot diagrams and ions, Patrick and a student were discussing the student’s answers and the student asked if his answers were correct. Patrick asked him to explain how he figured out the diagram. When the student had difficulty answering, Patrick responded, “You were correct but I want you to know why” (Observation, 10.28.11). Patrick expected his students to be able to explain their work and be confident in their answers. The National Research Council (1996)
identified critical thinking about the relationship between evidence and explanations as imperative to inquiry instruction. Patrick challenged his students to use reasoning and rationalization to further their understanding of scientific inquiry.

**Inquiry instruction in the classroom.** To determine the use of inquiry-based instructional techniques in Patrick’s classroom, the most frequently occurring qualitative codes were compared to the ISIOP verbal codes. During the TSI target lessons and the non-TSI lessons, Patrick’s instructional style focused on gauging and expanding students’ thinking with questions while also prompting student learning through discussion. According to the ISIOP verbal coding, Patrick was consistent in his method of instruction and interactions with his students regardless of the lesson being implemented.

Patrick frequently asked students questions to gauge or expand their thinking, and engaged students in discussions by asking questions that solicited participation. Patrick often asked questions that required students to recall facts, theories, procedures, or provide short specific answers, and sometimes he would ask questions to check on students’ progress (Minner et al., 2010). For example, to initiate a TSI target lesson, Patrick asked students to share their definitions of a scientist. As students shared their thoughts, Patrick led the class in a discussion about characteristics of a scientist.

*He asked students to identify the parts of the image that identified that character as a scientist. Students picked up on the obvious descriptions (test tube of chemicals, rubber gloves, white hair, goggles). Patrick then explained how he likes to look for the characteristics that we might overlook . . . He concluded this discussion with the idea that we need to expand our definition of a scientist and that there are many types of*
scientists (Observation, 10.11.11).

Asking students for their thoughts and opinions resulted in a discussion that facilitated learning and transition into the next lesson event.

Patrick facilitated enriching discussions and also encouraged students to explain their reasoning. During Patrick’s lessons, he prompted student learning by demonstrating how he would approach a problem, he also suggested different things to consider related to a task. Patrick used comments that Minner et al. (2010) categorized as prompting statements. For example, Patrick asked his students to design a lab to determine density using three liquids: water, maple syrup, and vegetable oil. The day of the observation, Patrick instructed students to work in their groups and design one experiment to test during the class period. As students worked on their procedure, Patrick checked in with each group and the students often asked for an answer or for Patrick to verify their steps. Through a series of leading questions, Patrick got the students to come to their own conclusions. It was difficult for some of the groups to create a complete experimental design, and they got frustrated. Patrick worked with these groups and encouraged them to refine their procedure. Eventually, each group conducted their own experiment to test density and they were able to begin to write lab reports. As shown by the previous example, Patrick facilitated an inquiry-based classroom that was aligned with the standards set forth by the National Research Council (1996); his students were able to identify a researchable question, design and conduct experiments, and think critically about the relationship between evidence and explanations.

Once his students completed the catalyst, Patrick reviewed the itinerary for the day and began a discussion about the lesson topic. During the lesson, Patrick took time to
review previously covered material and make connections to what was being discussed. Toward the end of a lesson, Patrick reviewed the definitions the students had created. As each group shared their definition, Patrick shared his own single sentence definition while highlighting key words and providing an example of appropriate usage. This extensive review helped the students fully understand the context of the scientific words. Using the language of ISIOP, Patrick guided his students through the lesson progression using signposts to situate their learning in context, direct their actions and foreshadow upcoming events.

**Identification of instructional practices.** Patrick was a novice teacher when he first enrolled in the TSI Aquatic Science professional development series. *I really did not know what inquiry teaching meant prior to the workshops, I had just heard the term thrown around a few times and knew it was something important that I should be doing* (Post-observation survey, 1.20.12).

He demonstrated motivation as an individual and as a teacher to learn about inquiry education. Observing Patrick after the third module of the professional development series was beneficial because he had begun to develop his own beliefs about inquiry education and the nature of scientific investigations.

