Learning to Teach Science Through Inquiry: Experiences of Preservice Teachers

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Abstract

This investigation explored the experiences of a cohort of preservice science teachers learning to teach science in their student teaching placements. Specifically, this investigation explored using inquiry instruction from the perspective of the preservice teacher. Participants included seven preservice biology teachers enrolled in a one-year Master of Arts in Teaching program. One part of this program was to learn different ways to teach science, with one aspect focusing on inquiry instruction. Data sources included three open-ended surveys and two semi-structured interviews. A constant comparative approach was used for data analysis to understand the experiences of the preservice teachers during their student teaching placements. Results indicate that at the start of their student teaching placements, participants held favorable views of inquiry instruction and anticipated its use in the classrooms. However, opportunities to observe these methods in their mentor teacher's classrooms were limited. This investigation reveals that while reform documents, as well as the majority of science educators, emphasize inquiry instruction, preservice teachers do not have the opportunities to practice this type of instruction during their student teaching placements. The successes and limitations of inquiry that did occur during their student teaching placements, as well as reasons preventing the use of inquiry, are explored.

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Introduction

Current national science standards call for an inquiry-oriented approach to teaching that allows students to experience science as an "active process" that closely mirrors the actual work of scientists (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996, 2000, 2012). While inquiry instruction has been emphasized by the national standards since 1993, there has been little indication that these methods are widely used. On one hand, this does not come as a surprise as the culture of teaching, and the process of

learning to teach, favors "continuity rather than of change" (Lortie, 1975, p. 29). While the culture of teaching as a whole is resistant to change, there is a push for teacher preparation programs to place an emphasis on giving preservice teachers the tools to "become critical about the status quo" (Kang, 2008, p. 495).

There are a variety of definitions of inquiry instruction. The *National Science Education Standards* (NRC, 1996) define inquiry as

> …a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (p. 23).

The NRC (2000) identifies five essential features of inquiry instruction; learners: (1) are engaged by scientifically oriented questions, (2) give priority to evidence, (3) formulate explanations from evidence, (4) evaluate their explanations in light of alternative explanations, and (5) communicate and justify their explanations. While aspects of both the definition and the five features were included in this investigation, for this paper, inquiry instruction is used to indicate a student-centered teaching strategy that focuses on scientific questioning, observations, and data analysis rather than instruction dominated by a teacher-centered, didactic approach.

The required science teaching methods course in the teacher preparation program of this study placed an emphasis on inquiry instruction as an important method of teaching and learning science. In addition to learning how to effectively use inquiry instruction through the methods courses, preservice teachers enrolled in the teacher preparation program received supplemental training through two student teaching placements. During this time, the preservice teachers were encouraged to practice the variety of science teaching strategies previously learned in their methods course, including: inquiry instruction, demonstrations, modeling, and lecture.

Although the preservice teachers learned about inquiry instruction and were given the opportunity to practice it in an authentic school setting, the opportunity was met with challenges. The preservice teachers were themselves unlikely to have been taught with this strategy. This new knowledge of *how* to teach science directly conflicted with the "apprenticeship" they experienced as students in a secondary school setting. Therefore, they have had very little direct experience with execution of inquiry instruction outside of the methods course. In addition, it is quite possible that the mentor teacher with whom the preservice teacher was paired may have used more traditional teacher-centered approaches over student-centered ones. A recent investigation suggests this may be a common occurrence. Lotter (2004) found that in a group of thirteen preservice science teachers, most "disagreed with their cooperating teacher's instructional methods" and wished to "see more inquiry-based instruction" (p. 35).

There have been studies that looked at the effect of preservice teachers' learning histories on their teaching practices (Eick & Reed, 2002; Smith et al., 2007), but little has been written on the experiences of preservice teachers learning to incorporate inquiry instruction into their own teaching. Therefore, the purpose of this investigation was to examine the experience of a cohort

of preservice teachers learning to use inquiry instruction with varied learning histories under the direction of mentor teachers with their own varied epistemological beliefs and pedagogical methods. Specifically, the following questions guided this investigation:

1. How do preservice teachers define inquiry instruction?
2. How does inquiry instruction fit into their goals and expectations of student teaching?
3. What opportunities exist for preservice teachers to observe inquiry instruction? What effect does this have on the way they teach?
4. What obstacles in using inquiry instruction are encountered during student teaching?

Literature Review

Although inquiry instruction has been a prominent feature of national science standards for 15 years, questions of who uses it and how to best increase its adoption into K-12 classrooms remains somewhat elusive. There have been multiple studies looking at a wide variety of factors that influence its use in the classroom and factors preventing them from being more widely used (Eick & Reed, 2002; Haney & McArthur, 2002; Lotter, 2004; Smith et al., 2007).

Since the majority of science teachers do not frequently employ inquiry instruction, it is helpful to understand who *does* use them. Several researchers have looked at different characteristics of teachers to find correlations with their teaching methods. Smith et al. (2007) examined the educational background of teachers inclined to use inquiry instruction. Their study looked at a national sampling of eighth-grade science teachers and found teachers holding science degrees "tended to be more likely than their counterparts" to use inquiry instruction in their classrooms (Smith et al., 2007, p. 188). Kang's (2008) case study of 13 preservice science teachers reached similar conclusions with students lacking in content knowledge "relying on the traditional didactic teaching approach(es)" (p.495). Similarly, Eick and Reed (2002) considered how preservice teachers reported how they best learned science as an indicator of whether or not they themselves would use inquiry instruction. They found that preservice teachers that needed to experience science in order to learn science were more likely to use inquire instruction in their own lessons than preservice teachers that learned science best through explanation.

