ANALYZING IMPACTS OF TEACHING PREPARATION FOR GRADUATE STUDENT TEACHERS OF INQUIRY-BASED BIOLOGY LABORATORY COURSES

by

KRISTEN REGINA MILLER

(Under the Direction of J. Steve Oliver)

ABSTRACT

A prominent trend in higher education instruction is that of graduate students teaching undergraduate courses. It is equally as common for these novice teachers to undertake their assignments with limited teaching preparation.

The purpose of this dissertation study was to analyze impacts of a pedagogically specific teaching preparation program for graduate student teachers of inquiry-based biology laboratory courses. Data analysis focused on the graduate student teachers, but impacts on student classroom behaviors were also examined.

Four science graduate students assigned to teach laboratory sections of an undergraduate, non-science majors' biology laboratory course participated in this one-semester study. Data were collected and analyzed primarily using qualitative research methods. Analysis of data indicated that commonalities exist across graduate laboratory assistants' (GLAs) reported benefits to their teaching characteristics from the preparation program (e.g., improved abilities to teach in ways that enable students to build understanding of science as inquiry; improved teaching confidence). Commonalities also exist across the GLAs' reported actions of the preparation that impacted these teaching characteristics (e.g., reflective practice; peer and mentor observations).

Additionally, the research examined how the actual teaching experience appeared to impact development of desired pedagogical attributes of teaching science as inquiry. Three of the four GLAs were able to develop pedagogically appropriate conceptualizations of teaching science as inquiry and successfully enact them, but the fourth was only able to conceptualize inquiry in relation to his work as a scientist and demonstrated less success in implementing his limited ideas of teaching science as inquiry. Student observation data suggest that the development and enactment of inquiry behaviors is unrelated to teachers' enactment of various conceptualizations of teaching science as inquiry.

Interpretation of results suggests that new teachers are capable of enacting reform-based biology teaching, and this form of teaching can be enhanced by providing pedagogically specific teaching preparation. However, the context of the teaching classroom, including the nature of the students and the nature of the goals of the course, can also have a great influence on the actual enactment of teaching regardless.

INDEX WORDS: Inquiry, College, Biology, Graduate Student, Teaching Assistant, Laboratory, Teaching

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# DEDICATION

For Mary

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# CHAPTER 1

# INTRODUCTION

Tanner and Allen (2006) described post-secondary education as “a profession with no formal training” (p.1), acknowledging that many college and university instructors enter their classrooms without experiencing any formal teaching preparation. For example, in the sciences, higher education instructors tend to have strong science content backgrounds but lack pedagogical preparation that comes with specializing in education (Sunal et al., 2001, p. 247). Undergraduate classes (often large lectures) are commonly taught by graduate students, especially at large researches institutions (Marincovich, Prostko, & Stout, 1998). These novice teachers are interchangeably referred to as TAs, (Teaching Assistants), GTAs (Graduate Teaching Assistants), ITAs, (International Teaching Assistants), or if they teach laboratory courses only, GLAs (Graduate Laboratory Assistants). Similar to faculty, TAs rarely have preparation for teaching at any school level, including college (Golde & Dore, 2001).

In a survey report of the experiences of doctoral students across disciplines, it was reported that graduate students in the sciences tend to hold teaching assistantships more frequently than in other disciplines (Golde & Dore, 2001). The majority of the surveyed graduate students expressed a desire to teach (Golde & Dore, 2001) at the college/university level, yet as Tanner and Allen (2006) aptly stated: “…experiencing teaching as a graduate teaching assistant is not in and of itself equivalent to the integration of pedagogical development into graduate study” (p. 5). In the absence of formal preparation, TAs often teach without basis for their development as teachers except the live-and-learn experiences in the classroom

(Shannon, Twale, & Moore, 1998). In this light, higher education institutions are entrusting valuable undergraduate learning experiences to teachers who are often only a few years older than their students and have never stepped foot in a classroom as an instructor.

Several documents including the *National Science Education Standards* (*NSES*) (NRC, 1996) and Project 2061 (AAAS, 1990) are widely utilized as the frameworks for current science education reform, grades K-16. Among numerous common goals, these documents emphasize the need for a more scientifically literate population with a greater conceptual and practical understanding of the nature of science. Using more "inquiry"-based science experiences in the classroom is one method described in these documents to achieve the goals. The *NSES* (NRC, 1996) define inquiry as:

> …the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world…Students will engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world, but they also should develop the capacity to conduct complete inquiries. (p. 23)

The *NSES* state that in order for teachers to adequately instruct using a greater emphasis of science-as-inquiry experiences, they need preparation in science content, "…evidence for the content they teach [and] the "process" of science: what scientific inquiry is and how to do it" (p. 92). *NSES* guidelines for how to teach college science courses in conjunction with current science education reform is not a well-studied topic (Tanner & Allen, 2006). In fact, while extensive professional development materials and experiences exist for K-12 teachers, few exist for instructors of college students. This may be due to a pervading attitude at the college-level that inquiry is simply too difficult to implement. A recent survey of full time science course faculty examined these instructors' views of classroom inquiry and revealed that they viewed teaching as inquiry as a "free for all" experience that is "time consuming, unstructured, and student directed" (Brown, Abell, Demir, & Schmidt, 2005, p. 786), more appropriate for science majors rather than non-science majors, and difficult to implement due to "…limitations of time, class size, student motivation, and student ability" (p. 786).

While the needs of graduate student instructors differ from those of K-12 teachers for a myriad reasons (e.g., population and number of students, intention of teaching assignment, knowledge about a career in teaching, experience teaching), a case can be made that college level instructors experience many of the same struggles as K-12 teachers when attempting to teach science education in view of the call for reform. Therefore, it is important to consider K-12 teacher education research in combination with higher education research that supports this common need for teaching preparation in how to engage in classroom inquiry.

*Obstacles to science education reform*

Teacher education researchers have identified a multitude of factors can affect teachers' willingness and ability to implement teaching reform in any discipline. Some of these reasons include teacher belief systems  (Tobin, Tippins, & Gallard, 1994), lack of support and mentoring (Huling-Austin, 1992; Luft & Patterson, 2002), change to an unfamiliar school setting, teaching responsibilities outside of the field, and lack of opportunities to reflect on their experiences (Luft & Patterson, 2002). Despite the fact that studies conducted over 20 years ago noted that science and mathematics teachers often get lumped together into one group, they can face starkly different experiences in both content and pedagogy (Sanford, 1988). Only recently was a distinction made between types of challenges that teachers in different disciplines must overcome (Luft & Patterson, 2002). Keys and Bryan (2001) acknowledged that research on "…the role and knowledge of teachers in the reform process has been minimal" (p. 641), perhaps due to the lack of attention that has been paid to this important component of the science reform movement.

One means to contend with discipline-specific reform obstacles are to provide better support systems for preservice teachers, namely in the form of well-planned and subject-specific induction programs (Luft & Patterson, 2002). For science teachers, attempting to teach using inquiry-based activities teachers' or to understand scientific inquiry was a way of knowing and learning may not be easy or intuitive. In addition to the obstacles just mentioned, Crawford (2000) asserts that effective inquiry teaching requires a rich pedagogical content knowledge, including the nature of science and command of difficult teaching skills such as "how to coach, mentor, and collaborate with students" (p. 637). Therefore, induction programs that specifically support future science teachers through inquiry-based science reform efforts are critical (Salish I Research Project, 1997 as cited in Luft & Patterson, 2002):

> Beginning science teachers need support as they struggle with the mechanics of implementing student-centered inquiry activities in teacher centered-environments (Loughran, 1994; Sanford, 1988), and they need support as they confront the disparity between their student-centered ideology and their survival-based teacher-centered practice. (p.267)

Successful induction programs have been reported to improve teachers' confidence in teaching science as a result of improvement in ability to use inquiry as well as actively challenging teaching ideologies (Luft & Patterson, 1999, as cited in Luft & Patterson, 2002). Luft & Patterson (2002) continued:

> If we expect beginning science teachers to refine their beliefs, practices and knowledge in ways that are conducive to standards-based science instruction, then induction programs must attend to this process….Small group discussions, purposeful dialogue about demonstrated lessons, participation in science-rich lessons, observations of exemplary science classes, and feedback on one's teaching can further facilitate the process of refining beliefs and practices, and construction of knowledge of science and science teaching. (p. 271)

Additionally, science education reform efforts have demonstrated that teachers experience difficulty in developing conceptualizations of teaching science as inquiry, perhaps due to lack of opportunities to actually engage in science experiences (Kielborn & Gilmer, 1999). Professional development that is geared towards providing discourse experiences as a means to reflect on these changing beliefs can help with this, however, and can enable teachers to enact pedagogically-appropriate conceptualizations of inquiry in the classroom (Windschilt, 2003).

### *Defining teaching science as inquiry*

If you spend time reading the literature of science education reform, it does not take long to realize that the word "inquiry" is deceivingly enigmatic. In fact, inquiry can mean many things to many people based on the context of a study including the students, teachers, and lessons (Anderson, 2002). It is common for "inquiry" to be poorly defined or not defined at all. Therefore, it is critical when presenting a case for pedagogically-specific professional development that one operationalizes their views of inquiry.

For the purposes of this dissertation study, I describe my efforts made to engage in science education reform at the college level in reference to my endeavors undertaken to assist the GLAs in the Division of Biological Sciences at the University of Georgia (UGA) with *teaching science as inquiry*. In order to teach science as inquiry, or what Chiappetta (1997) referred to as "scientific inquiry," a focus must be placed on "active student learning and…understanding a scientific topic. Here the content becomes a critical aspect of the inquiry (p. 23)." Activities in which students engage and the teaching methods used to demonstrate those activities should show that science is a process of inquiry, similar to how scientists "do" science. The *NSES* (1996) states:

> For students to develop the abilities that characterize science as inquiry, they must actively participate in scientific investigations, and they must actually use the cognitive and manipulative skills associated with the formulation of scientific explanations. This…describes the fundamental abilities and understandings of inquiry, as well as a large framework for conducting scientific investigations of natural phenomena. (p. 123)

Engaging students in this process can therefore draw a parallel in application between scientists' work and how students might approach problems in their own lives that need to be investigated (Flick, 2003, as cited in Abrams, Southerland, & Silva, 2008, p. xvi).

A difficult task in teaching science as inquiry, however, is that it requires that students utilize metacognitive skills to actively learn how to inquire (i.e., how to ask relevant questions and justify explanations or ideas). Metacognitive skills are often lacking in college students (Kincannon, Gleber, & Kim, 1999), so it is imperative that when teaching science as inquiry, teachers work to develop these abilities. Lederman, Abell, & Akerson, (2008) explained:

> At the same time that students are developing abilities for doing inquiry, they are building understanding about scientific inquiry…The understandings are often the result of metacognition in relation to inquiry-based activities…That is, good teachers help student think about the thinking processes that they have used and focus students on knowing how to improve. (p. 15)

*Science as inquiry in introductory biology laboratory courses at The University of Georgia*

In the past 10 years, biology faculty at the University of Georgia (UGA), a research intensive institution, have made extensive efforts to meet the NRC's guidelines for teaching science through inquiry lessons in a laboratory environment. The ongoing conversion of laboratory activities from a traditional "cookbook" format of prescribed activities that led to expected results (i.e., verification-type activities) to activities that required students to actively work to design experiments, interpret results, and justify conclusions has been met with numerous challenges. Some of these challenges include time constraints of finishing laboratory activities, students feeling lost due to a lack of step-by-step instructions, and the need to educate graduate student instructors with science backgrounds in the practical aspect of teaching science as inquiry in an instructional setting. All introductory biology laboratory courses are taught by GLAs to a total undergraduate population of approximately 3500 students per academic year (fall, spring, and summer semesters). The GLAs who teach these laboratory sections are primarily students seeking M.S. or Ph.D. degrees in a biological science field (e.g., microbiology, genetics, cellular biology). Their assignment to teach for the Division of Biological Sciences (versus their home department) is decided upon by their department graduate coordinators, sometimes with input from their major professors. These decisions are not usually made for reasons of graduate student interest in teaching but are more commonly made because there is a lack of funding to support the graduate students with research assistantships or simply because it is time for the graduate students to fulfill the required teaching commitment (as stipulated by their home departments).

In a typical fall or spring semester, approximately 40 graduate students teach introductory biology laboratory sections. About 50% of this cohort are first year graduate students. Additionally, approximately one-third to one-half lacks prior teaching experience while the remaining have taught for at least one semester in either the Division of Biological Sciences or for their home department. Generally, 20% are international students, and it is common for several of these students to have recently arrived in the United States to start their graduate work.

*BIOL 1103L*

BIOL 1103L is one of two introductory biology laboratory courses for non-science majors. Its content focus is cellular/molecular biology. The curriculum in BIOL 1103L requires that GLAs teach science as inquiry. As laboratory activities are designed to engage students in the processes of science, students work in small groups to talk through and design some or all of their own experiments for almost every laboratory topic. Rather than introducing a new laboratory topic each week, the BIOL 1103L manual is comprised of fewer laboratory topics that have greater content depth than can be achieved if changing topics on a weekly basis; each laboratory topics is covered in a two to three week "series" of related activities (all of which are deductive). The curriculum has moved away from weekly quizzes as the primary means of content assessment; instead, the lab is now designated as a Writing Intensive Course. Approximately 60% of the BIOL 1103L course grade is earned through different types of writing assignments. Some assessments used are formative writing assignments; for these, students earn a small percentage of points for their efforts to explore new ideas and articulate their ideas about a topic at hand. Others assessments are summative writing assignments, worth a greater percentage of points, that challenge students to demonstrate proficiency in content and process skills. Additional assessment points are given for pre-laboratory assignments and group presentations.

Using this framework, three of the six BIOL 1103L laboratory series (*enzymes* (*Carb Cutter), antibiotic resistance*, and *Mendelian genetics*,) in the BIOL 1103L course proceed as follows: GLAs provide a 5-10 minute overview of the content topics and intended learner outcomes that will be addressed in a particular laboratory as well as how that laboratory fits into the grand picture of a 2-3 week laboratory series. If known, the GLA will relate what the students will be doing in lab to how the same topics will be covered in lecture. By keeping the GLAs' introduction to the laboratory to a minimum, an atmosphere for student active engagement is encouraged. If a pre-laboratory assignment was handed in at the beginning of laboratory session, GLAs will then work through some of the pre-laboratory questions with which students typically have difficulty. Then, with provided laboratory objectives in mind, the GLAs explain to students what equipment is available for their use during the laboratory period. Students then work in groups to design an experiment that can be conducted to meet the objective of the laboratory class. During this experimental design process, GLAs rotate amongst the student groups to check on progress. GLAs will often prompt students to explain their thinking if they see the students struggling. Finally, when finished with their designs, each group must present them to the GLAs before starting their experiments. Experiments are eventually conducted and groups are given time in class to discuss and interpret results within their groups and with the class as a whole.

By being frequently engaged in self-generated experiments, students are given the chance to experience how science is sometimes done (the use of experiments is not the only way to facilitate students' understanding of scientific inquiry). Conducting experiments in an instructional laboratory setting has been a long-standing focus of instructional science laboratory experiences, but the actual question asked and protocol to explore that question has traditionally been provided for students. However, when students have the ability to ask and explore questions of interest to them in order to reach laboratory objectives, an important aspect of current science education reform efforts is realized: students are more actively involved in what they are studying and how they study it (see Teaching Standards, *NSES*, pp. 22-23). The other three laboratory series (*scientific investigations, water quality, genetic testing (Case It)*) engage students in parts of the experimental design process (e.g., data interpretation only) and/or require that students take part in other forms of active learning (e.g., library or online research, collecting field data, group presentations, investigating genetic diseases through computer-based simulations) to learn about other aspects of doing science.