When completing the post-observation science content data, I recorded having witnessed scientific inquiry-based learning in each of his classes. However, Patrick identified minimal use of inquiry during one of the observed TSI target lessons and indicated more use of scientific inquiry during the other TSI lesson and the two non-TSI lessons. During the first TSI target lesson and the two subsequent non-TSI lessons,
Patrick and I identified four categories of the nature of scientific inquiry that the student investigations addressed. However, for the second TSI target lesson, Patrick identified only two categories of the nature of scientific inquiry, whereas I identified three categories. Patrick used questions to direct the investigation during three of the observations, but not during the second TSI target lesson. Patrick consistently helped students understand that scientific explanations have specific characteristics. He showed his students that skepticism leads to scientific advances and new methods can be developed through scientific investigations. Patrick shared that

*The templates and lesson plans that we used are confusing and impractical; I feel like the experience and insight I’ve gained in teaching through inquiry was through non-target activities that I got really hooked on and experimented with in my class* (Post-observation survey, 1.20.12).

The science content data and the pre-observation questionnaire support this statement. Patrick identified two or three phases of inquiry used during the non-TSI lessons versus one phase of inquiry during the TSI target lessons. These data are interesting since the TSI target lessons are designed to promote and facilitate inquiry education in the classroom. The differences between what was recorded and what was observed may be related to Patrick’s beliefs regarding inquiry practices and the principles of inquiry.

Patrick experienced positive results with his students when he implemented inquiry-based learning in his classroom.

*I plan on trying a lot more student-generated labs, and I think would ideally end up with a course that was full of student-generated labs*
Patrick provided his students with a classroom environment conducive to scientific discussions, investigation experiences, and a supportive learning community.

Allison’s Classroom

Allison is a seventh grade life science and eighth grade earth and space science educator at a suburban public school on Oahu. Allison has five years of experience teaching science education. I conducted two classroom observations in her general education life science classes and then two observations in her grade seven honors life science classes. Allison had twenty-five students in her general education life science class; ten were classified as special education (SPED) and two students were labeled as English Language Learners (ELL). Allison managed the behaviors and learning progression of her students with the occasional help of a classroom aide. Allison identified her instructional style as “using scientific investigations to introduce and teach content and process skills simultaneously” (Pre-observation questionnaire, 11.21.11).

Investigation expectations and behavior. As students entered Allison’s classroom, she reminded them to get their lab notebooks from the closet and take a seat. Allison had the agenda and any logistical information written on the board in the front of the room. If homework was due, Allison took the time to review and check students’ work. Depending on the assignment, Allison introduced the assignments and reviewed the tasks to be completed for that class period. She used the general learning outcomes (GLOs) to guide student learning, and asked the students to identify which GLOs they would address during that lesson. This routine helped students be aware of Allison’s
behavioral expectations upon entering the classroom and resulted in a quick start to the class. Allison maintained the same classroom expectations for all of her students.

Allison’s classroom had three different learning areas; classroom seats with desktops facing the board, a carpeted reading area, and a modified lab space with table space and sinks. She was able to use the classroom space to manage student behavior and activities. She could divide the class into groups with each group working in a different space, or she could begin the lesson at the desks and then have students move to the lab space to conduct the investigation. For example, Allison divided her general education life science class into two groups during a non-TSI lesson. She had a classroom aide supervise half of the class as they worked independently at their desks while Allison reviewed homework and helped students create posters illustrating the functions of a cell. She would frequently check-in with the aide to monitor student progress, while moving among her students, listening to their ideas and helping clarify their thoughts or questions. Allison created a dynamic classroom environment where students felt comfortable; they were able to move about the workspace to retrieve lab equipment and they worked well independently or in groups.

Allison emphasized safety and patience during the laboratory investigations. For example, during an introduction to a lesson on microscope use, she explained to students the importance of safety when handling microscopes.

*She* instructed students to identify the location of the cord before they begin to manipulate the microscope. She told students they must be aware of water sources close to the microscopes and that they need to not pull the microscopes close to the edge of the table... She
emphasized the need to be patient when focusing the lens and they need to be safe and careful with the microscope (Observation 10.24.11).

During labs, Allison implemented safety standards; she would ask that student’s hair be pulled back, their lanyards be tucked into their shirts, and that they be aware of their lab supplies. Allison repeated instructions to ensure that the students understood the direction and that they were paying attention. Her instructions were often clear and concise statements that prevented confusion when beginning a new activity. In this way, Allison developed a classroom of scientists through managing behavioral skills and providing a safe environment for investigation.

Inquiry instruction in the classroom. Allison’s use of inquiry instruction was determined using the qualitative codes obtained from the post-observation narrative and the ISIOP verbal coding categories. According to the qualitative coding, Allison provided signposts for her students most frequently through instruction and review, while gauging their learning through questioning. Allison emphasized the progression of the lesson and provided learning prompts during both TSI target lessons and non-TSI lessons. She was consistent in her instructional style.