Educational backgrounds alone do not indicate whether a teacher will use inquiry instruction in their classrooms. Several studies have looked at other characteristics that make up teachers' identities (Eick & Reed, 2002; Haney & McArthur, 2002). These include experience conducting science and personal epistemologies. In looking at preservice teachers' ability or willingness to use inquiry instruction, it's important to do so in the context of their views of knowledge and how it is acquired or built. Eick and Reed (2002) found that "student teachers who regularly performed structured inquiry had stronger identities as inquiry-oriented teachers" (p. 411). Part of the formation of an "identity" as a science teacher comes from beliefs about science and the nature of science. Haney and McArthur (2002) examined the core and peripheral constructivist beliefs of four preservice science teachers enrolled in a course aimed at enriching their understanding of constructivist practices, an integral part of inquiry learning. They found that core beliefs, those that were both expressed in interviews and observed in their lessons, were resistant to change (Haney & McArthur, 2002). This indicates that when a preservice teacher's core beliefs are in conflict with inquiry or constructivist practices, "they act as barriers in the

development of constructivist beliefs, almost in spite of the prospective teacher's desire to put the constructivist beliefs into practice" (p. 800). Peripheral beliefs, however, if encouraged, can move towards the core and be put to practice:

> We believe that synergistic belief pairings provide the prospective teacher with a needed support structure. When teachers perceive support, they are more likely to bring outlying peripheral beliefs closet to the core. In other words, with support it is more likely that beliefs will predict action. (p. 800)

Along with the support of cooperating teachers, reflection on their teaching practices also helped move peripheral beliefs to core beliefs (Haney & McArthur, 2002). Similarly, Kang (2008) argues that "reflection on teaching practices form a more sophisticated perspective or initial successful adoption of teaching practices informed by more sophisticated epistemologies than their espoused beliefs may serve as a starting point for them to refine their beliefs" (p. 494).

Some research has looked at the preparedness of preservice teachers to use inquiry instruction (Roth, McGinn, & Bowen, 1998; Windschitl & Thompson, 2006). Roth et al. (1998) found that a group of preservice science teachers, who had taken science methods courses and held science degrees, were not prepared to incorporate inquiry instruction. These teachers were unable to engage with a scientific problem at a level higher than a group of eighth-graders that had been enrolled in a 10-week open inquiry study. This suggests that if teachers are going to effectively use inquiry instruction, they need to have participated in these communities of practice (Roth et al., 1998). Windschitl and Thompson's (2006) results support Roth et al.'s findings. They found preservice teachers' "histories with investigative science shaped their thinking about what a model is and what it means to do inquiry" (Windschitl & Thompson, 2006, p. 812). They examined preservice science teachers' conceptions of inquiry, the role modeling plays within their conception, and if a course focusing on scientific modeling could further their understanding. At the beginning, participants' conceptions of models and the role they played in science were unsophisticated. However, Windschitl and Thompson (2006) found that "instructional focus on models in science […] can advance the thinking of most preservice teachers about the nature and function of models" (p. 819).

Although a teacher may have the background knowledge, attitudes, and skills needed to implement inquiry instruction, it does not mean she or he will do so. Research has found certain factors may act as roadblocks, preventing both novice and experienced teachers from implementing them (Cherian, 2007; Lustick, 2009). Teachers may have an interest in incorporating inquiry instruction, and think this type of instruction is superior to other teaching strategies, but find competing demands within their classrooms. One such demand is the fact that preservice and new teachers struggle with classroom management as well as the goal of surviving (Lustick, 2009). Other demands include time constraints and school or district pressures to stick to established curriculum (Cherian, 2007; Lustick, 2009). Teachers feel the time it takes to *really* incorporate inquiry instruction does not exist in the age of standards based testing. For example, one preservice teacher in Cherian's (2007) study reported they "wanted to explore constructivist activities" but were pressured to stick with a standard curriculum (p. 39). Finally, a lack of knowledge and experience with inquiry instruction could also act as a barrier (Blanchard, Southerland, & Granger, 2009).

Research that has looked at the availability of preservice teachers to observe effective inquiry instruction all indicates these opportunities are limited (Crawford, 2007; Fazio, Melville, & Bartley, 2010; Lotter, 2004). For example, in Lotter's (2004) study of 13 preservice teachers, only "31% observed their cooperating teacher using an inquiry-type lesson" (p. 32). Further, there were no observations of "open or guided inquiry laboratories during their student teaching" (p. 32). Her study is not the only one that has found this. Crawford's (2007) case study of five preservice teachers and their mentors revealed that none of the mentor teachers widely used inquiry instruction in their classrooms and some initially were not very open to their preservice teacher's use of inquiry instruction. These mentor teachers declined to use inquiry instruction despite having taking science teaching methods courses that emphasize inquiry instruction themselves (all but one mentor teacher) and being involved in the creation of the teacher education program that emphasizes inquiry instruction. Finally, Fazio et al. (2010) reported that only 30% of preservice teachers in their investigation observed mentor teachers using inquiry instruction in their classrooms.

While research showing that the opportunities to observe inquiry instruction may be extremely limited, preservice teachers are still expected to be proficient in using them in order to meet national and state standards. Little has been written about the experience of preservice teachers navigating these multiple worlds: the world of expectations they have for themselves as effective science teachers, the world idealized in the science teaching methods course, and the world of reality they observe in their mentor teachers' classrooms. The aim of this investigation is to address this gap in the literature by examining the experience of a cohort of preservice science teachers as they negotiate learning and implementing new teaching methodologies in these multiple worlds from their perspective.

Methods

Participants

The participants of this study were seven members of the science cohort in a one-year Master of Arts in Teaching program. The program is divided into four cohorts: English, social studies, math, and science. Within the science cohort, participants may specialize in biology, chemistry, or physics. All seven participants specialized in biology, were Caucasian, and ranged in age from 22-30 (pseudonyms are used for all participants). Four members of the cohort were female, three male. The second author of this paper was also a member of the biology cohort therefore had the unique perspective of being a participant-researcher. The first author served as the professor for the required science teaching methods course and the chair of each participant's masters committee. Thus, selection of participants was based on convenience (Gall, Gall, & Borg, 2003).

The one-year masters program began with coursework during the summer session. At the start of the fall semester, the first student teaching placement began and coursework continued with evening classes. The participants started out primarily observing their mentor teachers, and slowly ramped up their teaching hours. By the end of the ten weeks, each participant taught a minimum of 130 hours. The following spring semester, participants began a second, nine-week

student teaching placement and continued coursework in the evenings. Each participant had one high school and one middle school student teaching placement.