This study is the report of results from an attempt to assess a teaching preparation program for GLAs teaching an introductory biology laboratory course for non-science majors at UGA. The program was designed to better enable the GLAs to teach a science curriculum that requires students to actively engage in scientific inquiry. The relative effectiveness of this teacher induction program as self-reported by the GLAs, the GLAs' development of personal conceptualizations of teaching science as inquiry, and how those conceptualizations were translated into classroom practice were evaluated primarily through qualitative data collection and analysis.

*Purpose and rationale*

The purpose of this dissertation is to investigate how preparation in teaching science as inquiry provided to BIOL 1103L GLAs is related to their thinking and teaching. If science education reform purports that undergraduate students should be taught by science instructors who are current on both content and teaching methods, we cannot expect novice science instructors (i.e., graduate students often fresh from their own undergraduate degree programs) to tackle this reform on their own. Tanner and Allen (2006) stated:

> Universities and colleges thus have a special obligation to provide the best possible learning environment for all students, even in the fact of limited resources, particularly at underfunded state institutions…real progress might be made in the teaching of the science by integrating pedagogical training into the graduate experiences of our future science faculty. By providing our budding PH.D.s, our future faculty, with meaningful exposure to "best practices" in a variety of teaching settings, we could begin to articulate the science education pathway for students, K-16, and transform college and university-level teaching into a significantly better trained profession. (p.2)

Conducting an investigation of a program designed to help GLAs teach science as inquiry allowed me to learn what aspects of the teaching preparation affected GLAs' knowledge of how to teach science as inquiry, confidence in teaching (in general) and in teaching science as inquiry, ideas of what science is and how it should be taught/experienced, views of the role of a teacher and of a student, and their ability to teach science as inquiry to undergraduate students. This information holds practical significance as it provided substantiated evidence of benefits for a discipline- and pedagogically–specific teaching preparation program. It also provided a template for a graduate student instructor/teacher preparation program for other inquiry biology laboratory courses. It simultaneously identified problematic circumstances in developing and implementing this type of educational experience for GLAs. Additionally, this study allowed me to move beyond defining the necessary components of a teaching preparation program and begin to understand how these components help the GLAs to develop as teachers and to implement the inquiry curriculum.

Researchers have reported how teacher beliefs about teaching (Crawford, 2007), the nature of science (Crawford, 2007; McDonald & Songer, 2008), and authentic learning and science (McDonald & Songer, 2008) can affect how teachers develop conceptualizations of teaching science as inquiry as well as enact it, so it is also important for the efficacy of a graduate student instructor science teacher preparation program to understand not only how GLAs develop beliefs about teaching science as inquiry in the context of their preparation, but also if and how they were able to enact those beliefs.

*What is the need for graduate student instructor teacher education?*

Evidence has demonstrated that regardless of discipline, graduate student instructors desire and request teacher education and mentoring, especially at a discipline-level (Diamond & Gray, 1987; Jones, 1993; Worthen, 1992). Many higher education institutions have made efforts to address these wishes and appeals through two different types of teacher preparation programs: university-level or departmental-level (Shannon et al., 1998). University-level preparation, provided by various higher education faculty and administrators, is generally designed to reach graduate student instructors across disciplines and is often completed in one session (e.g., one full day or less). The focus of this preparation tends to encompass administrative and managerial classroom practices rather than the development of instruction-specific teaching practices (Gray & Buerkel-Rothfuss, 1991) such as inquiry pedagogy. In contrast, preparation offered under the heading “departmental-level” varies from “…brief general orientations to structured teaching practicums supervised by faculty mentors” (Shannon et al., 1998, p. 441). Therefore, given that the likelihood of teaching as a faculty member after receiving a Ph.D. is high (Golde & Dore, 2001), a pedagogically sound, discipline-specific teaching preparation program offers essential validation for necessary professional development experiences for graduate student instructors.

*Why study teacher education programs for graduate student instructors?*

Views of the nature of learning and the nature of science can dictate how and why one teaches and therefore also have a powerful influence on how that individual’s students learn; researchers have reported that teacher beliefs about the content they are teaching, the methods by which they are teaching and assessing student learning, and how students learn that content can affect teaching practices (Cochran-Smith & Lytle, 1999; Pajares, 1992). For example, implementation of science curriculum that is based on inquiry activities can be hampered by teachers’ beliefs that science exists as a body of facts to be memorized and that students can only learn science adequately if they memorize facts (Keys & Bryan, 2001). In other words, two different curricula can exist for the same teacher: an intended one and a practiced one. Therefore, a well-investigated inquiry science teaching preparation program for graduate student instructors can provide insight into our future faculty’s views of the nature of science and therefore the likelihood that they would attempt to teach science as inquiry.

Additionally, studying whether or not GLAs experience a change in confidence and beliefs (towards teaching in general, towards teaching science as inquiry, towards ability to teach inquiry) over the course of the semester in which they receive training and put that training into practice may provide insight into students’ experiences in the laboratory course (BIOL 1103L) investigated in this study. For example, some students may experience a more thorough view of science as a process depending on their GLAs' beliefs of teaching science as inquiry or the nature of science. This, in turn, may lead to greater student engagement (Dunbar, Egger, & Schwartz, 2008) and perhaps a shift in students' willingness to read or comprehend science phenomenon. This greater sense of "I *can* do science!" is an integral part of students' perception of how well they perform in a science course (self-efficacy). Researchers have documented correlations between student self-efficacy and attitude toward careeer choice (Lent, Lopez, & Bieschke, 1991) along with enrollment in future courses (Zimmerman, 1995). Therefore, it would be informative to have data that suggest specific factors from the teacher preparation or other factors can positively impact GLAs' confidence to teach science as inquiry. This information may contribute to a better understanding of issues that might affect implementation of inquiry science as well as student experiences in inquiry science laboratories.

Another difficulty that teachers face in implementing current science education reform is that it is often the case that they themselves cannot lead by example; they have never been taught through learning experiences that encourage them to inquire (Windschitl, 2003). Researchers document that despite the nature of the pedagogical education experiences teachers might receive, they will often teach as they were taught in undergraduate courses (Grossman, 1991). In the case of graduate student teachers who have likely never engaged in any pedagogical education in teaching, it is reasonable to assume that these first-time teachers will have little to no understanding of teaching science as inquiry and should therefore not be expected to demonstrate any teaching methods other than those they experienced as students. In this light, preparing GLAs to teach science as inquiry is of critical importance to the implementation of an inquiry-based curriculum in undergraduate science laboratories.

Discerning the understandings gained from the teaching preparation that the GLAs actually employ was worthy to investigate for two reasons. One, instruction as viewed by a participant observer may be something similar to or different from what a GLA reports experiencing. This could be an important realization for both parties. GLAs might gain insight into their teaching that can help them increase their abilities to teach science as inquiry while the researcher might gain insight on better means of teacher preparation. For example, perhaps the GLAs report implementing one type of inquiry teaching strategy when in fact, they actually used a different one or maybe none at all. The researcher might need to consider how to better explain or demonstrate these desired teaching behaviors to help GLAs accurately realize what they are enacting in the classroom. From this experience, both parties would potentially better understand the reality of intended curriculum versus practiced curriculum.

Two, immediate feedback to both the GLA being observed and to the researcher on observed “best practices” of teaching science as inquiry allowed for active reflection. Rather than waiting a period of time to discuss observations, thereby increasing the chance that crucial details of the teaching experience might be forgotten, immediate feedback helps to secure meaningful reactions about teaching science as inquiry in the minds of the GLAs and the researcher.

The goals of the BIOL 1103L curriculum are to 1) improve student communication in the sciences, both orally and through written means; 2) to understand that science is a process rather than a prescribed method; and 3) to realize that science is not completed without cooperation and collaboration of peers. It is important to creators of this laboratory curriculum for students to understand that science involves collaboration of ideas and interpretations and consequently, a reliance on cooperative learning with peers. Such learning requires trial and error processes, argumentation of ideas, and a partnership with peers to solve problems. Therefore, in this dissertation, it was essential to make a judgment about how students responded to varying levels of employed inquiry teaching strategies designed to meet these goals so that I could consider a modified (i.e., more appropriate) structure of the teaching preparation program.

*Significance of study*

The significance of this study comes from its potential to affect multiple audiences. Science graduate students and their faculties are provided with a pedagogically-reasoned teaching preparation program that not only better enables graduate students to adequately fulfill their teaching assistantship responsibilities but also may help prepare these graduate students for future faculty positions that require teaching. Faculty advisors have reported that their science graduate students who engaged in "intensive" K-12 outreach activities accompanied by pedagogically-focused workshops and seminars showed improvement in their graduate research (Trautmann & Krasny, 2006). Examples of progress were seen in "broadened perspectives on…research questions" and a "reconnect with the basic science behind their specific fields" (Trautmann & Krasny, 2006, p. 161). Seemingly, then, a strongly endorsed teaching preparation program for teaching science as inquiry by the graduate instructors themselves as well as their faculty advisors provides leverage when arguing that more time and money be invested in pedagogically appropriate graduate teacher development. Additionally, it is critical to the designers of a biology laboratory curriculum that provides students with experiences in learning science by doing science that GLAs' conceptualization of teaching science inquiry are understood. Without this knowledge, curriculum and professional development are short-stepping effective efforts to develop pedagogically sound teaching preparation and curriculum.

Finally, undergraduates would benefit in their learning experiences if their instructors are prepared to teach inquiry-based content as it is presented in a laboratory manual.

All of the above mentioned aspects of the teaching preparation program are dimensions towards understanding the "effectiveness" of this professional development experience. Collecting and interpreting multiple forms of instructor data as well as student observations provided analysis sensitive to GLAs' authentic experiences as it gave a detailed, in-depth assessment of how novice college inquiry science teachers need to be prepared to teach science as inquiry.

*Research questions*

The following research questions were addressed in this study:

1. What aspects of the teaching preparation program impacted the following GLA characteristics, and how?

    a. knowledge of scientific inquiry and how to teach in ways that enable students to build understanding of science as inquiry

    b. confidence towards teaching (in general) and towards teaching inquiry

    c. ideas of what science is and how it should be learned

    d. views of the role of a teacher and of a student

    e. ability to teach science as inquiry

    f. what other factors, if any, impacted these same teacher characteristics, #1, and how?

2. Which aspects of the GLA preparation did the individuals who received it employ? In what ways did the GLAs enact the conceptualization of inquiry teaching that was

associated with them across the semester's experience and their concurrent teacher development?

3. Which student behaviors changed (i.e., how did students respond) as a result of employed GLA strategies?

*Theoretical framework*

In his discussion of one's goals for undertaking a research study, Maxwell (2005) stated:

> …your goals inevitably shape the descriptions, interpretations, and theories you create in research. They therefore constitute not only important *resources* that you can draw on in planning and justifying the research, but also justifying the *validity threats*, or sources of bias for the research results that you will need to deal with… (pp. 15-16)

As the primary researcher in this study, I enlisted the use of a constructionist stance when considering the first two research questions. As Crotty (1998) explains, the "reality," or obtained knowledge, inherent to this stance is created from humans interacting with the world and other human beings. The meanings and patterns that we determine, therefore, are "developed and transmitted within an essentially social context" (p.42) but are also constantly changing as the meanings can be revisited, reinterpreted, and then redefined (Benzies & Allen, 2001, p.4). In my study, a science teaching preparation program that addresses science as inquiry was investigated through qualitative and quantitative analysis of GLA interviews, pre- and post-semester GLA surveys, and classroom observations of GLAs and students. Via these interactions, surveys, and observations, I determined if patterns of GLAs' views of the preparation program, of the actual teaching of science as inquiry, and if any other factors critical to determining the relative "success" of this program were present in the data.

I was interested in communicating with and observing GLAs as they enacted their interpretation of the teaching preparation they received in order to begin to understand the effectiveness of the preparation in relation to the program's goals. When considering this process, I needed to take into account that it would likely be tempered by the GLAs' experience and intentions. A symbolic interactionist perspective helped inform my study as its three essential tenets include 1) "that human beings act toward things on the basis of the meanings that these things have for them"; 2) "that the meaning of such things is derived from, and arise out of, the social interaction that one has with one's fellows"; and 3) "that these meanings are handled in, and modified through, an interpretive process used by the person in dealing with the things he encounters" (Blumer, 1969, p. 2 as cited in Crotty, 1998, p.72). This perspective is often employed in constructionist-based studies since constructionist epistemology and symbolic interactionism both focus on the building of meanings built through interactions between humans and their surroundings. Crotty explained:

> …symbolic interactionism is all about those basic social interactions whereby we enter into the perceptions, attitudes, and values of a community, becoming persons in the process. At its heart is the notion of being able to put ourselves in the place of others – the very notion we have already expressed in detailing our methodology and have catered for in the choice and shaping of our methods. (p.8)

Employing a symbolic interactionist perspective in this study provided different paths for me to follow in my data collection process. It also allowed me to interpret patterns and revisit them throughout my study so that clarified or even new patterns might emerge. For example, I used multiple forms of query into GLAs' beliefs about inquiry; the methods chosen were designed to elicit what the GLAs brought to the onset of their first teaching assignment in terms of knowledge of science inquiry and teaching science as inquiry. Then, at multiple points during the semester, GLAs were again asked individually to explain their understanding of the word inquiry. My goal in using this staged, intermittent questioning method was to take the immediate context of defining conceptions of inquiry in the first person (i.e., at the time of interviews) and attempt to capture how GLAs' views of inquiry at that time were different or similar to previously articulated beliefs, and why. This allowed for the possibility that the immediate situation of a conversation about inquiry might cause a previously held belief to be revisited and possibly reinterpreted.

As symbolic interactionism focuses on the nature of social interaction (Benzies & Allen, 2001, p.7), it required me to place myself in the shoes of my GLA participants in order to have the most credible interactions with them. While this was possible in numerous situations (as I am a graduate student), I was sometimes limited by the fact that I am the participants' supervisor as well as the researcher. In certain instances, I found that I needed to treat a situation from a professional standpoint, and this practical circumstance did not allow me to be anything *but* a supervisor. Therefore, in order fulfill professional responsibilities, I needed to stand back from the urge to move into the GLA role that might allow access to valuable data . In other cases, spending such a significant amount of time with the GLA participants created a level of trust that a researcher and study participant might not normally experience, and there were times when I was pulled out of my professional role to work with GLAs on a more personal level. These multiple roles required that I constantly evaluate the contexts in which I collected data as the role(s) I took could inadvertently influence how I asked questions and eventually analyzed data. To contend with this important issue of validity of data collection, survey, interview, and questionnaire questions were carefully crafted so as to elicit the richest data possible. Through these data collection methods, GLA participants provided judgment, perceptions, and experiences for me to analyze and draw conclusions about relative success of the teaching preparation program.

*Preview of remaining chapters*

In Chapter 2 of my dissertation, I provide a review of research studies on topics relevant to this study. The three major sections of this review include 1) the use of the word “inquiry” within science education reform literature; 2) barriers common across disciplines that teachers face when attempting to implement reform as well as those that are specific to the field of science education; and 3) the necessity for pedagogically-specific teaching education for new teachers.

In Chapters 3, 4, and 5 of my dissertation, I provide analysis of a teaching preparation program developed to help novice graduate student instructors (GLAs) teach introductory undergraduate biology laboratories with an inquiry focus to non-science majors. Chapter 3 presents analysis of data as it relates to the impacts of the program on the teacher characteristics described in the first research question (i.e., a. knowledge of scientific inquiry and how to teach in ways that enable students to build understanding of science as inquiry; confidence towards teaching (in general) and towards teaching inquiry; deas of what science is and how it should be learned; views of the role of a teacher and of a student; ability to teach science as inquiry). This initial analysis helped provide the focal points for more in-depth analysis of dissertation data. Chapter 4 presents analysis of data as it relates to how the GLA participants came to conceptualize teaching science as inquiry over the course of their teaching assignment. This analysis further explores how the teaching preparation and how other factors influenced the GLAs’ teaching characteristics described in Chapter 3, but in relation to how they developed beliefs about teaching science as inquiry. Chapter 5 presents analysis of data as it relates to the GLA participants' enactment of their conceptualizations; this data analysis addresses the second and third research questions as it analyzes both GLA and student behaviors.