Allison most frequently provided students with instruction to guide their learning. She provided directions to students for how to complete a task, situated the lesson in a broader context, gave a list of activities for the lesson, and later reiterated this itinerary for students. For example, during a TSI-target lesson, Allison began the lesson by introducing the “big picture,” learning about fish form and function. The lesson activity consisted of three parts. First, it was important for Allison to situate the context of each activity in the broader learning objective. As the lesson progressed, Allison reviewed
what was to be accomplished during the activity and what products students were expected to create. Working with younger students required more frequent reminders and providing signposts during a learning progression helped students keep track of the lesson.

Allison gauged student understanding of a topic by asking questions that required students to recall facts, terms, and definitions. During the TSI target lesson, she asked students to draw and label the parts of a fish. Once students completed this task, Allison directed them to the smart board that had an image of a fish form to complete. Instead of telling the students what parts were missing, Allison asked students to identify the parts, where they went, and what a fish might use them for. She was able to determine their prior knowledge and then add to their understanding of fish anatomy. When reviewing homework, Allison would often ask students to share their answer. For example, during one homework review she asked each student to share and when one student had difficulty answering, she went over to the student’s table and found that the student had incomplete notes. Allison worked closely with her students and used questions to gauge student learning.

Allison prompted student thinking by providing information to guide them. For example, during a non-TSI target lesson about microscopes, she demonstrated how to properly use a stereoscope. She explained each part of the microscope, how to use it, its function, and how to get the best results. As she began her explanation, students asked questions about the lights of the microscope. These questions led into a conversation about the relationship between the lights, magnification, and the stage of the microscope.
By providing students with information, Allison was able to foster a productive discussion that gave students a better understanding of the scientific instrument.

Allison communicated with her students frequently, providing feedback to their questions, acknowledging their participation, correcting misconceptions, and encouraging participation while discouraging undesirable behavior. According to Minner et al. (2010), Allison provided comments that were categorized as feedback. Allison closely monitored student progress while rotating between each group of students. For example, during an assignment, one of Allison’s students became frustrated and had difficulty. Allison tried to help him clarify his ideas, however, he was being negative and responding in an unpleasant manner. Allison made it clear that his behavior was not appropriate and she was trying to help him with his assignment. After helping him, Allison continued to monitor the rest of the class, later returning to the same student. She checked his progress and again explained to him that they could work together to overcome his frustration. Allison helped her students by listening to their ideas and providing feedback to guide their learning progression.

**Identification of instructional practices.** Allison identified her use of inquiry instruction in each of the observed lessons. On each of the pre-observation templates, she identified the following phases of inquiry: instruction, initiation, investigation, and interpretation. In the science content data, Allison and I both recorded inquiry instruction as a fixture in her lessons. For each of the observations, Allison helped students understand that scientific investigations produced new ideas or new methods. During a non-TSI target lesson, she used mathematics and technological tools to help students
enhance their data collection and showed students that different scientific domains require different methods.

Allison implemented inquiry instruction in her classroom by engaging students in scientifically oriented questions (NRC, 2000; Wee et al. 2007). She provided support for her students by creating an environment where they could communicate effectively. She was able to manage student behavior and retain attention by establishing routines, clearly defining her expectations for behavior, and providing concise instructions. Allison prepared her students to conduct scientific experiments and investigate scientific phenomena.

Cross Case Analysis

The participants in this case study each had different experiences in science education and inquiry-based instruction. However, despite these differences, each of the teachers effectively implemented scientific inquiry in their classrooms. All three of the case study participants provided signposts for their students and prompted student learning using comments to further student thinking. Each of the participants provided students with explicit instructions and detailed expectations. They also gauged students’ previous knowledge and made connections between previously covered material and what was being discussed. In this way, the teachers managed classroom behaviors and prepared students for scientific investigations. They also helped to guide student learning using comments that prompted further inquiry. They helped students by providing additional contextual information or used minimal cues to help students answer a specific question. Occasionally, when students asked for an answer, they did not provide an answer directly and instead they encouraged the students to find the answer for
themselves. Each of the case study participants used inquiry techniques when introducing content and when facilitating classroom discussion.

During each of the classroom observations, I witnessed similarities between instructional styles. Allison and Patrick frequently used questions to gauge students’ thinking. Patrick and Andrew used group or classroom discussions to prompt student learning. Allison and Andrew both provided their students with feedback during the scientific investigation. The similarities between each of the case study participants could be associated with the student dynamics in the classroom.