It is important to note that participants were not "required" to include inquiry instruction in their teaching placements in order to successfully complete the program. Instead, they were encouraged throughout the program to incorporate inquiry instruction when possible. Additionally, because inquiry instruction was presented as a successful strategy in the methods course, the second author felt it was important enough to look at how the participants' experiences aligned with what they learned about inquiry instruction from the first author.

Setting

Each participant completed two student teaching placements, one in the fall semester and one in the spring semester. As indicated earlier, each participant also had one middle school and one high school student teaching placement. Four placements were in an urban setting, five in a suburban setting, and five in a rural setting. The populations at 10 of the placements were predominantly Caucasian students and the populations for the other 4 placements were predominantly African American students. Four of the placements were at Title 1 Schools and the percentage of students eligible for free/reduced lunch ranged from as little as 3% to as high as 83%.

Data Collection

Data collection included three open-ended surveys (created specifically for this investigation) and interviews of each participant. Participants completed the first open-ended survey prior to the start of their fall student teaching placements. Participants were asked to describe their ideal science classroom, the methods they intend to use, how they would like to use inquiry instruction, and their expectations for the student teaching placement (see Appendix A). Participants completed the second open-ended survey at the end of their fall field placements. This survey asked the participants to reflect on what they observed in their teaching placements, focusing on their experiences with inquiry instruction (see Appendix B). Other questions asked how they went about planning lessons, to reflect on their overall student teaching placements, and the role their mentor teacher played in their development as teachers. Participants completed the third open-ended survey at the conclusion of the spring teaching placement. They were asked to describe the methods of their mentor teacher, their experiences with inquiry instruction, to compare the two student teaching placements, and to learn their goals for their first year teaching (see Appendix C).

The purpose of these surveys was to understand the cohort's experience of learning to teach science and the opportunities and challenges they faced incorporating inquiry instruction into their teaching. Semi-structured interviews were also used to clarify and elaborate on the written survey responses (see Appendix D). Each participant completed two interviews, one at the end of the fall teaching placement and one at the end of the spring teaching placement. Finally, as a participant-researcher, the second author kept a journal documenting her student teaching placement with extensive field notes and other written reflections.

Data Analysis

A constant comparative approach was used for data analysis (Creswell, 2013). The responses to the survey questions were read and re-read to develop major themes, prior to the semi-structured interviews. The semi-structured interviews were used to confirm the themes identified and to gain additional insight from the participants. After the interviews, all three surveys, as well as the interview transcriptions were reviewed again to ensure all themes had been fully developed. Findings were then triangulated by the second author's experience and journal entries.

Results

This section begins by presenting the participants' definitions of inquiry instruction prior-to and after the student teaching placement. Then, the participants' goals for their placements are presented. Next, their experiences with their mentor teachers are discussed. Finally, we present obstacles the participants experienced with respect to inquiry instruction.

Preservice Teachers Define Inquiry

Bell, Smetana, and Binns (2005) define inquiry as "a learning process in which students answer research questions through data analysis" (p. 30). At the start of the fall student teaching placement, when asked how they defined inquiry instruction, most responses were consistent with Bell et al.'s (2005) definition. Central to the definitions provided were students conducting experiments to investigate either their own questions or questions posed by their teachers. Bell et al. (2005) also characterized levels of inquiry based on the amount of information that is provided to students (see Table 1). To categorize the participants' definitions using these levels of inquiry, three of the responses focused on students working to answer their own questions, or level four inquiry. For example, Lisa defined inquiry as "letting students create their own path to answer their own questions" (survey response) while Lindsay defined it as "instruction that is guided by student questioning" (survey response). Two participants provided a level three definition where students are "collecting data to answer a guided question" (Chris, survey response). In this definition of inquiry, the teacher is setting the focus of the inquiry. The remaining two responses included aspects of both level three and level four inquiry in their definitions, recognizing that inquiry can be used to answer either a teacher's guided question or the students own question.

Table 1
Levels of Inquiry from Bell et al. (2005)

Inquiry Level	Description
1	Confirmation – Students confirm a principle through an activity in which the *results* are shown in advance
2	Structured inquiry – Students investigate a teacher-presented question through a *prescribed procedure.*
3	Guided inquiry – Students investigate a teacher-presented question using *student designed/selected procedures*

4	Open inquiry – Students investigate topic-related questions that are student formulated through student designed/selected procedures.

While the inquiry levels within the participants' definitions were closely aligned, variations in other aspects of their definitions were present. Of the seven participants, three explicitly stated student use of evidence or data as an integral part of inquiry. For example, Chris stated inquiry was "students collecting their own data in order to answer a guided question" and Jennifer defined inquiry simply as "students using evidence in discovering topics." While these two definitions varied on the level of inquiry, both identified use of data/evidence as an important component.

Student-constructed meaning was another important component of the responses. For example, Lindsay stated that inquiry instruction is a way of teaching that "forces the students to think on their own instead of being spoon-fed." Similarly, Aaron explained inquiry instruction as a way to "study a natural phenomenon that fosters critical thinking." Although critical thinking was not explicitly stated in the remaining definitions, it was certainly implied. Students "finding their own answers" (Carrie, survey response) or "draw[ing] conclusions" (Adam, survey response) cannot happen unless the student is analyzing evidence to develop possible solutions.

The survey administered after the first student teaching placement and the program-mandated science teaching methods course, again asked the participants to define inquiry. At their core, the definitions remained the same. Analyzing data and promoting critical thinking remained the central aspect. Two additional characteristics emerged, however. In three instances, inquiry as a way to engage in explorative/discovery learning was now included. Two participants also added emulating the work of scientists as a key aspect of their definition of inquiry, whereas prior to the student teaching placement and methods course, this aspect was absent.

Goals for Student Teaching

The second research question focused on the participants' goals for each student teaching placement. The primary purpose was to determine what role, if any, inquiry instruction played for each student teaching placement. Results revealed that while the participants hoped to include inquiry instruction, it was not their only goal.