The final chapter of my dissertation provides a summary of findings and implications from Chapters 3-5. It also provides recommendations for the current teaching preparation that I conduct with GLAs at the University of Georgia. Finally, suggestions for continued research on the topic of teaching preparation for new graduate student teachers of inquiry-based science laboratory courses are made.

# CHAPTER 2

# LITERATURE REVIEW

The following literature review summarizes research studies on topics relevant to this dissertation study. The review begins with a general discussion of the word "inquiry" as this term is used within the literature of science education reform. The chapter then provides an examination of research regarding obstacles to implementing reform across any field of study (e.g., mathematics, history) and those hurdles specific to science education reform. An attempt will be made to link this research, which is primarily built on evidence collected in K-12 school settings and science education teaching programs, to the current research that is being conducted in a higher education setting. Finally, the research which builds the case for the need for teaching preparation, especially pedagogically-specific education, is examined. The specific research of interest deals with one population of novice teachers, i.e., graduate student teachers of non-science majors introductory biology laboratory courses.

## *What is inquiry?*

In any subject area, **general inquiry** can be defined as "… an image of individuals actively asking questions and seeking understanding, one that occurs in the rhetoric of many disciplines" (Van Zee, Hammer, Mary Bell, & Peter, 2005, p. 1038). In a school setting, general inquiry describes situations that arise which interest students; and as a result, students pose questions that interest them and make efforts to try to understand the perplexities with which they are faced. The relative simplicity of defining the word inquiry is lost, however, when you start using it in context of specific fields of study, such as science education. In fact, one of the most apparent and sometimes frustrating aspects of the extensive literature on inquiry in science teaching is myriad interpretations that one will discover of this deceptively simple word.

Several documents including Project 2061 (Rutherford & Ahlgren, 1990) and the *National Science Education Standards* (*NSES*) (NRC, 1996) and are widely utilized as the foundations for current science education reform, grades K-16. Among numerous common goals, these documents emphasize the need for the United States to have a more scientifically literate population with a greater conceptual and practical understanding of the nature of science. Using more "inquiry"-based science experiences in the classroom is one of the methods described in these documents to achieve these goals. For example, the *NSES* (NRC, 1996) define inquiry as:

> …the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world…Students will engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world, but they also should develop the capacity to conduct complete inquiries. (p. 23)

The *NSES* state that in order for teachers to adequately instruct using a greater emphasis of science-as-inquiry experiences, they need preparation in science content as well as "…evidence for the content they teach, [and] the "process" of science: what scientific inquiry is and how to do it" (NRC, 2000, p. 92). Within this one document, inquiry is seen as three non-mutually exclusive items: something scientists do, something students do, and something teachers do. This multi-dimensional view of inquiry is complicated further by the fact that these definitions can change depending upon how a person interprets them within their own experiences (Anderson, 2002). For the purposes of this dissertation, clarifications of these dimensions of the word inquiry in the discipline of science education will be made in order to set the context for the chapters that follow.

A commonality that *does* exist when defining the word inquiry in the discipline of science education is fallback to the two critical science reform documents just cited: the *National Science Education Standards* and *Project 2061*. Most explanations of "inquiry" are based on the five "essential features of classroom inquiry" as defined in the *National Science Education Standards* by the NRC (2000): These five elements are:

1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to **evidence**, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions.
4. Learners evaluate their **explanations** in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations. (p. 25)

However, even though both of these widely referenced reports describe inquiry as a process, they do it in different ways. The NRC (1996) focuses on inquiry being both how scientists do science as well as how students "…develop knowledge and understanding of scientific ideas" (p. 23). Project 2061 addresses the process of science as a unique way of knowing about the world that we live in and the relationships within. This means of knowing necessitates "observing, thinking, experimenting, and validating…represent a fundamental aspect of the nature of science" (p.1). *NSES,* therefore, describes inquiry as a learning tool, while Project 2061 emphasizes inquiry as a process skill.

In addition to the variation of definitions within these documents, multiple interpretations arise from what has been described as the current "three goals of science education discussions: (a) understanding how scientific inquiry proceeds, (b) being able to successfully perform some semblance [of] scientific inquiry, and (c) understanding how inquiry results in scientific knowledge" (NRC, 2000 as cited in Abrams, Southerland, and Silva, 2008, p. xvi). This may be because the word inquiry is being used to describe "…means and ends" (Hackett, 1998); within teaching, inquiry is used to describe ways of "…teaching methods and strategies" (direct quote taken from Hackett, 1998, p. 35; Anderson, 2002) while for students, inquiry refers to outcomes such as "…content that students should understand and be able to do" (Hackett, 1998, p.35) or a desired "skill-set" (Settlage, Meadows, Olson, & Blanchard, 2008, p. 204). This distinction is similar to the one made earlier between how *NSES* and *Project 2061* emphasize inquiry. For instance, studies of inquiry in science teaching have focused on targeted outcomes such as development of students' science process skills (Roth & Roychoudhury, 2006) and a standard against which teachers should teach (Anderson, 2002). Additionally, studies have been conducted that focus on "inquiry as a means to hone scientific reasoning abilities of students" (Abrams et al., 2008, p. xxi), "inquiry as a means of interacting with competing knowledge claims" (p. xxii), and a means "to bring [student] into the ways of thinking, doing and knowing that are endemic to science" (pp. xxiii-xxiv).

Considering the multitude of complex factors that affect how a teacher implements inquiry in the classroom, Abrams et al. (2008) purport that we must allow for flexibility in interpretation of inquiry as the reality of the differences from one classroom to the next necessitate a variety of equally important perspectives. One means to potentially clarify what inquiry is as it relates to science teaching is to define how it is being used (i.e., the goals of using inquiry). For example, a teacher might need to define if s/he is **teaching science *by* inquiry** or **teaching *as* inquiry**. An implication of defining pedagogical strategies is that specific instructional methods of reaching intended student outcomes may become more apparent to the teacher. I will share some of these strategies further in the sections that follow.

**Teaching science by inquiry**, also referred to as "teaching science through inquiry" (Chiappetta, 1997, p.23), implies that students learn by asking questions and making observations (similar to general inquiry). There is no prescribed format or approach to help students discover science understandings when teaching science by inquiry; this allows for incredible flexibility in teaching strategies as seen from lesson to lesson or even within groups of students working on the same lesson. This includes the option of open-inquiry where almost no instruction is given to students (i.e., often seen as a free-for-all in learning science) and guided inquiry where the work of students is managed by a teachers' instructional plan.

Chiappetta (1997) also described a second way of viewing inquiry teaching in science:

> In contrast to teaching science *by* inquiry (general inquiry) is the notion of teaching science *as* inquiry (scientific inquiry). Teaching science as inquiry stresses active student learning and the importance of understanding a scientific topic. Here the content becomes a critical aspect of the inquiry. (p. 23)

**Teaching science as inquiry**, or "**scientific inquiry**," implies instructional methods that focus on engaging students in lessons which show that science is a process of inquiry. This in turn supports the general notion of how scientists do science. Teaching science as inquiry allows for a bridge to be drawn between the steps that scientists take to investigate phenomena and how students might approach problems in their own lives (Flick, 2003, as cited in Abrams et al., 2008, p. xvi). Learning about inquiry in this light also implies that students should become experienced in actually learning how to inquire: how to ask relevant questions and justify explanations or ideas. The *NSES* (NRC, 1996) states that for students to be taught science as inquiry, they need to:

> …develop the abilities that characterize science as inquiry, they must actively participate in scientific investigations, and they must actually use the cognitive and manipulative skills associated with the formulation of scientific explanations. This…describes the fundamental abilities and understandings of inquiry, as well as a large framework for conducting scientific investigations of natural phenomena. (p. 123)

This active engagement is indicative of the need for students to use metacognitive skills. Therefore, when teaching science as inquiry, teachers need to consider how to enhance these abilities. Lederman, Abell, and Akerson (2008) explained:

> At the same time that students are developing abilities for doing inquiry, they are building understanding about scientific inquiry…The understandings are often the result of metacognition in relation to inquiry-based activities…That is, good teachers help student think about the thinking processes that they have used and focus students on knowing how to improve. (p. 15)

Finally, what inquiry teaching can actually enhance in a classroom environment (e.g., content knowledge, process skills) and how well it can do this is also not well-defined (Abrams et al., 2008, p. xii). Yet K-12 educators are still being pushed to implement “inquiry” in the classroom. Here enters yet another confounding issue to clarification of the term inquiry, that of personal interpretation: what is inquiry in *my* classroom? For instance, two fourth grade classes in the same school, taught by different teachers, might have two very different experiences of inquiry. A number of reasons may contribute to this including "…particular students, context, and content" (Abrams et al., 2008, p. xii) and teacher beliefs (Keys & Bryan, 2001).

Whether teaching science by inquiry or teaching science as inquiry, numerous teaching strategies exist that can be used in inquiry instruction to help meet intended teaching and/or student learning goals. Many of the strategies that I highlight in this document are ones that the students and graduate laboratory instructors involved in this research study experience in BIOL 1103L (the introductory undergraduate biology laboratory course that is the focus of this study).

Inquiry instruction may focus on activities that develop students' **science process skills**, the components necessary for students to actively engage in the process of science. As one example, these might be activities where students are confronted with data that they must interpret in light of alternative explanations. These alternatives might be given by the teachers or may come from classmates who are viewing the same data but from a different perspective. Building on their personal interpretations, students must be able to justify and defend their stance, an aspect of the process of science that is critical to the credibility of scientific knowledge. As Chiappetta (1997) stated, "The acquisition and frequent use of these skills can better equip students to solve problems, learn on their own, and appreciate science" (p. 24).

Another teaching strategy in an inquiry classroom that teachers might employ is conducting activities that revolve around **discrepant events**. Discrepant events might occur for students during a lesson when they are presented with results that did they not expect. These unexpected results may be part of a short-term learning experience when students engage in a new activity, make predictions, test them, and then collect data that is not what they expected. Or, discrepant events may link to something more deeply seated in the students, such as misconceptions about a given scientific process. Either way, getting the “wrong” result is likely to get students’ attention. It is up to the teacher to make sure the situation does not turn into an “I failed that experiment” but instead follows a new investigative path: “What could have caused the results you actually observed?” This new path of inquiry might lead to class discussions of observed events and potentially new predictions (Chiappetta, 1997), and it also might help dissolve common misconceptions.

**Inductive activities** are those that allow students to start with observations of a phenomenon and then *induce* what is happening (often determining a name or principle for what they see). In case of science teaching, teachers who employ these activities in an inquiry classroom might allow students to make observations about a phenomenon, have students discuss this phenomena and then give it a name or generate a rule to explain their observations. In this way, students are seeing patterns first and then defining those patterns second. In his science textbook *Biology, An Inquiry Approach*, Anton Lawson (2004) purposefully introduces new terms (often the bold-face words) to students only *after* the phenomenon that they describe is first given. In this way, students are drawn to the “pattern” being described and are then able to link the concepts to new terms. Following research about how our brains work to learn material the most effective and efficient ways possible, Lawson uses this learning technique so that that the “…new terms have something to connect within memory and are therefore more easily understood and remembered” (p. vii).

**Deductive activities** work in the opposite way to inductive activities but may also be used in inquiry classrooms. These activities present a new term or rule first and then follow that term or rule by examples that provide evidence for the term or rule. This is a more traditional approach to presenting scientific concepts and content but can still be used to start or augment an inquiry experience. For example, these activities might be used to enhance content knowledge of more complicated or difficult processes where simple observations up front cannot accurately depict the entire phenomenon at hand (Chiappetta, 1997, p. 25).

All of the afore-mentioned strategies can be used in an inquiry classroom in **small-group investigations.** By allowing students to work with one another in small group settings, students are able to work through a project with a few students instead of an entire class. The chances, in this setting, that students would be able to have an active role in some part of the activity are high, rather than potentially having to sit passively in a class of 30 students. Additionally, small-group investigations allow for teachers to potentially gain a greater sense of where students are having difficulties. Rotating between five or six group projects might allow for teachers to more easily interact with all students rather than feeling that they must talk to all 30 students individually in order to gauge progress. Small group settings may also produce a “safer” learning environment where students are more apt to discuss topics with a few peers rather than in front of an entire class.

Finally, there are multiple means by which students and teachers can **gather information** to enhance inquiry in the classroom. Besides making observations and collecting data from classroom or laboratory experiences, both students and teachers can engage in other kinds of scientific communication to gather information about a topic being discussed. This may be through talking within peer communities or to other teachers or parents, finding information in books or articles, or perhaps even interviewing a “local expert.”

For the purposes of this dissertation, the word inquiry is placed in the context of Chiappetta’s (1997) definition of teaching science as inquiry. In this light, discussion of how graduate student laboratory instructors (GLAs) are prepared to teach science education reform and how they actually implement it should be considered in the conceptual framework of teaching science as inquiry. The next part of this literature review considers hurdles faced by new teachers when implementing reform in their disciplines.

*Factors that influence teachers' abilities to teach science as an inquiry process*

While the literature cited above indicates that defining inquiry is paramount to helping reach intended teacher and student goals, it may not be as easy to realize these qualifications as one would hope. A rich body of teacher education research indicates that a multitude of factors can affect teachers' willingness and ability to implement teaching reform in any discipline. Some of the reasons include teacher belief systems (Tobin, Tippins, & Gallard 1994), inadequate pedagogical content knowledge, or PCK (Crawford, 2007), lack of support and mentoring (Huling-Austin, 1992; Luft & Patterson, 2002), change to an unfamiliar school setting, teaching responsibilities outside of the field, and lack of opportunities to reflect on their experiences (Luft & Patterson, 2002). Despite the fact that studies conducted over 20 years ago noted that science and mathematics teachers often get lumped together into one group even though they can face starkly different experiences in both content and pedagogy (Sanford, 1988), only recently was a distinction made between types of challenges that teachers in different disciplines must overcome (Luft & Patterson, 2002). Even in the recent past, researchers reported that research on "…the role and knowledge of teachers in the reform process has been minimal" (Keys and Bryan, 2001, p. 641), perhaps due to the lack of attention that had been, and continues to be, paid to this important component of the science reform movement.