Patrick and Andrew were able to facilitate classroom discussions since their students were older and worked well in groups. Both Patrick and Andrew had their students work in small groups first and then had them share with the entire class. As the individual groups shared their thoughts or results, members of other groups were encouraged to contribute to the discussion. Allison and Andrew often acknowledged what a student said for the whole class to hear and sometimes rephrased a student response so it was more articulate.

Allison provided students with feedback during their individual work while Andrew mostly addressed student comments during classroom discussions. In the beginning of their classes, Allison and Patrick used questions to gauge student understanding of the new subject matter. In a seventh or ninth grade science class, students are often introduced to brand new content that they have never learned about. Allison and Patrick asked students to share facts or information about the new topic before providing a comprehensive review. Allison, Patrick, and Andrew used inquiry education in their classrooms using a variety of instructional techniques.
Differences between the participants’ instructional style were more difficult to identify using the qualitative coding. Since the actions, comments, and questions of the case study participants were all coded using the same categories, it was important to look at differences in frequency. Each of the participants used certain methods of instruction more frequently than others. Allison and Andrew most frequently used signposts to guide a lesson, while Patrick used questions to gauge and expand student learning.
Chapter 5. Discussion

Based on the three case studies, there is support for both assertions that (a) the teacher participants used project supplied inquiry education techniques in their science classrooms, and (b) teachers were able to identify the phases of inquiry used and their teaching behaviors reflected inquiry techniques outside of project instruction. Each of the case study participants was able to identify the phases of inquiry used during their instruction.

The pre-observational questionnaire, the nature of science content comparison data, and the post-observation survey responses provided evidence of inquiry instruction in the classroom for each teacher participant. Qualitative data in the post-observation reflective narrative and the ISIOP verbal code categories contributed to a comprehensive case study for each participant. Each teacher used signposts to guide student learning and prompted comments to further student thinking. Andrew, Patrick, and Allison facilitated classroom discussions that broadened student understandings of the topic. Although each of the teachers used instructional techniques that were appropriate for the grade, age, and ability of their students, all three of the participants used inquiry-based learning in their classrooms. Inquiry education promotes a scientifically literate population where students are able to understand the characteristics of science and develop the ability to apply that knowledge and understanding to everyday situations (Bozdin & Beerer, 2003; NRC, 1996).

The participants in this case study had different experiences teaching science; Andrew was an experienced educator who had used inquiry extensively in his classroom for years. Patrick had a few years of science education experience but was learning about
inquiry and was experimenting with inquiry instruction. Allison had taught for five years
and she implemented inquiry at a level appropriate for her students. Although Andrew
had years of teaching experience and practice using inquiry techniques, his participation
in the TSI Aquatic Science professional development series helped him to reflect on the
process of student learning instead of solely on the content. Andrew’s instructional
techniques reflected some of the essential features of classroom inquiry as outlined by the
National Research Council (2000); “learners formulate explanations from evidence” and
“learners communicate and justify their proposed explanations” (Wee et al. 2007, p. 75).

Patrick entered into the program not understanding the extent of inquiry education
but through this process he began to develop his own definition of inquiry and refined his
inquiry instruction. In his classroom, Patrick witnessed the positive results of inquiry
instruction and he started to implement student-directed investigations.

During the classroom observations, Allison used inquiry-based learning to further
her students’ understandings of science. Due to the age and ability of her students, she
used instructional techniques that were often teacher-directed. Through effective
classroom management and curriculum design, Allison created a classroom environment
that nurtured learning and scientific investigation. In sum, these teachers did implement
inquiry-based lessons in their classrooms; however, each teacher participant had his or
her own interpretation of inquiry instruction.

**Inquiry Case Studies**

Researchers have used case study formats to investigate the impact of
professional development programs on teacher beliefs, behaviors, and practices (Adams
& Krockover, 1999; Brown & Melear, 2006; Luft, 2001; Crawford, 2007). Findings from this case study differ from those larger studies in scope and focus, as discussed below.

Luft (2001) investigated how an Inquiry-Based Demonstration Classroom (IBDC) in-service program influenced inquiry instruction of secondary science teachers. However, Luft also studied how the changes in the teachers’ practices affected student performance. In this study, I focused on the teachers’ ability to identify their use of inquiry instead of examining the influence of inquiry on the student population. Adams and Krockover (1999) conducted a case study using an observational rubric similar to the ISIOP, the Secondary Science Teaching Analysis Matrix (STAM), a tool that investigated the relationship between teacher beliefs and practices. Brown and Melear (2006) also used the STAM; they investigated the link between teacher preparation courses, secondary science teachers’ beliefs about scientific inquiry, and their use of teaching inquiry. These two studies examined the relationship between beliefs regarding inquiry and the practical use of inquiry in the classroom. This study investigated the teachers’ ability to identify their use of inquiry and if they were able to use inquiry regularly in their classroom. I was able to learn about their beliefs about inquiry through using interview questions and pre-observational questionnaires.