Goals for the Fall Placement

Before the start of the student teaching placements, members of the science cohort overwhelmingly sought to learn classroom management skills. In response to the survey question "what do you hope to gain from your student teaching placement?" five of the seven participants indicated classroom management as one of their top priorities, if not the only priority. The two participants who did not identify classroom management as their top priority had prior teaching experience (Chris had previously been enrolled in another teaching certification program and was a long-term sub in a middle school science class, while Lisa had taught large confirmation classes at her church for several years). Both identified their priority as learning more about lesson planning and teaching in general.

The theme of classroom management was also central to the survey administered upon completion of the first student teaching placement. When asked what the most important thing

they learned from the experience, most responses fell under the general theme of classroom management. While there were a greater range of responses than in the responses prior to student teaching and responses were more specific, they were all still related to classroom management. For example, Carrie and Jennifer both responded that the organizational techniques they learned from their mentor teachers were extremely important. To the same question, Adam responded that classroom management was "hands down" the most important thing learned in his placement. "How to be cool under pressure, keeping the class under control, and preventative [behavioral] techniques" were three specifics he identified. Similarly, the most important thing Lindsay learned was how keeping students intrigued resulted in a well-managed classroom. Even the two participants with prior teaching experience came away with classroom management related knowledge as among the most important things. Lisa identified the importance of being strict from the beginning as the most important thing learned while Chris identified both instructional techniques and classroom management techniques as the most important things learned. He recognized that "kids love to hear real world examples and experiences" and that teachers should not to take everything in the class personally.

Goals for the Spring Placement

The participants' goals for the second placement were vague and narrow in scope. When asked what they wanted to get out of their next placement, most indicated "something different" (Carrie, interview) or a "new perspective" (Lisa, survey). Classroom management concerns remained a top concern for the participants. At least three alluded to the fact that their first placement had been in a relatively affluent school, with limited behavior problems. They hoped for a more diverse and challenging experience in their second student teaching placement. As Aaron, who during his first placement taught honors biology in a suburban and predominately Caucasian school put it, "I don't expect to be in an ivory tower when I get out and I need to know how to deal with that. I know I don't have all the tools to deal with [behavior problems]." Similarly Carrie stated "I had wonderful students at [my school] and behavior was never an issue, I would love a situation where I could hone my behavior management techniques... I really want to be able to say 'I've been in that situation.'"

If this time around the participants were not concerned with behavior problems, they did seem concerned about learning to reach a different age group of learners. In response to the question on what she wanted to gain from her second placement, Lindsay stated "personally, I hope to come to a decision in which age I would prefer to teach…that is still something I am struggling with." Similarly, Aaron stated he wanted to get a "feel for middle school." They all seemed well aware that soon it would be time to apply for jobs and wanted to be able to find the their best fit.

When asked about plans to implement inquiry instruction in the upcoming placement, the participants' enthusiasm had waned. In a follow-up interview with Carrie, when asked whether she intended on using inquiry instruction in her upcoming middle-school placement she responded:

> Um, yeah, I don't know where, you'd have to sit down and look at the curriculum and see where it would fit in best. It would obviously need to be at the end of the year with

> middle school because the beginning of the year, I think they are very immature. So maturity level wise, you'd have to wait a little bit.

To the same question, Aaron responded:

> I would like to, it's a little too early for me to judge. This school has a weird curriculum that I haven't been introduced to before, so I have to figure out how that works and how to incorporate it with it and incorporate my teaching style.

Jennifer, at the time of the interview, had met with her spring mentor teacher and based on that meeting did not anticipate planning an inquiry based lesson because "her whole semester [was] planned out."

After the second student teaching placement, classroom management concerns were not as prevalent in the survey responses. This time, the most important thing learned by the participants related to the emotional work of teaching. For example, Lisa said the most important thing she learned from the second student teaching placement was the importance of remaining "positive" and "not letting other teacher's negativity affect her." While Lisa's response focused on interactions with teachers, Aaron's focused on student interactions. His response to this same question was succinctly stated to "love your kids." Similarly, Lindsay stated that the most important thing she took away from her second student teaching placement was "getting to know your students and to be able to relate to them."

Mentor Teachers

The third research question focused on the participants' observations of their mentor teachers as well as how the mentor teachers impacted participants' decisions to incorporate inquiry instruction into their classroom.

Observations of Mentor Teachers

Overall, participants characterized their mentor teachers' approaches to teaching biology as didactic and routine. In both the fall and spring placements, the mentor teachers taught a mix of middle school life science, high school biology I, AP biology, and biology II (anatomy and physiology). In the life science and biology I classes, it was reported that a typical lesson included lecture with guided notes, sometimes followed by a guided activity/lab or web-quest, and finally wrapped up with a unit test. Adam's mentor teacher's approach was "direct instruction (PowerPoint lecture based with guided notes), with many lab exercises and science related activities mixed in. At the very least, the class did some form of activity or experiment every other day" (Adam, interview). Similarly, Jennifer and Lindsay both described their mentor teachers' approach as a mix of lecture and hands-on activities. The three mentor teachers that taught biology II (anatomy and physiology) had similar, didactic structures for their classes as well. In all three of these cases, the mentor teacher's primarily used PowerPoint with guided notes accompanied by diagrams for students to color and label. Hands-on activities were rare in the biology II classes, but there were several dissections scattered throughout the semester. When asked to describe how their mentor teachers lectured, all participants indicated that they used PowerPoint with guided notes.

Mentor teachers using PowerPoint presentations with guided notes were common for both the middle and high school placements. The only exception was for one mentor teacher, Mrs. Jones. She taught both biology I and biology II (anatomy and physiology), and while she used exclusively PowerPoint for the biology II class, in her biology I class, she never used PowerPoint, seemingly lecturing extemporaneously, or from the whiteboard. Two of the three mentor teachers teaching biology II exclusively used the PowerPoint slides provided by the publisher that accompanied the course textbook. These PowerPoint presentations primarily contained text with a few slides of anatomical diagrams.

This didactic teaching style used by the mentor teachers was also consistent with the participants' own learning histories through middle and high school. When asked to describe how they themselves were taught in science classes, most recalled lectures accompanied by procedural cookie cutter type labs. A few participants remembered teachers who had made science exciting with explosive demonstrations but no one recalled their teachers using inquiry instruction to learning science.