One means to contend with discipline-specific obstacles are better support systems for beginning teachers, namely in the form of well-planned and subject-specific induction programs (Luft & Patterson, 2002). In respect to science teachers, teaching science as inquiry and teaching science for inquiry may not be easy or intuitive tasks. Crawford (2000) asserts that effective inquiry teaching requires a rich pedagogical content knowledge, including of the nature of science, as well as skill in difficult teaching skills such as “how to coach, mentor, and collaborate with students” (p. 637). Therefore, induction programs that specifically support science teachers through inquiry-based science reform efforts are critical (Salish I Research Project, 1997 as cited in Luft & Patterson, 2002):

> Beginning science teachers need support as they struggle with the mechanics of implementing student-centered inquiry activities in teacher centered-environments (Loughran, 1994; Sanford, 1988), and they need support as they confront the disparity between their student-centered ideology and their survival-based teacher-centered practice. (p.267)

Successful induction programs have been reported to improve teachers’ confidence in teaching science as a result of helping to improve their ability to use inquiry as well as actively challenging their teaching ideologies (Luft & Patterson, 1999, as cited in Luft & Patterson, 2002). Luft & Patterson (2002) continued:

> If we expect beginning science teachers to refine their beliefs, practices and knowledge in ways that are conducive to standards-based science instruction, then induction programs must attend to this process….Small group discussions, purposeful dialogue about demonstrated lessons, participation in science-rich lesson, observations of exemplary science classes, and feedback on one’s teaching can further facilitate the process of refining beliefs and practices, and construction of knowledge of science and science teaching. (p. 271)

Researchers have also demonstrated that teacher beliefs about the importance of the content they are teaching in regard to their specific students, the methods by which they are teaching and assessing that content, and how students learn that content can affect teaching practices (Cochran-Smith & Lytle, 1999; Marshall, Horton, Igo, & Switzer, 2009; Parajes, 1992). In other words, two different curricula can exist for the same teacher: an intended one and a practiced one. In the case of inquiry-curriculum, teacher beliefs that science exists as a body of facts to be memorized and/or that students can only learn science adequately if they memorize facts can hamper implementation of inquiry curriculum (Keys & Bryan, 2001, p.635). Similar to the Salish I Research Project (1997), Simmons et al. (1999) found that new science and mathematics teachers demonstrated teacher-centered lessons even though they held student-centered beliefs. Marshall et al. (2009) reported that mathematics and science teachers (K-12) reported that their students should spend between 18-20% more time engaging in inquiry activities than what the teachers were actually enacting. Brown, Abell, Demir, and Schmidt (2006) found that college-level instructors believe that for students to learn science as inquiry, learning experiences needed to be authentic and open. For these instructors, such learning requirements necessitate environments that are open and focused on student-directed learning, and this was something with which they were not willing to engage in their classrooms. Yerrick, Parke, and Nugent (1997) contend that to address this multi-faceted belief system, science teachers must be given opportunities to reflect on their beliefs about teaching and learning inquiry if they are expected to understand science reform and possibly allow their current beliefs to change. Luft (2001) also argues that teachers should be given numerous opportunities to reframe or redefine their current beliefs related to inquiry instruction.

Another difficulty that teachers face in implementing current science reform is that it is often the case that they cannot lead by example; they have never been taught by teaching methods that allowed them to learn through inquiring (Akerson & Hanuscin, 2007; Windschilt, 2003). Research documents that despite pedagogical training teachers might receive, they will often teach as they were taught (Grossman, 1991), especially at the elementary level (Smolleck et al., 2006, p. 137). In fact, teachers at the elementary level who are given the task of meeting *NSES* standards might be considered to face the greatest variety of challenges as they likely have the least science subject matter knowledge as well as the least PCK in science. Numerous other factors affect these teachers' abilities to implement inquiry including the psychological notion that inquiry is too difficult to implement effectively, the lack of time they have in a given day to give to science lessons, too many students, lack of money for adequate supplies, lack of support from other teachers and administrators, or the belief that inquiry can only be handled by gifted students (Smolleck, Zembaul-Saul, & Yoder, 2006, pp. 140-1). Again, these reasons may reflect a difference between personal and cultural beliefs. Keys and Bryan (2001) explained:

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

Teacher role identity is yet another aspect of developing teacher characteristics that can affect how a teacher implements reform. Teachers with weaker role identities are not able to consistently conceptualize their role as teachers when teaching inquiry, and so they are more likely to revert back to teacher images with which they are familiar: those of former teachers.

Having stronger identity roles better enables teachers to bring those roles into the classroom (Eick & Reed, 2002).

Recently, Smolleck et al. (2006) reported that in addition to some of the plausible reasons for not implementing inquiry enumerated above, beginning teachers also need to "…feel confident utilizing inquiry, both as learners and as teachers, so students can learn to participate in the processes of science" (p. 140). In order to investigate self-confidence in elementary science teachers in regard to the teaching of science as inquiry, Smolleck et al. designed, validated, and implemented a 69-item Likert-type scale instrument called the *Teaching Science as Inquiry* instrument, or TSI. Following the social learning theories of Albert Bandura who postulated that self-efficacy relates to the confidence one has to do something correctly and is specific to the context in which it is presented, Smolleck et al. created the *TSI* to be specific to the teaching of science as inquiry. Theoretically, a teacher with high self-efficacy for teaching science as inquiry would be more likely to actually enact this teaching while teachers of lower self-efficacy would be less likely (Marshall et al., 2009). The 69 items in this instrument were created to account for the different continuum levels of the NRC's stated five essential features of inquiry (NRC, 1996, p.25); they measure both personal self-efficacy as well as outcome self-efficacy. Smolleck et al.'s study also outlines the benefits and downfalls of past, more generalized self-efficacy instruments in relation to their potential use in the study of the teaching of science as inquiry.

Another recent attempt to understand teachers' beliefs about inquiry teaching in science classrooms is the *Inquiry Teaching Belief* (ITB) instrument, "…an instrument that simultaneously captures the qualitative and quantitative information regarding teachers' beliefs of inquiry science teaching" (Harwood, Hansen, & Lotter, 2006, p. 70). This instrument utilizes a series of cards that list/describe activities in which students might be engaged in a science classroom. Subjects then position these activity cards within chosen distances from a "classroom card." If an activity card supports an inquiry-based classroom, it is placed close to the classroom card; activity cards that are less supportive are placed farther from the classroom card. Data are then collected by having subjects verbally describe their inquiry classroom model as well as answering open-ended questions about it. Quantitative data are also collected by physically measuring the distances between the activity cards and the classroom cards. The relative distances are then assessed with quantitative measures to infer the importance that a subject placed on activities that were supportive of inquiry-classrooms, not supportive, or neutral (i.e., shorter mean distances between activity cards and classroom cards would be indicative of greater support for an activity that would enhance an inquiry classroom). Pre/post test measurements of these activity cards would allow for a means to asses changes in subjects' views of inquiry-based science instruction. Additionally, if an:

> …intervening event [s], such as…a methods class [or] authentic research experience…has an impact on the subject, the change in their value of the relative distances and variation of these distances can provide a quantitative insight into the effectiveness, or perceived effectiveness, of the intervention. (p. 73)

Both of these studies are unique in self-efficacy instrument use for the reason that they are so pedagogically-specific in focus. While a multitude of self-efficacy instruments have been successfully validated and used across disciplines, they tend to focus on large-scale teacher efficacy beliefs rather than specific ones (Wheatley, 2005). Wheatley (2005) suggested that in addition to constructing and validating discipline-specific efficacy instruments, teacher education research must also "reconceptualize" the notion of teacher efficacy to consider what the data from instruments might really tell us. In his view, teacher efficacy research omits at least two critically important types of efficacy beliefs for teacher educators: efficacy beliefs regarding learning to teach better (p. 750) and teachers' outcome expectancies "…that would result from skillful use of new curricula or methods *with which they have little or no skill"* (emphasis in original text, p. 751). This latter concern could be particularly applicable to teaching science as inquiry since many teachers have little to no actual experience with inquiry.

*How professional development can help overcome hurdles to implementing discipline-specific reform*

There have been considerable efforts made to provide preservice and inservice teachers with professional development in order to contend with the numerous barriers faced when implementing science education reform, but these efforts often require substantial time investment on the part of both the practicing teacher and the supporting mentor. The results of these efforts indicate that teachers do not necessarily alter their practice even though they may report a change in their beliefs of how science should be taught (Schneider, Krajcik, & Blumenfeld, 2005, p. 285). However, other studies have demonstrated that when teacher education materials are generated and utilized with other forms of professional development (e.g., opportunities to reflect on enactment) teachers are given greater opportunity to enact reform (Schneider et al., 2005). Blancher, Sutherland, and Granger (2008) found that after engaging teachers in a science research experience designed to give both authentic science practice as well as an analysis of the type of inquiry inherent to this research, the teachers "changed to be much more student centered, with a strong focus on students actively conducting investigations" (p. 355). Penuel, Fishman, Yamaguchi and Gallagher (2007) found that after inquiry professional development was given to practicing teachers, implementation was critically dependent on the teachers having time to plan how and when to implement it as well as having technical support during implementation.

Researchers indicate that for elementary school teachers who lack a science background, professional development efforts geared towards building a better understanding of the nature of science (NOS) (also referred to as inquiry) are not always successful in long-term retention of proper notions of this topic (Akerson, Abd-El-Khalick, & Lederman, 2000), especially if they are given on a short-term basis such as one part of a teaching methods course or a workshop. However, providing ongoing assistance while these teachers are actually practicing allows them to build, reflect upon, and teach appropriate conceptions of NOS using "inquiry science methods" (Akerson & Abd-El-Khalick, 2003). Kielborn & Gilmer (1999) reported that actually engaging preservice teachers in investigations that involved the process of science enables them to "…internalize and transform new information for their own use and understanding" (p. 93) and therefore have a greater ability to teach science as inquiry to their students.

A more recent study by Park Rogers and Abell (2008) echoed this notion: "Not understanding inquiry teaching can make it difficult to translate one's beliefs about the nature of scientific inquiry into the practice of inquiry teaching" (p. 594). Even when preservice teachers have a science background, however, conceptualization of inquiry does not necessarily arrive any easier. In a study of 14 Master of Science students in secondary science teaching in which all participants held science degrees, Windschitl (2004) found that when actually engaging these students in inquiry activities, they tended to follow a "technical procedure" to the inquiry investigations they were asked to design. They struggled with actually enacting an inquiry experience that had theoretical grounding. He concluded that despite their science backgrounds, these students struggled with asking a good question and designing a study to test that question, and that these struggles with enacting "authentic" inquiry in the classroom must be taken into account when constructing preservice teaching courses:

> From a constructivist perspective, we know that preservice experiences can be best designed only if we first understand the frameworks of knowledge that preservice teachers bring with them to the program and the broader culturally reinforced models that maintain everyday ways of thinking about the disciplinary activities of scientists. (p. 508)

Windschilt also reported a number of additional factors that may influence preservice teachers' conceptualizations of inquiry including how they were taught (i.e., who they observed teaching) in K-12 education, how their undergraduate laboratory courses were taught and the roles student took within these labs, and their undergraduate coursework in a teacher education program (Windschilt, 2003).

As just presented, researchers indicate that multiple considerations must be taken into account when developing professional development experiences for teachers attempting to implement science education reform. While all of this literature follows from studies of K-12 teachers, it can be applied to new graduate student instructors as well. For this growing novice teacher population, little pedagogically specific teaching preparation has been documented. The forthcoming section of the literature review introduces this void in higher education teacher education research.

### *The need for graduate student instructor teaching preparation*

To account for classroom anomalies, it is sometimes wryly noted that college teaching is the only profession requiring no formal training of its practitioners.
(Nowlis, 1968)

Graduate student teaching assistants (TAs) have a significant history in higher education instruction that dates back to the late 1700's (Hendrix, 1995). Today, graduate students continue to comprise a significant portion of undergraduate teaching faculty at most higher education systems in the United Sates, especially at large research institutions (Marincovich, Prostko, & Stout, 1998). As detailed in Cavell (2000), the American Association of University Professors 1995 report described a 35% increase in numbers of graduate student instructors at colleges and universities from just 20 years earlier. There is much agreement that this significant jump in numbers of graduate student instructors will only expand as higher education institution costs continually increase; this phenomenon will especially be felt at large research institutions where full-time faculty face increasing demands to undertake and publish research (Boyer, 1991 as cited in Shannon, Twale, & Moore, 1998; Sykes, 1988). These trends are also being felt in other countries, and U.S. models of graduate student teaching assistant preparation are being used to guide their practices (Park, 2004).

For many of these research-oriented colleges and universities, teaching assistants are often viewed as “cheap instructional labor” (Nelson, 1995, p. 19). For example, a survey completed in 1991 of 118 public and private United States higher education institutions revealed that “…68 (93 percent) of the responding institutions said laboratory instructions is done primarily by graduate teaching assistants, however other personnel frequently are involved as well” (Sundberg and Armstrong, 1993, p. 145). In 1995 at the University of Illinois at Urbana-Champaign, TAs taught 2/3s’ of undergraduate courses offered (approximately 500 courses per year) (Nelson, 1995, p.20). Sykes (1988) explained that the main reason that graduate assistantships mean anything at all to most research faculty is because these faculty experience “THEFT… The Historic Escape From Teaching” (p. 36) where teaching falls down the chain of faculty concerns. Should these numbers continue to grow, the need for TA preparation in pedagogical methods through professional development will continue to need to be addressed.

Researchers have demonstrated that regardless of discipline, graduate student instructors desire and request teacher preparation and mentoring, especially at a discipline-level (Diamond & Gray, 1987; Jones, 1993; Worthen, 1992), but this teacher education can sometimes be hard to come by (Prieto & Meyers, 1999). Many higher education institutions have made efforts to address these wishes and appeals through two different types of teacher training programs: university-level or departmental-level (Shannon et al., 1998). University-level training, provided by various higher education faculty and administrators, is generally designed to reach graduate student instructors across disciplines and is often completed in one session (e.g., one full day or less). The focus of this now common preparation tends to encompass administrative and managerial classroom practices rather than the development of instruction-specific teaching practices (Gray & Buerkel-Rothfuss, 1991) such as such as inquiry pedagogy.

In contrast, preparation offered under the heading "departmental-level" varies from "…brief general orientations to structured teaching practicum supervised by faculty mentors" (Shannon et al., 1998, p. 441). The latter part of this continuum is still somewhat uncommon to find, although efforts have been made to provide ongoing, "sustained" professional development. For example, Belnap and Withers (2008) describe an effort that focuses on consistent, pedagogical discourse amongst graduate student instructors and faculty who together view and discuss video tapes of the graduate students' teaching. This lack of sustained mentorship occurs despite the fact that TAs consistently report a desire for additional departmental training and faculty mentorships (Jones, 1993) and that multiple benefits of strong mentorship for graduate student instructors have been well documented (Boyle & Boice, 1998). Unfortunately, because mentoring TAs (or any student) is time consuming, the number of faculty willing to provide this one-on-one professional development is low, especially in research institutions where faculty emphasize publish or perish mentality (Shannon et al., 1998).

When TAs are not afforded teaching preparation, they may lose the chance to obtain valuable forms of feedback from mentors  or peers; even brief teaching education preparation has been found to improve teacher efficacy (Prieto & Meyers, 1999). Instead, their training often comes from trial and error experiences in the classroom (Shannon et al., 1998). It has been determined, however, that these abrupt teaching experiences can be beneficial. With increased teaching experiences, TAs mature as instructors (Sprague & Nyquist, 1991) and have reported better attitudes toward teaching (Prieto & Altmaier, 1994,). However, Davis and Minnis (1993) report that the heavy class and/or research loads placed upon TAs as soon as they enter graduate school do not allow them to teach effectively, and those that actually wish to pursue a teaching career face limited options for long-term professional development. These authors feel that graduate school faculty should be preparing their graduate students for higher education faculty positions as opposed to providing them with only enough training to get through their current TA position.

A recent thrust to better prepare STEM (Science, Technology, Engineering and Mathematics) graduate students for future faculty roles (and therefore implementation of science education reform in teaching) has been through graduate student – K-12 teacher partnerships. Examples of these programs include Graduate Teaching Fellows in K-12 Education (GK-12) funded through the National Science Foundation (NSF) (Trautmann & Krasny, 2006) and the Partners in Inquiry (Pi) program through the University of South Carolina. In these programs, STEM graduate students are paired with K-12 science and math teachers for a designated period of time (e.g., one full academic year). The graduate students provide science content expertise to

K-12 educational settings and develop their inquiry teaching skills through practice, reflection, and feedback (Stiegelmeyer & Gilmore, 2010) with partner teachers. Teachers and graduate students may teach inquiry lessons that have already been created or may work together to create and implement new ones (Trautmann & Krasny, 2006). Studies on the effects of these programs on teacher beliefs and efficacy in the STEM students are just emerging (Stiegelmeyer & Gilmore, 2010) but indicate that prior teaching experience may only moderately influence use of inquiry-teaching behaviors. Additionally, gains in frequency of use of inquiry teaching skills may be positively correlated with frequency of peer and non-mentoring faculty interactions regarding their teaching. Finally, these types of partnership experiences may help STEM future faculty learn the importance of students being able to determine their own questions of interest for study. Other positively affected teaching characteristics of graduate student instructors include improved teaching ability, better research practices, interest and skill in outreach, consideration of teaching as another career goal, and a better ability to manage multiple tasks and responsibilities (Trautmann & Krasny, 2006).