Despite differences in design, the findings from this study are similar to the studies reviewed. Luft (2010) determined that the professional development program positively impacted the participants’ instructional behaviors and provided opportunity for educators to use inquiry techniques. Adams and Krockover (1999) concluded that longitudinal research is important when investigating the effect of science teacher education programs. Brown and Melear (2006) found that although inquiry-based science
courses are necessary, these courses may not be sufficient in changing beliefs or behaviors of secondary science teachers. The participants in the current study expressed in the post-observation narratives that the workshops “... impacted teaching design...” (Patrick) and influenced instructional approaches. Based on these results, I believe that the TSI Aquatic Science professional development program has an effect on the beliefs and behaviors of science teachers. I found that the participants in this study had a positive experience using inquiry in the classroom and plan to continue using scientific inquiry investigations.

**Improvements**

The case study participants were expected to implement inquiry education in their classrooms as a part of the TSI Aquatic Science professional development series. I found that each of them used the project-supplied inquiry education techniques while teaching. However, implementation of the TSI curricula could have been improved if the requirements for completion were consistent. Patrick commented in the post-observation interview that the forms required for the TSI Aquatic Science project were impractical. Allison and Andrew made similar comments. The documents that the participants first received from the TSI Aquatic Science project were complex. The participants in the Oahu cohort were the first to receive the TSI phase diagram (see Appendix A) and other documents meant to be used following the TSI target lessons. These forms and documents have since been changed; the TSI development team has subsequently tried to streamline the requirements for participants. The TSI Aquatic Science program was developed with the intent to seek input from participants in order to improve the program
and revise the curricula. This study will contribute information about how the TSI lessons are implemented and received by our teacher participants.

I was able to develop three case studies that described the inquiry practices of the teacher participants. The ISIOP observational protocol was useful to categorize the comments and questions that occurred during observed lessons; however, there were data collected that was not useful in answering the research questions. Interpretation of the qualitative data could have been more discriminate between cases. The data collected did not allow me to differentiate among the participants’ styles of inquiry instruction. Each of the case study participants used inquiry; they used it to different degrees and adapted instructional techniques that were appropriate for their classrooms. It is difficult to compare the teachers directly since there are differences among their school settings, subject matter, and experiences.

**Limitations**

Collection of data was limited by the scheduling of the TSI Aquatic project and Department of Education approval. Classroom observations could not begin until the teachers participated in the module three workshop. During the workshop, teachers received supplies and lesson plans for the TSI target lessons. Classroom observations had to wait until the workshop was complete and the Department of Education granted approval. The case-study participants and I worked together to determine the time and date of each observation. Due to these time restrictions, I had to conduct all of the observations during the fall semester. If I had been able to observe classes during the fall and spring semesters, the teachers may have had more time to refine the TSI target lessons.
Future Research

The TSI Aquatic Science professional development project is about to begin a new cohort consisting of Oahu and Kauai teachers. It would be interesting to conduct a longitudinal study to follow the instructional behaviors and practices of teachers beginning the new TSI workshop series. The final cohort of the TSI program would be receiving curriculum that has been edited multiple times and is more ready for publication, a workshop series that has a finalized agenda and goal, and requirements that are easier to complete. This final group of participants will experience a program that has been revised and modified, and data collected may be more accurate about the effects of the program on their instruction.

Conclusion

There is evidence to suggest that the TSI Aquatic Science professional development program provided experiences that helped teachers develop their understandings of the non-linear process of inquiry learning. This study was conducted during a yearlong professional development series. More research needs to be conducted about the effects of an extended intervention. Longitudinal studies would provide greater insight into how each teacher participant modifies their instructional behaviors once the requirements of the professional development series are no longer necessary.
Appendix A

Figure 1. Teaching Science as Inquiry phase diagram (Seraphin, K., Philippoff, J., Kaupp, L., & Laurie, M., 2012)
Appendix B

Post-Observation Survey Questions

1. What was your initial concept of teaching "science as inquiry" prior to the TSI workshop? How do you feel about inquiry education now, after three modules?

2. As a part of the project you have to implement 'target' lessons. What difficulties/benefits have you encountered implementing these lessons?

3. Has your experience teaching inquiry specific lessons modified your instructional practice or lesson design? What TSI teaching or learning strategies have you begun to use?
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