When asked if they observed their mentor teacher using inquiry instruction in their fall placements, of the seven participants, six stated they had. However, their use was on a very limited basis. Five of the six participants that observed inquiry instruction being used indicated it was only occasionally, "maybe once or twice" during the ten-week term. One participant reported her mentor used inquiry instruction on a regular basis. The remaining participant did not observe their mentor teacher using inquiry instruction at all. The second student teaching placement provided the same limited opportunity to observe inquiry instruction being used. Of the seven participants, only two reported observing their mentor using inquiry instruction more than once. Of the remaining five participants, one observed one inquiry lesson and the remaining four did not observe their mentor using inquiry instruction at all.

The participants who observed their mentors using inquiry instruction thought their effectiveness was mixed. Often they found lessons that used inquiry instruction were met by resistance from students. For example, in his fall placement, Aaron observed his students growing frustrated with an activity that required them to order the formation of a zygote without first being given background information. His mentor teacher's response to this frustration was "Don't worry, it's just a little inquiry." Lindsay characterized an osmosis inquiry activity she co-taught with her mentor teacher as unsuccessful because only a few students were able to "get" the concepts of diffusion and osmosis. "A lot of them didn't like answering the questions and trying to think for themselves…they would come and ask you 'what is the answer to this?'" She felt overall, the students didn't get much out of the activity.

On the other hand, some participants reported that they observed successful inquiry instruction. One mentor teacher, who taught an honors biology class and a section of regular biology, only used inquiry instruction in the honors course. She felt the mentor teacher reserved inquiry instruction for the honors students because "they were more motivated and required less instruction" than the traditional biology class (Lisa, interview). In a lab to extract DNA from bananas, students in the honors class were given a list of supplies and asked to figure out the required steps for extracting the DNA and to write up a lab report. The regular biology class was given the step-by-step procedure and asked to answer a series of questions about what they had

done. Lisa felt that the honors class got more out of the exercise because they were not as concerned with answering the questions. Like Lindsay's experience though, many of the students seemed paralyzed by the activity, asking the teacher for "the answer." Although some of the students did not get much out of the lab, others did. Lisa reported that there were several students who were successful in extracting the DNA and had meaningful discussions within their groups to figure out how and why each of the supplies was used.

The participants felt the resistance to these lessons was due in large part because of students' limited exposure to inquiry instruction in the past. Since the students were used to being taught didactically, they had difficulty with designing experiments or solving problems on their own. The classes where inquiry instruction was used, like in Lisa's honors biology class for example, were successful when the "teacher [had] scaffolded them slowly into this type of lab" and when students "were already comfortable with general lab procedures and practices…and skilled at using the equipment in the room." Six of the participants felt that if inquiry instruction was used more often, students overall would have been more receptive to it.

Influence of Mentor Teachers

When asked about the format of the lessons they developed and taught, the participants indicated that they closely followed the format of their mentor teachers. This largely came in the form of PowerPoint slides with guided notes, accompanied by activities. There were two main reasons given for doing this. First, participants felt their mentor teacher's strategies were successful and therefore they would also be successful if they followed that approach. For example, when asked how he went about lesson planning, Adam responded "I think my mentor's style of lessons were effective for her classes, so the ones I designed stayed within that same style, just with some personal touches." In fact, Lisa followed her mentor's approach so closely that her mentor teacher was slightly bothered by it. She recalled:

> But the reason I did was because it was successful for her, [and the] teacher she was mentoring, that was the same format she encouraged them to use. Because they were so successful, [I thought] it must be pretty good.

Second, participants did not want to deviate too much from what their students were accustomed to. Jennifer responded "I had never written a unit plan, and I did not want to deviate from what the students were used to so I used my teacher's plans as a model structure." No specific reasons were provided for not wanting to deviate, but the other participants made similar comments.

In the survey administered prior to the start of student teaching, all participants expected to use inquiry instruction and thought these approaches would "help students reach their full potential" (Carrie, survey response) and "challenge students to figure out things on their own" (Lisa, survey response). When asked in the survey at the end of the first teaching placement if they incorporated inquiry instruction, these types of lessons were for the most part absent. The two exceptions were Aaron and Carrie who developed inquiry-based units as the basis for their action research projects. Along with Aaron and Carrie, Lisa and Rebecca both reported using inquiry instruction in their second student teaching placement.

When asked if they would be more likely to incorporate inquiry instruction if they had observed their mentor teach using these strategies more often, all participants indicated that they would. Adam explained: "a lot of the lesson planning I did was under [my mentor's] aide and under her instruction…. I probably would have used them more because the way I teach is greatly influenced by my mentor."

In the final survey after the second student teaching placement, Lindsay recognized disconnect between what she herself was learning in the science teaching methods class and her experiences in the classroom. She said, "[our science teaching methods] class has stressed science as a way of knowing. While in the classroom, I didn't really see this concept from my mentor teacher. I found biology taught as a way of knowing the body (human physiology and anatomy), but not discovering, questioning, and finding."

Obstacles to Inquiry Instruction

The final research question focused on the obstacles participants encountered when trying to incorporate inquiry instruction into their classroom. Results showed that the use of inquiry instruction in their classrooms remained limited even though many of the mentor teachers seemed supportive it. Several obstacles to using inquiry instruction more widely were identified by the participants. Meeting curriculum requirements was prominent in the responses related to the challenges of using inquiry instruction. Because of state mandated grade level expectations and district mandated curriculums, both mentor teachers and participants felt pressured to speed through material to ensure completing the curriculum prior to the end-of-year test. Lindsay identified her first semester mentor teacher as generally supportive of inquiry instruction, but "was under a lot of stress to get things covered and through it. She was like 'this always worked, let's do this.'" Teaching topics that were on the tests meant sacrificing inquiry instruction for more didactic approaches. Carrie reported that while her second mentor teacher thought inquiry instruction was a very important aspect of science education, she had to treat inquiry activities as an "add-on" (interview). In order to comply with the district wide pacing guide, for each nine-week quarter, her mentor teacher first had to "get through the material" and only used inquiry instruction as time allowed.