Another recent form of future faculty professional development has been through efforts to assist science graduate students better handle the “synergy” of teaching, learning, and research (Brower, Carlson-Dakes, & Barger, 2007). For example, through the Delta program, graduate students, faculty, staff and postdoctoral associates engage in an intensive learning community that uses multiple educational strategies to improve teaching and research at the higher education level.

*Why study teacher training programs for graduate student instructors?*

> “…if the professional preparation of doctors was as minimal as that of college teachers, the United States would have more funeral directors than lawyers” (Association of American Colleges as cited in Rushin, Saix, Lumsden, Streubel, Summers, & Verson, 1997, p. 86).

Inquiry is a component of major science education reforms but is not a clear, unambiguous term within these efforts. Much research on encouraging teaching of inquiry has been undertaken with teachers and students of K-12 classrooms, but little exists for graduate student teachers of undergraduate courses. This K-12 research can inform the preparation of graduate student teachers because commonalities exist between the hurdles that K-12 preservice and inservice teachers face when implementing reform and those which novice graduate student teachers experience when teaching undergraduate laboratory courses. Developing pedagogically specific teaching preparation for graduate student instructors, and studying the effectiveness of that preparation, is critical to the efficacy of implementation of science education reform at a higher education level.

One can clearly see that graduate student instructors are at a large disadvantage for successful implementation of science education reform. They are hampered by the same difficulties that new K-12 teachers experience, yet they face these obstacles with little sustained teacher education support. How can we expect that college undergraduates will receive adequate science instruction if their graduate student instructors are unprepared to teach? Systematic studies of teaching preparation for graduate student instructors need to take place in order ensure that this large body of higher education instruction is met with pedagogically sound, sustainable preparation.

Given that the likelihood of teaching as a faculty member after receiving a Ph.D. is high (Golde & Dore, 2001), a pedagogically and discipline-specific teaching preparation program offers essential validation for critical professional development experiences for graduate student instructors. In reference to inquiry laboratory courses, Wood (2009) concurs that "Implementation of inquiry-based courses in place of traditional labs may require additional resources, including more extensive training of TAs" (p.24). It is the goal of this dissertation to carefully examine this type of preparation program in the context of novice graduate student instructors assigned to teaching inquiry-based introductory biology laboratories to undergraduate non-science majors.

# CHAPTER 3

# ADVANCING INQUIRY TEACHING AMONG BIOLOGY GRADUATE TEACHING ASSISTANTS[1]

[1]Miller, K.R. & Oliver, J.S. (2010). *Unpublished dissertation, The University of Georgia.*

Note to reader: This is the first of three chapters that are intended to be submitted as manuscripts to professional journals. This manuscript presents analysis of the impacts of a teaching preparation program developed to help novice graduate student instructors (GLAs) teach introductory undergraduate biology laboratories with an inquiry focus to non-science majors. The second manuscript will present analysis of how these same GLAs came to conceptualize teaching science as inquiry over the course of their teaching assignment. The final manuscript will present an analysis of the GLAs' enactment of those conceptualizations.

*Introduction*

Science education reform efforts have been paramount in K- 12 education for over 20 years, but these efforts also have been developed in a parallel fashion for the higher education curriculum. One focus of more recent efforts has been to provide students with inquiry experiences: opportunities to practice science as it is undertaken by scientists, thereby engaging in the process of science (see Yang & Heh, 2007, p. 452, for characteristics of the processes of science). The *National Science Education Standards* (*NSES*) suggest that as a student activity, inquiry is "multifaceted" and involves many stages of "doing science" including creating questions from observations, researching established knowledge on a topic, planning and carrying out investigations, and disseminating results (NRC, 2000). Engaging in these types of activities challenges students to think beyond memorization of facts and develop higher order thinking skills in order to learn science content and concepts. This study is a report of research that is centered on an effort to encourage laboratory teaching in college level biology to be more focused on scientific inquiry.

Teachers who accept the challenge of providing students with opportunities to experience the aspects of science described above need to engage in teaching science as inquiry (Chiappetta, 1997). When instructors teach science as inquiry, they employ instructional strategies that support lessons designed to engage students in the processes of science. They work to develop students' metacognitive skills needed to learn how to ask questions and also justify explanations or ideas (Chiappetta, 1997). The National Research Council (NRC, 1996) describes a continuum of inquiries in which students might engage that are based on the five essential features of classroom inquiry (NRC, p.29, 2000). According to this model, if an instructor engages students in some of the features, then they are leading partial inquiries; full inquires meet all features. Guided inquiry experiences provide students with varying levels of scaffolding to meet these essential features; if little to no guidance is given the investigations are considered open inquiry (NRC, 2000). In this study, I refer to "inquiry" within the framework of teaching science as inquiry as qualified by Chiappetta (1997) and the *NSES* (NRC, 2000).

Numerous studies have documented the vast number of undergraduate courses that are taught by graduate students (Belnap & Withers, 2008; Hiimae, Lambert, & Hayes**,** 1991; Marincovich, Prostko, & Stout, 1998). These instructors are frequently entering into a graduate program directly from earning their undergraduate degrees and are therefore often close in age to their undergraduate students. Additionally, these instructors are generally new to teaching and tend to lack any pedagogical coursework or teaching preparation (Golde & Dore, 2001); this is not unlike higher education faculty in the sciences (Golde & Dore, 2001; Sunal et al., 2001). Given titles such as GTA (graduate teaching assistant) or TA (teaching assistant), these novice teachers are often expected to carry out all responsibilities that higher education faculty would assume as instructors of lecture courses. If, in fact, a majority of these graduate students are likely to assume faculty positions at higher education institutions (Golde & Dore, 2001), it is reasonable to expect that these future faculty will be able to adequately teach science as inquiry.

Yet a lack of training experiences exist for these instructors to meet the goals of the *NSES*, despite the fact that graduate student instructors consistently report the desire for some sort of teacher training that extends beyond half- or one-day university orientations (Diamond & Gray, 1987; Jones, 1993; Worthen, 1992).

*Introductory instructional biology laboratory courses at The University of Georgia*

The National Research Council has specifically targeted the instructional undergraduate science laboratory as a place where science education reform should be implemented (NRC, 2000). By engaging students in laboratory activities that allow them to learn through engaging in the processes of science, students are given opportunities to experience how scientists learn content and concepts in their discipline. At the University of Georgia (UGA), Division of Biological Sciences, faculty and staff have worked to convert four undergraduate introductory laboratory courses (two for science majors and two for non-science majors) from a "cookbook" style curriculum (i.e., one containing explicit instructions for conducting verification experiments that lead to pre-determined results) to one where students are actively involved in design of experiments, data collection, and argumentation. Concurrently, preparation to teach these laboratories has greatly expanded. What began as a meaningful attempt to teach graduate laboratory assistants (GLAs) how to teach the inquiry-activity laboratories via written notes and verbal guidance has changed into a more formalized process. Currently, GLAs teaching non-science major introductory-level biology laboratory courses structured around cellular and molecular biology receive teaching preparation that includes an introductory instructional workshop on the multiple facets of inquiry, ongoing reflective discourse with peers and teaching mentor, and mentor and peer observations.

This article is a report of the study of different aspects of the preparation program that impacted the GLAs, including how the GLAs responded to the preparation in terms of teaching skills developed, teaching confidence, views of science, scientific inquiry and teaching science as inquiry, and the roles of students and teachers in introductory biology laboratory courses. The significance of this study lies in the potential for the analysis of findings to contribute to a paucity of literature on the relative effectiveness of graduate student teacher preparation and a growing literature on pedagogically-grounded preparation for future science faculty. Additionally, analysis of findings may also contribute to research studies on undergraduate learning, laboratory course design, and graduate students' skills as scientists and researchers. The teaching preparation program was evaluated primarily through qualitative analysis of quasi-structured interviews and was supported with analysis of data from teaching observations as well as pre-post demographic and self-efficacy surveys.

The study was designed around the following research questions:

1. What aspects of the teacher preparation program impacted the following GLA characteristics, and how?

a. knowledge of scientific inquiry and how to teach in ways that enable students to build understanding of science as inquiry

b. confidence towards teaching (in general) and towards teaching inquiry

d. ideas of what science is and how it should be learned

e. views of the role of a teacher and of a student

f. ability to teach science as inquiry

g. what other factors, if any, impacted these same teacher characteristics, #1, and how?

*Who are our instructors?*

At UGA, the introductory biology laboratory sections are generally taught by graduate students seeking either M.S. or Ph.D. degrees in a biological science field, i.e., microbiology, or genetics. Approximately 40-45 of these GLA instructors are needed to teach the more than 90 laboratory sections across four different courses offered each fall and each spring semester. Depending upon one's teaching assignment, each GLA is assigned to teach either two or three laboratory sections per week, and each section generally has 20 students. The GLAs teach for the Division of Biological Sciences for a variety of reasons that include departmental requirements and lack of research funds available to support students on research assistantships. GLAs are currently listed as 90% instructor of record for their laboratory sections (lecture faculty are listed as the other 10%) and are considered responsible for teaching, grading, and conferencing with students. Instructional and administrative support is given to the GLAs by a Laboratory Coordinator (me) and by lecture faculty.

In a typical semester in which GLAs are assigned to teach for me, over two-thirds are in their first or second semester of graduate school. It is common that at least one third to one half of the GLAs have never taught before and that the remaining GLAs have taught either previously for the Division of Biological Sciences, for their home department, or at another higher education institution. International students can comprise up to 20% of the GLA population in a given semester, and it is common for some of these students to have recently arrived in the United States to start their graduate work.

*BIOL 1103L*

BIOL 1103L is one of the two introductory biology laboratory courses for non-science majors offered at the University of Georgia; its content focus is cellular and molecular biology.

The laboratory manual for this course underwent a conversion to an inquiry laboratory approach in the spring semester of 2006. Currently, in a 15-week semester, six content topics are covered (*scientific investigations; enzymes (Carb Cutter), antibiotic resistance, water quality, genetic testing (Case It), and Mendelian genetics (C. elegans)*); each laboratory topic is covered in two or three weeks. This allows time to delve into content in greater depth than if laboratory topics change from week to week. It also allows for what the GLAs refer to as "roll-over" time: that is, time for students to finish their experiments in a second or third lab session if they were not able to finish in the first one. This is considered by the GLAs to be invaluable because students are not confined to designing, implementing, and analyzing results of an experiment in one laboratory session; having this breathing room lessens stress on both the students as well as the GLAs.

In addition to these changes in how science teaching is conceptualized within this laboratory course, changes have also taken place in how content and conceptual understanding are assessed. As inquiry-based activities encourage development of critical thinking skills, then assessment should do the same. Rather than continuing a traditional means of assessment that focuses on passive learning experiences (e.g., weekly quizzes in multiple choice, true/false or fill in the blank format, a formal laboratory report), formal assessment is structured after the guidelines given by the Writing Intensive Program (a program within the Franklin College of Arts and Sciences, UGA). Approximately 60% of the BIOL 1103L course grade is earned through different types of writing assignments. Some assessments used are formative writing assignments; for these, students earn a small percentage of points for their efforts to explore new ideas and articulate their ideas about a topic at hand. Others assessments are summative writing assignments, worth a greater percentage of points, that challenge students to demonstrate proficiency in content and process skills. Additional assessment points are given for pre-laboratory assignments and group presentations. Most BIOL 1103L activities are deductive; students know the topic that they will study before engaging in their investigatory activities.

I considered three of the six laboratory series (*enzymes*, *antibiotic resistance*, and *Mendelian genetics*) to have a greater student-generated experimental design emphasis than the other three series, and I therefore believed that students would have greater involvement in the five essential elements of inquiry (NRC, 2000). In these laboratory series, students work in pairs or groups to design an experiment that meets the given objective for each particular laboratory. They must complete their designed task using available equipment and materials, and they are given guiding questions providing them with main points to consider when developing their experiments. The other three laboratory series (*scientific investigations, water quality, (Case It) genetic testing*) do not engage students in a full experimental design process but instead have students taking part in other forms of active learning activities (e.g., library or online research, collecting field data, group presentations, investigating genetic diseases through a simulated PCR/gel electrophoresis software program) to learn about the content topics. These activities tend to focus on one or two aspects of designing or implementing an investigation such as data collection and analysis, and interpretation or communication of results. Additionally, the progression of the laboratory series is tied to such factors as consideration of when the same topics might be covered in the accompanying lecture course and the timing of some activities (e.g., one week of the *water quality* laboratory series is field-based and so must occur when there are longer daylight hours).

*Purpose and rationale*

If undergraduate science education reform purports that undergraduates should receive science teaching by instructors who are knowledgeable about science content and pedagogy, we cannot expect novice science instructors (i.e., graduate students often fresh from their own undergraduate degree programs) to tackle this reform on their own. Tanner and Allen (2006) stated:

> Universities and colleges thus have a special obligation to provide the best possible learning environment for all students, even in the face of limited resources, particularly at underfunded state institutions…real progress might be made in the teaching of the science by integrating pedagogical training into the graduate experiences of our future science faculty. By providing our budding Ph.D.s, our future faculty, with meaningful exposure to "best practices" in a variety of teaching settings, we could begin to articulate the science education pathway for students, K-16, and transform college and university-level teaching into a significantly better trained profession .(p.2)

Evaluation of the teaching preparation program described in this study by the participating GLAs it holds practical significance as evidence of benefits for a discipline- and pedagogically–specific preparation program may be substantiated; this would suggest a potential template for a graduate student instructor teaching preparation program for other inquiry science laboratory courses. It would also simultaneously identify problematic circumstances in developing and implementing this preparation.

Additionally, the findings of this study may affect audiences other than graduate student instructors. Science graduate students and their faculty advisors would be provided with a pedagogically-reasoned teaching preparation program that would not only better enable the graduate students to adequately fulfill their teaching assistantship responsibilities but would also help prepare them for future faculty positions that require teaching. Faculty advisors have reported that their science graduate students who engaged in "intensive" K-12 outreach activities accompanied by pedagogically-focused workshops and seminars showed improvement in their graduate research. Examples of progress were seen in "broadened perspectives on…research questions" and a "reconnect with the basic science behind their specific fields" (Trautmann & Krasny, 2006, p. 161). Seemingly, then, a strongly endorsed teaching preparation program for inquiry science by the graduate student instructors themselves as well as their faculty advisors provides leverage when arguing that more time and money be invested in pedagogically appropriate teacher education offerings. Additionally, it is critical to the efficacy of a curriculum intended to provide students with experiences in learning science by doing science that the designers of that curriculum understand how the graduate student instructors come to develop a conceptualization of teaching science as inquiry. Finally, undergraduates would benefit in their learning experiences if their instructors are adequately trained to teach content by the means in which it is presented in the laboratory manual.

*Theoretical framework*

I chose to take a constructionist stance informed by a symbolic interactionist perspective for this study. These approaches to planning and carrying out this study enabled me to act as a participant observer and obtain data that came in the form of knowledge about the GLAs actions and behaviors as they interacted with me, students, and one another. The meanings and patterns of these interactions were therefore "developed and transmitted within an essentially social context" (Crotty, 1998, p.42) but also constantly changed as the GLAs and students progressed through the semester. The actions of the GLAs fit within the framework of symbolic interactionism as explained by Benzies and Allen (2001) because the understandings and assumptions that the GLAs developed as they advanced through their inquiry teaching experiences were often revisited, reinterpreted, and then redefined.

The lens of a symbolic interactionist perspective is frequently used in studies that employ constructionism as an epistemology because both focus on the building of meanings through interactions between humans and their surroundings. The three foundations of symbolic interactionist perspective include 1) “that human beings act toward things on the basis of the meanings that these things have for them”; 2) “that the meaning of such things is derived from, and arise out of, the social interaction that one has with one’s fellows”; and 3) “that these meanings are handled in, and modified through, an interpretive process used by the person in dealing with the things he encounters” (Blumer, 1969, p. 2 as cited in Crotty, 1998, p.72). Therefore, constructionism and symbolic interactionism act together to help define meanings as they are socially constructed.

In this study, the primary source of data for the analysis were transcripts from multiple, individual interviews with the GLA participants (three per GLA participant). These rich sources of data were transcribed, coded for patterns, and then analyzed for emergent themes. To establish further confidence in these themes, they were compared to additional data sources including pre- and post-semester GLA surveys, classroom observations of GLAs and students, and informal discussions with GLAs. Through these interactions, surveys, and observations, I hoped to reveal patterns within the GLAs’ views of the teaching preparation program, of the actual teaching of science as inquiry, and of any other factors critical to determining the relative “success” of this program are present in the data. The presence or absence of patterns is critical to the development and implementation of the teaching preparation program.

## *Methods*

### *Researcher role*

During this research study, I served as the Laboratory Coordinator for introductory instructional biology laboratory courses offered through the Division of Biological Sciences at UGA. Part of my job responsibilities include hiring, supervising, and mentoring the more than 40 GLAs who teach these courses. Given these expected job duties, I had to constantly re-examine my potential bias in data collection, analysis, and interpretation. For example, it was not always possible to collect observational data as a researcher; GLAs would sometimes ask me to help with an aspect of the laboratory that they were teaching while I was attempting to collect data. In other instances, a GLA might ask me to assist a group of students that I was observing during the data collection process. Careful notation of these circumstances was made throughout the semester in order to document when analysis of data needed to have particular precaution taken. Additionally, I was a graduate student at the time of the study, adding another potential layer of complexity to data collection and interpretation. I had to evaluate my role in discussions with GLAs as sometimes I would slip in and out of discussions taking the role of a supervisor, researcher, and fellow graduate student. I managed these sensitivities to the project by consistently questioning and discussing my methods and data interpretations with faculty within the Division of Biological Sciences as well as in the Science Education program at UGA.

### *GLA preparation protocol*

The instructional components of the implemented preparation program are outlined in Table 3.1. The basis for the chosen elements partially came from my experience of working closely with the GLAs within the duties of my job and therefore responding to their support

Table 3.1
*Components of GLA teacher preparation program*

| Component | List of subcomponents or actions within larger component |
|---|---|
| EVENT 1: 3-hour training session at beginning of semester | |
| Pre-semester surveys | Demographic survey |
| | Response to inquiry teaching methods vignette |
| | *TSI* self-efficacy instrument |
| Presentation and subsequent discussion of presentation pieces | Chances of being future faculty/teaching as part of career |
| | Defining inquiry science |
| | Inquiry vs. traditional labs: differences in student and teacher roles, lab activities, lab manual format |
| | Benefits and limitations of teaching and learning through inquiry |
| | The “fit” of teaching and learning science as inquiry in relation to course mission/student goals and how we expect GLAs to serve in this mission |
| | Assessment strategies to determine if students are achieving intended learning goals (e.g., writing, verbal pre-labs, discourse, informal vs. formal) |
| | Current national science reform efforts |
| | Recognition of inquiry activities within a given lab |
| Engage in sample inquiry Activity | |

Table 3.1 continued
*Components of GLA teacher preparation program*

| | |
|---|---|
| EVENT 2: Continuing events throughout semester: Mini-teacher education sessions given within weekly laboratory preparation sessions. Undertaken to reinforce Event 1 session topics and as a means to examine these topics in context as they are put into practice | |
| | Watch and discuss video clips of teaching in both inquiry and traditional labs on same content topics (in the context of UGA) |
| | Researcher demonstrates how GLAs would lead a particular lab activity |
| | Researcher discusses teaching strategies presented in weekly instructional teaching notes |
| | Reflective discourse: During weekly preparation sessions GLAs orally reflect on and discuss teaching dilemmas and successes of teaching science as inquiry |
| EVENT 3: Trainer and peer teaching observations/interviews | |

requests. Other components of the training come from science professional development literature. For instance, Loucks-Horsley, Love, Stiles, Mundry, & Hewson (2003) emphasized that effective professional development should be based on "…needs, contexts and circumstance of participants" (pp. 31-32). They acknowledged that a critical emphasis in professional development should be for teachers to understand student learning and thinking (e.g., learning is constructed over time and therefore changes over time) and that this may often entail changing teacher beliefs about how students learn (e.g., teachers often believe that students who are not learning are not motivated to learn). Additionally, researchers have suggested that teachers should receive professional development support through subject-specific induction programs (Luft & Patterson, 2002) that emphasize development of content knowledge and skills in how to assess student learning (Loucks-Horsley et al., 2003) as well as circumstances under which teachers change beliefs and classroom practices (Akkus, Gunel, & Hand, 2007, p. 1746).

*Participant selection*

Each fall semester, approximately 10-12 GLAs teach BIOL 1103 laboratories (the number of GLAs is determined by the number of laboratory sections offered). Each section meets once a week for one hour and 55 minutes over the course of a 16-week semester. It is typical for one to three of these graduate students to have already taught this laboratory course. This study was conducted in fall 2009. At that time, 11 GLAs were assigned to teach BIOL 1103 laboratories. Three of them had already taught this particular BIOL 1103L course.

The three-hour workshop component of the semester-long preparation was conducted at the beginning of the semester before GLAs were given an opportunity to view the laboratory manual or teach any laboratories. At the beginning of this workshop, a research study consent form was given to all GLAs requesting their participation in the research study, per IRB guidelines for research involving human subjects. The consent form outlined expectations over the course of the semester if they agreed to participate in the study. The forms were collected and quickly reviewed to ascertain who agreed to participate in the study; all 11 GLAs agreed to participate. Initial data collection instruments were then distributed to all GLAs. GLAs who had previously taught the laboratory course and who agreed to participate in the study were not excluded from any preparation given over the course of the semester but were excluded from consideration as research participants.

A pre-semester demographic survey given was then administered to all GLAs and included questions related to demographic characteristics, experience with teaching and inquiry, and personality-related characteristics (see Table 3.3 for demographic data relevant to this study). After the workshop was complete, the surveys were reviewed and four novice BIOL 1103L GLAs were selected as study participants. GLAs marked with an (*) next to their names indicates selected participants. Refer to Appendix A for the entire pre-demographic survey. The main determining factors in participant selection included gender (desired to represent both males and females), past teaching experience, past experience with inquiry, reported likelihood of teaching in the future, and initial "buy-in" to inquiry teaching methods. This last item was based on written responses to a vignette (see Appendix B) which described a teacher using questioning strategies geared to elicit critical thinking from students. In this vignette, Tom (the teacher) realized that a critical component of some of his students' experimental design was missing. Rather than telling them what was missing, Tom uses guiding questions to help students re-evaluate their design in order to figure out the problem in their experimental design. I attempted to use maximum sample variability of these GLA characteristics when selecting participants in order to tell the most about the impacts of the teacher education provided.

Additionally, as I worked as the Laboratory Coordinator for introductory instructional biology laboratory courses for UGA at the time of the study, times and days of GLA observations were also taken into consideration when selecting GLA participants. For each of the four GLAs selected as participants, initial data collection plans entailed observing all three laboratory sections that a given GLA taught during the duration of three particular laboratory topics (e.g., each of the three weeks of the *enzymes* laboratory series; each of the two weeks of the *antibiotic resistance* laboratory series; each of the three weeks of the *Mendelian genetics* laboratory series). The reason for the focus on these three laboratory series was because I believed that they demonstrated the greatest latitude of opportunity for students to engage in the experimental design process and therefore the greatest breadth of the five essential features of inquiry (NRC, 2000, p. 25). After the first set of observations for the e*nzymes* laboratories, it was decided that due to the time demand involved with observing 12 laboratory sections for a multiple successive week period, I would observe two of each GLAs' assigned three laboratory sections for each of the remaining laboratory topics (i.e., *antibiotic resistance* and *Mendelian genetics*). To reduce chances that observations of teaching and student behaviors were due to the actual laboratory period (e.g., time and day), for the *antibiotic resistance* laboratory series, I conducted observations for the first and second laboratory sections for two of the GLAs and the first and third laboratory sections for the other two GLAs. I switched this order of laboratory observations for the *Mendelian genetics* laboratory series. In two circumstances this plan did not work due to one of the GLAs not being able to teach for reasons outside his control. In this case, I adjusted my observation schedule to meet his actual teaching sessions.

*Data collection instruments and analysis*

*Interviews.* I conducted quasi-structured interviews with the four GLA participants at three points during the semester: the beginning of the semester (within the first 2 weeks), midpoint in the semester (around week 7 or 8 of the semester), and the end of the semester (after the last laboratory has been conducted). These time points were chosen to account for change in GLAs' experiences during the semester rather than just a beginning and end evaluation (when valuable data of how and why GLAs' experiences are changing might be missed). Quasi-structured interviews were used so that a basic framework of questions guided the interview process but also allowed the interviewer to expand upon particular responses of interview participants. ATLAS.ti.6 software was used to aid analysis of interview data for emergent themes in responses across GLAs. Interview items are listed in Table 3.4.

Once interviews were transcribed, I coded data in the transcripts according to the three stages of data analysis presented by Strauss and Corbin (1998). In this model, data are coded in three stages: open coding, axial coding, and selective coding. I read through all transcripts for one GLA participant. I then began analyzing data by creating broad categories of variables (i.e., open coding). Once I finished with the GLA's transcripts, I used the same process for the other GLAs' transcripts. After this initial coding, I reviewed the codes to determine if I should keep the categories, merge some, or eliminate some. Next, using axial coding strategies, I revisited the categories to determine if relationships existed between them (i.e., if one category appeared to caused another to occur) and how these relationships related to my dissertation focus. Finally, I used the categories and the relationships between them to generate the themes presented as units of analysis in my dissertation (i.e., selective coding). It was through these themes that I was able to analyze and understand all categories and their relationships.

Trustworthiness during collection and analysis of interview data was established through member checking. As seen in Table 3.4, numerous interview questions were asked in all three interviews with each GLA. Therefore, for each GLA, I reviewed audiotapes of completed interviews before engaging in subsequent ones. When a question was asked in these later interviews, I waited until GLAs had finished responding before I reminded them of their previous answers to the same questions. By doing this, I was able to review past responses and my interpretation while gaining GLAs' contributions of clarification.

Triangulation of interview data was completed with analysis of data pre- and post-semester GLA surveys, behavioral observations of GLAs, and informal discussions with GLAs.

*Surveys.* A pre-semester demographic survey was given to all GLAs at the onset of the initial workshop to ascertain the following information provided in Appendix A. At the end of the semester, a post-semester demographic survey asked all GLAs for much of the same information as the pre-semester demographic survey, but new items were included as well (refer to Appendix C).

The *TSI* (*Teaching Science as Inquiry*) survey (Smolleck, Zembaul-Saul, & Yoder, 2006) was also administered to all GLAs as a pre- and post-semester survey in order to ascertain how confidence to execute inquiry instruction changed over the semester. This instrument was developed to represent a field-specific (science), pedagogical-specific (teaching science as inquiry) self-efficacy instrument. The pedagogical specificity is the *TSI*'s primary characteristic that sets it apart from widely utilized, self-efficacy instruments that are more "global" in nature; most of these instruments address teacher beliefs towards teaching (across all disciplines), and only a few address teaching in science. The purposes of and recommended decisions for which the *TSI* is valid, as stated by the author/publisher are:

> "The purpose of the study was to create an instrument that measures preservice teachers' self-efficacy in regard to the teaching of science as inquiry…there is not an instrument to measure self-efficacy and its impact on the teaching of science as inquiry…by developing, validating, and establishing the reliability of an instrument measure self-efficacy beliefs of preservice elementary teachers with regard to the teaching of science as inquiry…we hope this instrument will provide a foundation through which researchers can identify certain individuals and investigate the connections between beliefs and actual teaching behaviors and classroom practices." (p. 144-145)

In the case of the current study, I felt that the use of the *TSI* would be the most effective self-efficacy measurement of teaching science as inquiry because its premise was based on the same conceptual framework that I am employing (i.e., teaching science as inquiry) and because collecting this valuable data could potentially be used in future studies that focused on links between GLAs' self-efficacy towards teaching science as inquiry and enactment of these beliefs.

*Observations.* Observational data were collected using the *TA-IOP*, a tool that uses both quantitative and qualitative means of recording GLAs' strategies for leading inquiry activities and students' inquiry-based learning behaviors (Miller, Brickman, & Oliver, unpublished manuscript). It also allowed for a record of overall flow of the laboratory section that I was observing and post-observation discussion feedback notes between me and the GLAs.

*GLA participants*

Tara was the only GLA participant who brought formal teaching experience to this study. She had recently completed her M.S. degree in Cellular and Molecular biology and was beginning a Ph.D. program in Food Science. Her previous teaching experience was at the college level and included several semesters as a graduate teaching assistant (TA) for introductory *Anatomy and Physiology* (*A&P*) laboratory sections as well as an upper level undergraduate laboratory course, *Biology of Protists.* For *A&P*, Tara described her teaching experiences as carrying a traditional instructor role in the classroom: "…give them a PowerPoint and then teach them the lab" (pre-semester demographic survey, 08/09). *Biology of Protists* tended to be taught by engaging students in open-ended protist identification investigations and used traditional assessments of practical exams that identified organisms. Tara's role as a TA was strictly related to assisting students with protist identifications, leading help sessions, and grading papers.

Tara reported having no experience with inquiry and suggested that if a lesson included inquiry activities, "the lab wouldn't just entail memorization but would include critical thinking (e.g., short answer or essay type questions)" (pre-semester demographic survey, 08/09). Her descriptors of student and teacher roles in a typical instructional laboratory experience for undergraduates and in inquiry activities were almost identical: the teacher gives background lectures and helps students when they have questions, and students perform laboratory activities and answer follow-up questions. Tara was unsure at the beginning of the semester of the likelihood that she would teach as a future career, noting it was unlikely that she would become a faculty member. In response to the teaching vignette previously described, Tara responded that Tom's teaching methods were "okay" but that she would have been more direct in asking about a control; she would also require the students in the vignette to tell her why they should use a control and what the control in their experiment should be. In this way, she would "be sure they were going to perform the experiment correctly" (response to teaching vignette, 08/09).

Cameron came to this project with no formal teaching experience. He had taken a year off after graduating from college but had returned to the academy and was beginning a Ph.D. program in Marine Sciences. Cameron also reported having no experience with inquiry, although shortly into the semester realized that his introductory biology laboratory course taken as an undergraduate was inquiry-based. He reported that he just never knew "it had a name" and that his other introductory science laboratory courses such as chemistry and physics followed a traditional format (first interview, 08/09). Despite his reported lack of knowledge of inquiry, Cameron suggested that a lesson with inquiry activities might contain "hands-on labs and group activities" and described a typical instructional laboratory experience in biology for undergraduates as students and teachers taking passive learning and teaching roles: "Teacher goes over the lab for the day and then turns lab over to student to undertake. Teacher travels around answering questions and provides feedback" (pre-semester demographic survey, 08/09). His descriptions for inquiry activities given in his pre-demographic survey reflected more active roles for students and teachers:

> …students are active participants rather than passive listeners. Teachers provide general info but mainly step back to watch students find out information through activities. Teachers also serve to answer questions and help students understand why it is they are doing something (08/09).

Like Tara, Cameron reported that he was unsure whether he would teach in a future career and was unlikely to become a faculty member. In response to the teaching vignette, Cameron provided a summary of how Tom's teaching methods of redirection of questions, not interrupting the students, and not directly telling students what to do allowed for students to think through their experimental design more thoroughly. Cameron did not agree that the teacher in the vignette should have waited until the end to tell students to reconsider their experimental design: "I probably would not have asked the first question and focused on the need to improve the control" (response to teaching vignette, 08/09).