A second but related issue identified was the time available for a given lesson. Lisa commented that in order for students to "work through ideas and procedures," large blocks of time are needed. Standard fifty-minute classes, or even ninety-minute classes, limit the types of investigations that can be completed in a given class period. In these relatively short blocks of time, and with looming curriculum requirements, it was felt that it was easier to just tell the students what they needed to know. Aaron ran into similar limitations in his middle school placement the final semester of the program. The time in class, with only 50 minute periods, made it difficult to fit inquiry instruction into a class period.

Some of the participants in the program felt they were in "survival mode," stretched thin between student-teaching, graduate coursework, and their required masters' level research projects to devote as much time as they would have liked to lesson planning. "I really didn't put much thought into planning inquiry lessons" (Adam, survey response). The second nine-week student teaching placement coincided with when the program's research project became due which posed a problem for some. When asked about the factors that hindered or prevented his

use of inquiry instruction, Chris responded "Time. With the pressures of student teaching and requirement for the university I found [I didn't have] excess time to prepare inquiry lessons." The participants' lack of experience with inquiry instruction in their own learning histories made planning effective lessons using inquiry instruction more difficult and time consuming than teacher centered lessons.

Aside from administrative pressures, students' capabilities also limited the use of inquiry. Several participants observed inquiry instruction being met with resistance by students because it required them to do "more of the work" in the learning process than more traditional, teacher-centered approaches. Aaron, whose mentor teacher used inquiry instruction occasionally, commented that inquiry instruction was successful when used "at a lower level, higher level inquiries frustrated the students." Adam justified his teacher's limited use of these methods on the sophistication of his middle school students:

> We only did this…for a handful of labs. However, I think it has more to do with grade level. I really can't picture our 6^{th} or 7^{th} graders performing level 3 or level 4 inquiry projects. I just don't think they grasped the idea of scientific inquiry.

Similarly, Carrie felt her first semester high school students were "closed minded to it, to the idea that you would do an activity before you know what you are really doing." In the second student teaching placement, the experience with her seventh grade students was markedly similar, stating the students "were almost timid with [inquiry lessons]."

Like the participants, the learning histories of students in today's secondary classrooms are largely devoid of inquiry instruction. Lisa's perspective was:

> By high school, the students are so used to being taught, that when you tell them "no, you are doing this on your own," it blows their mind and it takes time to get used to that style of learning. So you spend a lot of time just saying 'no, no, no, it's okay to use your imagination, to be creative,' but [the students] aren't used to it.

This was confirmed in her second student teaching placement with seventh graders. She felt that her inquiry instruction was not successful with this group because they "weren't used to it." Similarly, Aaron thought his inquiry-based unit would have gone more smoothly and students may have learned more if they had experiences with inquiry instruction in the past. "[Inquiry] was not done with them throughout the year" which resulted in "a lot of griping about the amount of work they had to do."

Chris felt his mentor teacher for his first student teaching placement did not utilize inquiry instruction due to the nature of the courses being taught. His mentor teacher taught biology II (anatomy and physiology) and did not incorporate inquiry instruction because "there isn't a lot of discovery [to be done], just facts to remember." Lindsay, who worked with Chris' mentor teacher from his first placement in her second student teaching placement also struggled to pair inquiry instruction with the material being taught, "it was difficult to think of ways to [teach using] inquiry-oriented methods when the lesson's only objective was to memorize parts of the digestive system." When asked what hindered the use of inquiry instruction, Sean's survey

response was nearly identical "I felt I could not think of an effective way to make the material I was teaching into an inquiry based [lesson]."

Discussion and Implications

As argued earlier, little has been written about the experience of preservice teachers navigating multiple worlds: the world of expectations they have for themselves as effective science teachers, the world idealized in the science teaching methods course, and the world of reality they observe in their mentor teachers' classrooms. The aim of this investigation was to address this gap in the literature by examining the experience of a cohort of preservice science teachers as they negotiate learning and implementing new teaching methodologies in these multiple worlds.

The present investigation reveals that even though reform documents, the science education community, and teacher preparation programs emphasize inquiry instruction in science classrooms, the preservice teachers in this investigation found it difficult to incorporate inquiry instruction into their classrooms. As this investigation as well as others show (Luehmann, 2007; Lustick, 2009), there is disconnect between what preservice teachers learn in their teacher preparation programs and what they experience in their student teaching placements.

The limited availability of this group of preservice science teachers to observe their mentor teachers using inquiry instruction is consistent with the literature (Crawford, 2007; Fazio et al., 2010; Lotter, 2004). Observing their mentor teachers' successful instruction with teaching strategies that were largely devoid of inquiry, combined with classroom administrative issues, also translated into the participants creating more teacher-centered lessons. The experience of student teaching under a mentor teacher that primarily used teacher-centered approaches is consistent with the learning histories of the participants, fitting in with Lortie's (1975) analysis of the culture of teaching being resistant to change. Ideally, preservice teachers would be placed in classrooms where inquiry instruction is done effectively. However, as this is an unrealistic expectation, the goal should be to place preservice teachers in supportive environments, identify possible challenges they may face, and provide strategies for dealing with those challenges.

The positive view of inquiry instruction held by all members of this cohort is consistent with previous research (Eick, 2002; Lotter, 2004). While all members of the cohort indicated prior to student teaching that they intended to use inquiry instruction in their careers as teachers, the extremely limited use of inquiry instruction during student teaching indicates otherwise (Lortie, 1975). Although the participants did not use inquiry instruction as they anticipated, all continued to see it as a superior way of learning science content. After relatively little time in the classroom, the difficulties of implementing inquiry instruction in the classroom, even anticipated ones, became roadblocks. Like this cohort, participants in previous studies cited classroom management and curriculum demands as preventing the use of inquiry instruction (Cherian, 2007; Crawford, 2000; Eick, 2002; Fazio et al., 2010; Lotter, Singer, & Godfrey, 2009; Lustick, 2009). Whereas at the beginning of the semester participants recognized it would not necessarily be easy to implement inquiry instruction into the class, all anticipated their use. The hurdles of meeting curriculum requirements and managing student learning remained the main impediments to their use.