John was a first year graduate student in the Plant Biology Ph.D. program but had previously earned an M.S. degree in Plant Science. He entered this study with no teaching experience. He did not provide a guess as to what a lesson with inquiry activities might include or what the roles of a student and a teaching in an inquiry activity might be, and he reported having no experience with inquiry. Similar to Cameron's revelation that he had been involved in inquiry as it related to teaching, John reported soon into the semester that his research activities when earning his M.S. degree were "inquiry." John reported a high likelihood that he would teach for a career as a faculty member. A typical instructional biology laboratory experience for undergraduates, based on his experience, reflected passive teaching and learning: the student reads background material, listens to a professor give a general lecture, and follows a laboratory protocol. The teacher "is there to point out things and answer questions throughout the lab" (pre-semester demographic survey, 08/09). John felt the teacher in the inquiry vignette did an "appropriate" job because "instead of just giving them the answer he asked them questions that got them to think of other possibilities. I would have done something very similar if not the same" (response to teaching vignette, 08/09).

After completing college and working in the medical field for several years, Evan was beginning a Ph.D. program in biochemistry. Similar to John, Evan reported a high likelihood that he would teach for a career, would hold a faculty position, and did not have previous teaching experience. He did not give an answer to what a lesson would be like if it included inquiry activities what roles students and teachers might take in an inquiry activity. Evan reported that in typical biology instructional laboratory experiences, the professor gives an introduction "that students should be prepared for" as well as additional information (e.g. warnings) before "releasing" the student to work. The professor's role is to "monitor progress and help at any given point" (pre-semester demographic survey, 08/09). In response to the teaching vignette, Evan indicated that he "would simply state that a control needed to be added" (08/09). Due to the extensive first year coursework required by his home department, Evan had two course overlaps with our weekly preparation sessions and therefore would usually arrive late and have to leave shortly after, thereby only staying for about 20-30% of any given preparation session. This became particularly stressful for Evan as he was assigned to teach the first laboratory of the week; he personal course schedule was so full that we were unable to change his teaching schedule around to avoid this.

*Findings*

In the following sections, findings are presented that arose from the analysis of data related to the impact of the teaching preparation program. The data analysis and subsequent findings are presented under specific topic headings. Within each heading, data analysis from all GLAs is presented individually and through cross-analysis. The first section of data analysis considers aspects of the teacher preparation program that impacted GLAs' knowledge of scientific inquiry and how to teach in ways that enable students to build understanding of science as inquiry. Next, GLAs' confidence towards teaching (in general) and teaching science as inquiry as well as ability to teach science as inquiry is discussed. This is followed by analysis of GLAs' views of how science should be taught. Finally, GLAs' ideas of student and teacher roles in introductory biology laboratories and factors outside the teacher preparation that positivity impacted all of these teacher characteristics are discussed.

*Views of science, scientific inquiry, and teaching methods that enable students to build understanding of science as inquiry*

In this section, findings are presented that arose from the analysis of data related to the impact of the teaching preparation program. Specifically, this section will examine how the workshop impacted GLAs' views of science, knowledge of scientific inquiry, and how to teach in ways that enable students to build understanding of science as inquiry. This section is constructed by separating the analysis for individual GLAs, but within each GLA's analysis, cross-analysis of GLA data is given as appropriate. For each GLA, findings that resulted from analysis of experience with inquiry are presented with examples from each GLA participant. These examples surfaced among the data as the most definitive and representative instances of how the GLAs' views of the teacher characteristics in this section changed over the course of the semester.

Tara began the semester stating that she didn't have any experience with inquiry and guessed that a lesson with inquiry-based activities would involve critical thinking skills such as mid- or high-stakes writing assignments. When asked in her first interview what the word inquiry meant to her, Tara gave an example of her changing views: "inquiry is just a question... I introduce an idea, I ask what they think, why they think it, where they think we should go from there" (first interview, 08/09). Halfway through the semester and at the end of the semester, she held firm to her ideas that inquiry was a teaching method, but she also explained another dimension of inquiry, that of a learning mechanism: "it is a method for me of how to get them to learn. And it's a method for them of how to learn….questioning them to make them think" (second interview, 10/09). To her, science was a "philosophy or way of thinking in which you use the scientific method to solve problems and discover things" in any discipline or in life in general (first interview, 08/09). This view did not change over the course of the semester.

Tara's views of teaching science as inquiry were enhanced by several aspects of the teaching preparation that she received. When asked how the teaching preparation program impacted her knowledge of scientific inquiry and how to teach in ways that enabled students to build understanding of science as inquiry, Tara initially focused her response on the initial workshop element of taking part in a sample inquiry activity. This was important to her understanding of teaching science as inquiry because at the time of the workshop, Tara was having difficulty visualizing what an inquiry activity might look like. She later broadened her response to this question to include the entire training wworkshop. At multiple points during the semester, Tara explained that she would have never thought about teaching biology through inquiry activities, but saw inquiry as beneficial because the interactions that were the basis of this laboratory course allowed her to better tell if students were learning. Tara also found the weekly preparation sessions and teaching notes to be helpful as they allowed her to starting thinking about methods to approach teaching content.

In response to most interview questions about impact of the preparation program, John reported that defining inquiry science was the most important factor that influenced any of his teaching characteristics discussed in this study (e.g., confidence, knowledge of scientific inquiry). John described the importance of defining inquiry science because he never knew there was a name "for what scientific inquiry was or that kind of teaching method" as he had only experienced the "cookbook method" when a student in instructional laboratory courses (final interview, 12/09). However, he felt he did experience learning science as inquiry in his laboratory with his own research but never having a name for it. John held an unwavering view of science throughout the semester: a structured, testable way of understanding the environment. However, like the other GLAs, his description of inquiry expanded slightly as the semester progressed. In his first interview, John described inquiry in a general manner: asking questions to find out information (first interview, 08/09). However, by midpoint in the semester, John described inquiry as a way for students to approach science. An example of John's views on the efficacy of this approach is seen in the following quote: to him, inquiry was "a double-edged sword. If it works, it seems to like really drive home the point. I think students seem to get more but at the same time, if they don't get it at all, it just doesn't seem to work and they get agitated" (second interview, 10/09). At the end of the semester, John focused his view of inquiry as a teaching method, one in which instructors might take different roles depending on their involvement in what students are learning. To exemplify his view, John referred back to his past research laboratory experience where he was pretty much left on his own to figure everything out and contrasted that to what we were doing with the BIOL 1103L students: giving them guidance along the way to help them learn the information that we think they need to know.

Cameron reported that the weekly preparation sessions positively impacted his views of science, scientific inquiry, and teaching methods that enable students to build understanding of science as inquiry. He admitted that the initial preparation workshop did not impact his knowledge of scientific inquiry nor how to teach in ways that enable students to build understanding of science as inquiry because he was thinking more about logistics of the semester and not paying close attention to what was going on in the workshop. He recalled a little “test” (e.g., demographic survey) which asked what inquiry was, and that was the first time he had ever thought about that topic. Further discussion caused Cameron to recall that the workshop element of discussing differences between lessons taught with a traditional format versus an inquiry format impacted the teacher characteristics just mentioned, not because inquiry was new to him, but because his experiences taking introductory college biology laboratory courses was that they were all inquiry-based. For him, it was strange to think about a biology laboratory course being taught any other way: “I’m not sure if I see what a non-inquiry biology based lab is…” (final interview, 12/09). This was reflected in all of Cameron’s interview responses to what inquiry meant to him; from the beginning to the end of the semester, Cameron referred to inquiry as a responsibility someone has to go out and find the answer, and that this experience can be particularly meaningful when it is personal. To him, inquiry was a life lesson that taught skills that lessened the likelihood of being dependent on someone else. It didn’t follow a prescribed recipe, and in a formalized teaching experience, it required “equal footing” of teachers and students based on interactions presented in a non-judgmental atmosphere where any question was as valid as others (second interview, 10/09). In his final interview, Cameron described his view of inquiry as both a teaching and a learning method:

> I think inquiry is…it's where there's a structured problem where everyone has to come up with something and it encourage…the teacher is there to encourage people to like work it out on your own, you know. They're there to kind of be your crutch a little bit. I guess you have to think about things and there might not be the right way to do it but you can figure that out on your own and get interactions like them asking questions to the instructor and the instructor asking questions to them and really you know making it their own. The students making it their own…I guess give them the tools they need in life to do their own work themselves because no one is going to be there in the future to… (12/09)

For Cameron, science was a broad concept of "a pursuit of learning more about something. And taking active steps to do it, not just watching, but thinking all the way through" (first interview, 08/09). Like Tara, science did not stop with what we think of as a traditional science field (e.g., biology, genetics) but could be applied to any discipline or any issue in life. For both Tara and Cameron, learning the process of science was not just important to do well in class or in a particular course but was a skill necessary to gain in order to demonstrate independence in problem solving skills.

Similar to the other GLAs, Evan defined science as a way of approaching any field of interest in order to find out more about it, but clarified that this process had a method that needed to be used. In this process you need to question, experiment, get a result, and think it over before drawing conclusions. Of the four GLA participants, Evan seemingly struggled the most with defining inquiry. In his first interview, Evan defined it as asking questions in order to learn more about something (similar to his definition of science), but by mid-semester he, defined it as "a process of actually executing the lab that I teach" (second interview, 10/09). He revealed that he was having a hard time "nailing it down" but felt inquiry was a "process of doing the lab… a process of learning" (second interview, 10/09). At the end of the semester, Evan expressed that he still could not define inquiry except as a way of approaching science, something that he did in his research laboratory as a graduate student but with which his students seemed to have difficulty doing. This difficulty was something that didn't make sense to him because for him, it was natural. Evan's apparent struggle to characterize inquiry was not so much in what he was realized as inquiry (something he did as a scientist) but how to put it in the context of teaching. The following interview pieces exemplify some of Evan's interpretations of inquiry.

> a. I had somebody like "I'm not a bio major why do I need to know that?" If that question comes out, they are missing inquiry-based. They're missing it. It's like they're not even in the class (second interview, 10/09).
>
> b. *Context: In the final interview, Evan is describing inquiry in relation to his students not being able to follow directions. In the second week of the Mendelian genetics laboratory series at least one group of students approaches Evan because they do not understand the results of the matings of* <u>C. elegans</u> *that they set up the week before, It is clear that are having a conceptual problem because the* <u>C. elegans</u> *they think they crossed are not options offered in this lab. Evan describes the conversations that ensue:*
>
> Evan: I generally had many students come up and say, the second week, that they took a hermaphrodite wild type and a male mutant. The students are trying to figure out what's on their plate. I was like "well that's impossible." "Why is it impossible?" "Uh, because this is just not possible." And then I was like "Did you show me your experimental design before you started like you were supposed to?" "No." "Why?" "I don't' know." "Well, what's on your experimental design?" Exactly what they did. But you did not

> come to me like I stated. I said let me see your experimental design before you start working. And it's a little bit tough to see everybody's experimental design on my own (me: yes). I'm trusting that they are going to come to me, and they didn't. And there were a few of them who just they wanted themselves to start, and they failed miserably. There's inquiry…you learned that you should have asked. And, the ones who got it right…they're like "o.k. I just need a male, but what are we going to do with all the other ones? How are we going to figure this out?" (third interview, 12/09)

It was apparent in the discourse between me and Evan (in reference to this his views of teaching science as inquiry) that Evan did not gain much from the introductory workshop. As he put it "…I don't remember it at all" (third interview, 12/09). He reported benefits of the weekly preparation sessions that were helpful to him, but that they could have been more so if he was able to stay for the duration of each session. He appreciated being able to do a "dry run" of laboratory activities after I discussed them in conjunction with teaching strategies and potential problems, both practical and pedagogical (third, interview, 12/09). For him, reflective discourse was viewed as more of a venting session amongst peers rather than an instructional forum, but it was something he enjoyed. He explained in his final interview that there was no better way to learn how to teach inquiry than by actually getting in the room and teaching, but he capped this discussion by explaining the values of being observed:

> As annoying as that actually was, that last part where you followed me every time…that was the most effective… That was the most headache inspiring…but, because it was more nerve-wracking….Cause there's…I can't…I acted differently when you were there then when you weren't there. I don't know why. I think probably because I would…I could use you as a crutch. If I was lost on something. I could go right there. So I wasn't

> as tense then if…when you were gone I was like o.k. I've got to teach this somehow, I've got to try and figure this out on my own. There's no one I can go to and say uhh. And you saw that once in a while, I was like umm…o.k. I don't know how else to describe it to this student. The students don't understand…."Kris, how could you explain it to them?" That was extremely helpful, but I felt like I was constantly being watched. And I think that's normal with anybody, but that was by far the biggest help the entire semester. That's why I was like…I mean it showed me a lot that I could do with the next class and with the following classes. Every time I was consistently getting critiqued on that…Very time consuming for you, but very helpful for me. (12/09)

In summary, none of the GLAs' views of science changed over the course of the semester relative to their teaching experience. However, when asked to reflect on components of the semester-long teaching preparation that may have affected their ideas about teaching methods that enable students to build understanding of science as inquiry, three of the four GLAs demonstrated developing views of this teacher characteristic and were able to attribute pieces of the teaching preparation that contributed to this development. For the fourth GLA, (Evan), it did not appear that any particular aspect of the teaching preparation helped him to develop views of scientific inquiry in relation to teaching. For him, the actual teaching was the best teaching tool. His emphasis on benefits of being observed provides interesting insight into what he needed to teach science as inquiry: assistance in the classroom. While post-observation feedback was helpful to the development of his teaching methods, perhaps more so was the fact that I was there in the room with him when he taught as this assisted his teaching science as inquiry when he was unsure how to do it. The word "crutch" is telling of his feelings of my being present while he taught; he could query the source (me) for teaching assistance at any point. This need for my presence likely had to do with the fact that he missed majority of each preparation session, but perhaps also due to his struggles with the goals of the curriculum (i.e., why we were teaching science as inquiry to non-science majors).

*Confidence towards teaching (in general), confidence towards teaching science as inquiry, and ability to teach science as inquiry*

In this section, findings will be presented that arose from the analysis of data related to the impact of the teaching preparation on GLAs' confidence towards teaching in general, confidence towards teaching biology as inquiry, and abilities to teach science as inquiry. All GLAs reported at least one aspect of the teaching preparation that positively impacted their teaching confidence and multiple preparation elements that impacted their abilities to teach science as inquiry. This section identifies those parts of the teaching preparation and provides illustrative examples of these impacts on the GLAs. Additionally, results of the *TSI* self-efficacy instrument are presented and discussed.

When asked at the end of the semester how the teaching preparation impacted her confidence in teaching (in general) and teaching science as inquiry, Tara reported that she began her teaching assignment with high confidence in both her teaching abilities as well as her knowledge of biological concepts. She was at first unsure that any one training component affected this confidence but then carefully clarified that she "definitely felt more like a teacher now…but I think that's more the whole basis of the lab…" (third interview, 12/09). To further describe this position, Tara drew a comparison between her experience of a passive teacher role in *Anatomy & Physiology* and a more active one in BIOL 1103L. In the latter, the curricular design allowed her to "interact with the students more often...so I could tell if they were learning or not" (third interview, 12/09). For her, the actual teaching of these inquiry-based laboratories made her feel more like a teacher due to the interactive nature of the course design. Additionally, when asked to further clarify if any training components affected her teaching confidence (and how), Tara reiterated that the initial inquiry workshop and the weekly preparation sessions did, and for the latter, specifically the reflective discourse that took place amongst the GLAs during these sessions.

John was more definitive on his response to how the teaching preparation affected his teaching confidence, discussing only that the weekly preparation sessions helped him feel comfortable with what to expect in upcoming laboratories. He referred to reflective discourse that occurred during these sessions and how helpful it was to him to hear GLAs experienced with teaching the laboratories share their past successes as well as war stories.