It's difficult to predict how inquiry instruction will be used in this group of preservice teachers once they are certified teachers. However, if preservice teachers found it difficult to implement inquiry instruction with the support/assistance of their mentor teachers, it is likely that this task may be even more difficult when faced with the enormity of being a first year teacher. Eick's (2002) examination of two early-career teachers found just that. Although the teachers began the year with the intention of implementing inquiry, they "settled for more teacher-centered strategies as they got a handle on pressing management and discipline issues aggravated by their lack of experience" (Eick, 2002, p. 901). When in first year "survival mode," inquiry instruction may take a back seat to more didactic methods or traditional laboratory investigations that take less time to plan and are what the typical student is used to (Luft, Roehrig, & Patterson, 2003).

At least three of the participants reported not using inquiry instruction in their student teaching because they believed that the topics being taught did not lend themselves to inquiry. While inquiry instruction may not be suitable for every lesson, it is unlikely that during nine or ten weeks, none of the lessons could have been taught using inquiry. The participants had difficulty conceptualizing how certain topics, particularly ones in biology II, could be made into inquiry lessons. Even though dissection labs were in integral part of the biology II classes, the participants felt they lacked any aspect of inquiry. In theory, the biology II classes could have been full of inquiry, as this was the only course considered an elective and did not have any state or district mandated learning objectives. So even though some of the previously identified roadblocks to inquiry, such as curriculum pacing guides and end of course tests (Cherian, 2007; Eick, 2002; Lotter et al., 2009; Lustick, 2009), were totally out of the equation, inquiry instruction still was not used. Based on the survey responses and conversations with the participants as they were going through the program, they revealed that there were certain "standard inquiry" labs, the osmosis egg lab for example, used by several mentor teachers. Outside of these few lessons that incorporated inquiry instruction that everyone seemed to use, inquiry instruction was largely absent. Like their students, the participants' lack of prior experiences with inquiry instruction seemed to restrict their abilities to design inquiry-oriented lessons (Luehmann, 2007; Melville, Fazio, Bartley, & Jones, 2008).

These participants may have benefitted from explicit instruction through the masters program course work on creating lessons that incorporated inquiry instruction for specific biology concepts that traditionally are taught didactically. In addition, professional development or even a science-centered induction program addressing this hurdle could also be beneficial since the mentor teachers did not demonstrate a capacity to conceptualize inquiry instruction for wide range of biology concepts either (Luft et al., 2003).

Clearly the participants *want* to use inquiry instruction, but in light of their student teaching placements, they realize it's easier said than done. Their experiences in the classroom during student teaching confirmed many of the perceived challenges of teaching through inquiry. The confirmation of these challenges seems to indicate implementing higher level inquiry is less likely than anticipated (Cherian, 2007). While the participants' definitions of inquiry prior to student teaching leaned towards a higher level of inquiry, their actual observations of the mentor teachers as well as their own experiences in the classroom saw only lower levels, if at all.

Despite the trepidation, the good news is that the participants have not given up on inquiry as a pedagogical approach and still view it as a valuable and important way to learn and experience science (Fazio et al., 2010; Kang, Bianchini, & Kelly, in press; Lotter et al., 2009). Additionally, while small in number, some participants had positive experiences with inquiry instruction. As Lustick (2009) argued, perhaps with more teaching experience, the demands of meeting the required curriculum and the ability to effectively manage the class will grow easier, leaving time and energy to focus on including inquiry instruction. Like Eick's (2002) two participants, these participants may "[learn] that they have to recuperate from 'burnout' and cautiously implement the practices that they [prefer]" (p. 901).

State mandated curriculum requirements and the pressure of standardized high stake testing are severe limitations to the teaching of science through inquiry. The trend toward standardized testing only seems to be growing. For example, in a local school system, each of the eight units in seventh grade life science has a common, district-wide assessment in addition to the state mandated end-of-course test. If this trend continues, it is likely to only further squeeze out any currently available time for inquiry instruction and result in only opportunities for lower level inquiry, like level 1 confirmation activities (see Figure 1).

Only one of the seven participants indicated their mentor teachers regularly used inquiry instruction, aligning with previous research (Fazio et al., 2010). However, when asked to describe a typical lesson their mentor teachers did, most participants indicated their mentor teachers regularly accompanied didactic instruction with activities and labs. Without a more detailed description of these activities, it's impossible to know what these activities/labs entailed. At the very least, one could assume that some of these activities would be categorized as level 1 inquiry (see Figure 1). Although with level 1 inquiry, "students are provided the question and procedure, and the expected results are known in advance" (Bell et al., 2005, p. 32), it still provides students with opportunities to mimic the work of scientists, practice process skills, collect data, and communicate results.

If these daily, common activities are in fact inquiry, why didn't these preservice teachers recognize them as such? Clues to this conflict may come from the definitions the participants provided for inquiry. As indicated earlier, participants were given a clear definition of inquiry in their science methods course. Most central to their definitions was the presence of critical thinking. It's possible that the participants do not characterize confirmation activities (level 1), or even structured inquiry investigations (level 2), as inquiry, because they do not require the level of critical thinking that higher levels do. Additionally, as others have found (Capps & Crawford, in press; Fazio et al., 2010; Minner, Levy, & Century, 2010), participants in this investigation as well as some of the mentor teachers seemed to not have a clear understanding of what constitutes inquiry instruction. Thus, to help alleviate this confusion, it is imperative that the science education community present a solid and "unified conception of inquiry-based instruction" (Capps & Crawford, in press). Perhaps another answer to this problem would be for science methods courses to promote inquiry instruction *and* how to identify it (Melville et al., 2008). Instructors would have to both model inquiry instruction and make explicit what they are doing and why they are using inquiry instruction.

When asked what they wanted to get out of both their fall and spring teaching placements, pedagogical aspects of teaching were largely absent from the responses. This seems to indicate that inquiry instruction is not at the forefront of their concerns. Getting to experience a class with behavior problems that would allow the participants to practice their classroom management skills were of concern. With the common knowledge that new teachers typically get the most challenging class assignments, having a student teaching placement that really tested their abilities would allow them to enter their careers as teachers more confidently. As the participants transition into their careers as teachers and begin to feel their classrooms are well managed, they can then begin focusing on pedagogy and specifically inquiry instruction.

Limitations and Future Research

One limitation of this study was survey design. The pre and post surveys, created specifically for this investigation, were designed prior to the second author's own classroom experience. They were based on what she expected the student teaching placement to be like, the impact that mentor teachers would have, and her own abstract understanding of inquiry instruction and learning. If the survey had been designed and evaluated by a veteran teacher, the results may be different.

A second limitation of this study is that it is based on a sample of convenience. A third limitation is that the study only considered the perspective of the preservice teachers. A valuable addition to this research project would have been to include the mentor teachers as participants. Understanding the mentor teachers' attitudes regarding the use and limitations of inquiry instruction would have been an asset in situating the preservice teachers' experiences.

Uncovering who actually incorporates inquiry instruction into their classroom on a regular basis as an early-career teacher would be valuable. Given that the participants of this project remain enthusiastic about inquiry instruction, it would be interesting to follow-up with them after their first and second years of teaching. Knowing whether classroom management, curriculum requirements, and student sophistication issues continue to hinder the use of inquiry instruction, or whether early career teachers can find ways to overcome them, would fill a void in the current literature.

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Appendix A
Student Teacher Survey
Survey #1: Prior to Fall Field Placement
Name_____

1. What degrees do you currently hold?
2. Do you have prior experience teaching? If so, please describe your experience including length of time, subject, etc.
3. How would you describe a typical lesson you experienced in your middle of high school biology or other science class? Do you think these strategies were effective? Why or why not?
4. What do you hope to gain from your student teaching placement?
5. What do you hope to learn from your mentor teacher?
6. Please describe an ideal biology classroom. Please consider classroom set-up, lesson structure, and curriculum.
7. How do you define inquiry-oriented teaching?
8. When you have your own class, do you plan on incorporating this type of teaching method? Why or Why not?
9. If you answered yes to number 8, how do you plan on incorporating it?
10. Do you think there will be challenges to implementing inquiry? If so, what might the challenges be?
11. Other comments you would like to share:

Appendix B
Student Teacher Survey
Survey #2: End of Fall Field Placement
Name_____

1. How would you describe you mentor teacher's general approach to teaching biology?
2. What teaching methods does your mentor teacher use in a typical lesson?
3. Did you observe your mentor teacher using inquiry-oriented teaching? If so, please describe a lesson that you think you think used this approach.
   a. In your opinion, was the lesson successful? Why or why not?
   b. What were the challenges?
   c. What were the successes?
   d. How often did your mentor teacher use inquiry methods?
4. How did you go about lesson planning?
5. Were there outside pressures that effected how you shaped your lesson plans? Please explain.
6. What were the successes of planning and executing your lessons? Is there a particular example you can provide to illustrate this?
7. What were your difficulties in planning and executing your lessons?
8. Did you incorporate inquiry-oriented methods into your teaching?
   a. If so, how often did you use this method?
   b. Was it successful?
   c. What do you think contributed to its success?
   d. What were the factors that limited it's success?
9. Were there factors that hindered or prevented you from using inquiry-oriented methods?
10. Have your conceptions about what it means to teach biology been influenced by your mentor teacher? If so, in what ways?
11. Please rate your student teaching placement:

Below Expectations		Met Expectations		Exceeded Expectations
1	2	3	4	5

    Why did you give your student teaching placement this rating?

12. What has been the most important thing you've learned from your mentor teacher?
13. What do you hope to gain from your second field placement?
14. Do you view yourself as a "science teacher"?

Appendix C
Student Teacher Survey
Survey #3: End of Spring Field Placement
Name_____

1. How would you describe you mentor teacher's approach to teaching biology?
2. What teaching methods does your mentor teacher use in a typical lesson?
3. Did you observe your mentor teacher using inquiry-oriented teaching? If so, please describe a lesson that you think you think used this approach.
    a. In your opinion, was the lesson successful? Why or why not?
    b. What were the challenges?
    c. What were the successes?
    d. How often did your mentor teacher use inquiry methods?
4. How did you go about lesson planning?
5. Were there outside pressures that effected how you shaped your lesson plans? Please explain.
6. What were the successes of planning and executing your lessons? Is there a particular example you can provide to illustrate this?
7. What were your difficulties in planning and executing your lessons?
8. Did you incorporate inquiry-oriented methods into your teaching?
    a. If so, please describe an example or two of when you used this approach.
    b. How often did you use inquiry teaching?
    c. Was it successful?
    d. What do you think contributed to its success?
    e. What were the factors that limited its success?
9. Were there factors that hindered or prevented you from using inquiry-oriented methods?
10. Have your conceptions about what it means to teach biology been influenced by your mentor teacher? If so, in what ways?
11. Please rate your student teaching placement:

Below Expectations		Met Expectations		Exceeded Expectations
1	2	3	4	5

Why did you give your student teaching placement this rating?

12. What has been the most important thing you've learned from your mentor teacher?
13. Do you feel ready to begin your career as a teacher? Why or why not?
14. What are your goals for your first year teaching?
15. Do you plan on including inquiry teaching your first year of teacher? If so, how? If not, why not?

Appendix D
Interview Protocol

1. Clarify the student teacher's previous learning history.
2. Clarify response on whether or not mentor teacher used inquiry methods. If they did, have student teacher describe an example lesson.
3. Clarify any other aspects of survey response.
4. What were the most important things you learned in your student teaching placement?
5. Did you observe your mentor teaching use inquiry methods?
6. If you had observed your mentor teacher using inquiry methods more often do you think you would have been more likely to use them in your teaching teaching?
7. Do you think your mentor teacher was supportive of inquiry methods?
8. Did your mentor teacher provide you with feedback? What format? How often? Was it helpful?
9. How do you feel generally starting this placement versus if you think back to that first day last semester? (How to you feel now that you are done with both placements?)
10. If student teacher indicated on the survey that they used inquiry in their lessons:
    Can you describe the inquiry lesson(s) and what level of inquiry you would say it is? Overall, how do you think it went? Do you think it was successful?
11. Do you plan on using inquiry in your next placement/during your first year of teaching?