Like the other GLAs, Cameron discussed how both discourse amongst GLAs and with me during weekly preparation sessions was invaluable. For him, this active discourse "helps present a class where people want to talk and discuss things" (third interview, 12/09). Perhaps the preparation sessions actually served as a model for how to create a comfortable teaching atmosphere as it was evident from multiple discussions with Cameron throughout all interviews and during informal conversations that establishing a classroom atmosphere that encouraged this open discussion was essential to effective teaching. Cameron described the weekly preparation sessions as giving him confidence that his "horror stories" were no different than those of all other GLAs, even the ones who had taught this laboratory course before (third interview, 12/09). Cameron also reported that the post-observation feedback between him and myself helped him see that he "wasn't…doing something completely different from everyone else" and noted that he felt that GLAs who did not participate in this research study "missed out" because they were not able to receive the same level of feedback and discourse from and with me as he was given (third interview, 12/09). Finally, Cameron recalled a video clip watched during one weekly preparation session where two different instructors were teaching the same content, but one was leading a traditional laboratory section and one was leading an inquiry-based one. Although the sound quality in the clips was poor, Cameron found that just watching actions of students and the teacher was helpful to understanding physical roles of the two parties in each of the laboratories being viewed.

Evan reported that the only training component somewhat helpful for his confidence was the weekly preparation sessions because I told the GLAs "how we should probably go about it as inquiry" (third interview, 12/09). He picked from these given teaching strategies and added his own take on the laboratory topic; this end product was ultimately what he implemented in the classroom. However, it seems that Evan also gained confidence in how to improve his teaching from the times that I observed him as well. This boost in confidence may not have come from the post-observation feedback but rather from the times I stepped in to help him when he requested it. Having a live model allowed Evan to see inquiry teaching strategies in action. Much of this could have been gained from the weekly preparation sessions if he had been able to attend all of them.

*Analyzing the TSI data.*

The *TSI* is a 69-item Likert-item survey designed to determine both personal self-efficacy and outcome expectancy of elementary teachers who teach science as inquiry (Smolleck et al., 2006). The 69 items were developed to represent the varying levels of the five essential features of inquiry: planning investigations; giving priority to evidence; formulating explanations and conclusions; evaluating explanations in light of scientific knowledge; and communicating and justifying explanations (NRC, 2000, p. 29). For the purposes of this dissertation, *TSI* data for the four participants were analyzed to determine if differences existed between pre-semester *TSI* scores and post-semester *TSI* scores for each GLA. As I was looking for general measures of self-efficacy of teaching science as inquiry, I compared pre- and post-survey scores of all questions within each of the essential features (i.e., I did not analyze pre-post data for questions within each level for each essential feature nor did I analyze data for differences between pre-post scores of personal self-efficacy questions and outcome expectancy questions).

Paired sample t-tests were run for each GLA participant to compare self-efficacy scores related to the five essential features of inquiry prior to engaging in the teacher preparation program and teaching and after these experiences. Assumptions of matched pairs, normal distributions, equal variance of samples, and independence of observations was made. The significance level for all tests was set at 0.05. Mean pre- and post-test scores, their standard deviations (SD), t scores, and associated p values are given in Table 3.2.

For the first essential feature (*planning investigations*), there was a significant difference in pre-post *TSI* scores for Evan, $t(14) = -5.245$, $p = .000$ and John, $t(14) = -6.50$, $p = .000$, but not for Tara, $t(14) = -1.10$ , $p = .290$ or Cameron, $t(14) = -1.08$, $p = .301$. The mean self-efficacy scores for all four GLAs increased from the beginning of the semester to the end, but only two of the GLAs indicated a significant increase in scores.

For the second essential feature (*giving priority to evidence*), there was a significant difference in pre-post *TSI* scores for Evan, $t(15) = -3.66$ , $p = .002$; John, $t(16) = -4.78$, $p = .000$; and Cameron, $t(16) = -2.43$ , $p = .027$, but not for Tara, $t(16) = 1.73$, $p = .102$. The mean self-efficacy scores for three of the four GLAs increased significantly from the beginning of the

Table 3.2
*Significant p-values* for paired sample t-tests of pre- and post-semester TSI data (α=0.05)*

| **Essential Feature** | | | | | | |
|---|---|---|---|---|---|---|
| (1) Learners engaged by scientifically oriented questions. | | | | | | |
| | Pre score | SD | Post score | SD | t | P |
| **Tara** | 3.40 | .737 | 3.73 | 1.16 | -1.099 | .290 |
| **Evan** | 3.53 | .516 | 4.40 | .632 | -5.245 | .000* |
| **Cameron** | 3.67 | .617 | 3.93 | .884 | -1.075 | .301 |
| **John** | 3.73 | .594 | 4.60 | .507 | -6.500 | .000* |
| (2) Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions. | | | | | | |
| | Pre score | SD | Post score | SD | t | P |
| **Tara** | 3.76 | .752 | 3.11 | 1.62 | 1.734 | .102 |
| **Evan** | 3.44 | .629 | 4.31 | .602 | -3.656 | .002* |
| **Cameron** | 3.59 | .618 | 4.06 | .556 | -2.426 | .027* |
| **John** | 3.77 | .437 | 4.35 | .702 | -4.781 | .000* |
| (3) Learners formulate explanations from evidence to address scientifically oriented questions. | | | | | | |
| | Pre score | SD | Post score | SD | t | P |
| **Tara** | 3.85 | .689 | 4.08 | .862 | -1.000 | .337 |
| **Evan** | 3.77 | .725 | 4.23 | .439 | -2.144 | .053 |
| **Cameron** | 3.69 | .480 | 4.31 | .630 | -3.411 | .005* |
| **John** | 3.92 | .277 | 4.62 | .506 | -3.959 | .002* |

Table 3.2 continued
*Significant p-values* for paired sample t-tests of pre- and post-semester TSI data (α=0.05)*

| (4) Learners evaluate their explanations in light of alternative explanations, particularly hose reflecting scientific understanding. | | | | | | |
|---|---|---|---|---|---|---|
| | Pre score | SD | Post score | SD | T | p |
| **Tara** | 4.50 | .527 | 4.00 | .667 | 2.236 | .052 |
| **Evan** | 3.90 | .568 | 4.30 | .678 | -1.809 | .104 |
| **Cameron** | 3.50 | .527 | 4.50 | .527 | -3.873 | .004* |
| **John** | 4.00 | .000 | 4.90 | .316 | -9.000 | .000* |
| (5) Learners communicate and justify their proposed explanations. | | | | | | |
| | Pre score | SD | Post score | SD | T | p |
| **Tara** | 3.60 | 1.12 | 3.67 | 1.05 | -.174 | .865 |
| **Evan** | 3.87 | .742 | 4.33 | .488 | -2.168 | .048* |
| **Cameron** | 3.80 | .561 | 4.33 | .617 | -2.779 | .015* |
| **John** | 3.87 | .352 | 4.67 | .488 | -7.483 | .000* |

semester to the end, but for the fourth GLA, mean self-efficacy scores decreased, although not significantly.

For the third essential feature (*formulating explanations and conclusions*), there was a significant difference in pre-post *TSI* scores for John, $t(12) = -3.96$, $p = .002$ and Cameron, $t(12) = -3.41$, $p = .005$, but not for Tara, $t(12) = -1.00$, $p = .337$ or Evan, $t(12) = -2.14$, $p = .053$. The mean self-efficacy scores for all four GLAs increased from the beginning of the semester to the end, but only two of the GLAs indicated a significant increase in scores.

For the fourth essential feature (*evaluating explanations in light of scientific knowledge*), there was a significant difference in pre-post *TSI* scores for John, $t(9) = -9.00$, $p = .000$ and Cameron, $t(9) = -3.87$, $p = .004$, but not for Tara, $t(9) = 2.24$, $p = .052$ or Evan $t(9) = -1.81$, $p = .104$. The mean self-efficacy scores for three of the four GLAs increased from the beginning of the semester to the end, but for one of these GLAs (Evan), the increase was not significant. For the fourth GLA (Tara), her mean self-efficacy scores decreased from the beginning of the semester to the end, but the decrease was not a significant one.

For the fifth essential feature (*communicating and justifying explanations*), there was a significant difference in pre-post *TSI* scores for John, $t(14) = -7.48$, $p = .000$; Cameron, $t(14) = -2.78$, $p = .015$; and Evan $t(14) = -2.17$, $p = .048$, but not for Tara, $t(14) = -.17$, $p = .865$. The mean self-efficacy scores for all of GLAs increased from the beginning of the semester to the end, but for one of these GLAs (Tara), the increase was not significant.

Overall, interpretation of results found that John demonstrated the greatest frequency of significant increases in self-efficacy scores for all essential features of inquiry. Cameron demonstrated significant increases in self-efficacy scores for all essential features of inquiry but the first, and Evan data demonstrated increases in self-efficacy scores for three of the five essential features of inquiry (first, second, and fifth). Tara did not demonstrate any significant results from the pre-post *TSI*; her mean scores increased for the first, third, and fifth essential elements but decreased for the second and fourth essential elements. These results should be taken as general indications of changes in self-efficacy regarding teaching science as inquiry; they cannot be attributed to any one particular event that took place during the semester (e.g., the teaching preparation, the actual teaching).

The main pre-semester characteristic that separated Tara from the other three GLA study participants was her previous teaching experience at the college level. The *TSI* results may lend solidarity to the reported high confidence in teaching that Tara expressed at the beginning of the semester and that this particular teaching assignment (and its constituent components) did not do anything to significantly change that confidence. It is particularly interesting that Tara reported a decrease in mean self-efficacy scores for two essential elements; while these results were not significant, Tara's previous teaching experience gave her a comparison point from which to gauge her self-efficacy in this teaching assignment that the other GLAs did not have. So relative to this particular teaching assignment, interpretation of Tara's results suggested that teaching science as inquiry is more challenging than a more traditional teaching role assignment and therefore might lower a teacher's self-confidence in teaching science as inquiry well. It is also reasonable to assume the GLAs who came into this research study without teaching experience stood more of a chance of increasing self-efficacy due to the fact that they made it through the semester without any overwhelming problems and received support the entire throughout their assignment.

The overwhelming answer by all GLAs to the interview question about teaching preparation elements that impacted their abilities to teach science as inquiry was the weekly preparation sessions and the training that took place within: reflective discourse, discussion of teaching strategies, demonstrations of how to lead parts of laboratory exercises, and actually doing the laboratory exercises. For example, Tara explained that the weekly preparation sessions helped her to "figure out…made me start thinking about the best way to ask them questions and go through material" (third interview, 12/09). She took lessons learned from reflective discourse during these sessions and from the teaching notes and modified them by adding some of her own ideas or taking others away.

Individually, Tara and Cameron added pieces of data about additional preparation elements that assisted their abilities to teach science as inquiry. Tara emphasized that the three-hour workshop, especially the sample inquiry activity, gave her an idea of what to expect in upcoming laboratory sessions. Cameron added that the teaching and peer observations were also beneficial. Evan did not directly answer this interview question but alluded in his two previous interviews to the fact that my and peer observations were helpful for immediate feedback on what to do or not do when teaching a particular laboratory series. Actually conducting the laboratory during the weekly preparation sessions was invaluable for anticipating what would happen when he taught his own sections.

The analysis of the *TSI* data allows me to conclude that discourse, compared to other teaching preparation elements, provided the most substantial means of positive impact on GLA's confidence towards teaching, specifically teaching science as inquiry. Three of the four GLAs focused on discourse amongst GLAs during the weekly laboratory preparation sessions as providing the greatest sense of confidence in what they were doing in the classroom. Cameron also felt that discourse between he and I was critical to his self-confidence. The fourth GLA (Evan) indicated that teaching strategies directly given to him and having a teacher model to observe enabled him to develop teaching confidence. Whatever factor(s) of the teaching preparation positively impacted GLAs' confidence to teach science as inquiry carry important implications for development of self-efficacy of these instructors. Supporting the work of Dunbar, Egger, & Schwartz (2008) with preservice teachers, if GLAs feel more confident in teaching science as inquiry, there is a greater chance that they will actually implement it. This, in turn, leads to greater opportunities for students to experience science as inquiry and potentially have greater engagement in the classroom.

*How science should be taught*

As described earlier, none of the four GLA participants changed their ideas of what science meant to them over the course of the semester, but describing how it should be learned posed a challenge for some more than others. This section reflects GLAs' views of how science should be taught in relation to the teaching preparation received. Similar to previous sections, I primarily rely on data provided via the interviews as they provided the richest source of information to analyze in relation to GLAs' views on how science should be learned. When appropriate, quotes from GLAs or situations described by them are provided to exemplify the findings from analysis.

Tara ultimately indicated her uncertainty relative to how the teaching preparation affected her views of how science should be taught by referring to her previous college-level laboratory teaching experiences. On the one hand she felt that for introductory biology, using an inquiry-based format for teaching non-science majors works well because "everything is new for them and the course kind of goes along with it…" (third interview, 12/09). In this sense, she indicated that all elements of the teaching preparation positively affected her abilities to present introductory biology content and concepts to students. When teaching *A & P*, however, she could not envision how to use inquiry teaching methods as the learning goals for this course required students to memorize information (e.g., blood vessels, muscles) and regurgitate it on tests; therefore, the teaching education received from me did not change her ideas of how science content and concepts in *that* course should be presented to students. These conflicting views did not only surface at the end-of-semester interview but were actually presented during discussions and interviews with Tara throughout the semester. For example, Tara noted for "hard science" content material, such as that presented in *A & P,* memorization was the best means to learn information because students "just had to know it," and the best way to know it was to memorize content and concepts taught by an instructor in a lecture format (third interview, 12/09). In other classes that are more discussion based, such as social science classes, an inquiry-based format for the course might be more appropriate. It appears in this view that Tara did not consider introductory biology to be a hard science course. This may have influenced her willingness and observed extensive efforts to teach science as inquiry in her laboratory sections.

John was more cut and dry with his response to how science should be taught, and noted throughout the semester that his experiences teaching BIOL 1103L, including the teacher preparation, only reinforced these notions. To him, science should be taught such that students are given building blocks of a "a very good base, fundamental knowledge …good ole rote memorization. They need to know these definitions and eventually kind of build on those and see how those actually interact…" (third interview, 12/09). Students needed to be prepared to engage in inquiry experiences by learning science content and concepts through a more traditional means of learning: lecturing from an instructor and students memorizing the information. Only then could students be ready to apply it in higher order learning activities.

Of the four GLA participants, Cameron responded to the interview question of how the teaching preparation impacted his views of how science should be taught by illustrating his preference for inquiry instruction over traditional instruction because it "challenges people to pay attention more… it's more interactive I think people learn better with that" (third interview, 12/09). This preference was discovered by him as a result of the workshop experience presented at the beginning of the teaching preparation program (especially defining and illustrating what inquiry-based teaching and learning are) and by actually teaching the laboratories. He admitted that even if GLAs didn't understand what it meant to teach science as inquiry in the beginning, after a few weeks of teaching and the weekly preparation sessions, they "were pretty confident what it was" (third interview, 12/09). This assumed confidence of GLAs may have impacted what and how students learned. Greater knowledge of how science should be taught and therefore confidence in teaching science as inquiry would potentially enable students to learn through inquiry while lower confidence might suggest that students ultimately learned course material by more traditional learning methods. For Cameron, the format of the BIOL 1103L manual reinforced that science should be presented in a way that allows teachers to present concepts through scenarios and guide students to discover what those scenarios offer relative to content and concepts (third interview, 12/09). If this expected teaching of course material was realized, an interactive means of teaching and learning would be demonstrated where students are not afraid to ask questions and where instructors give students the confidence to see that they can figure things out on their own and do not need to be entirely reliant on their instructor.

In his final interview, Evan did not provide a direct response to the interview question of how teaching preparation impacted his views of how science should be taught. However, as evidenced in responses during the first and second interviews, email correspondence, and informal discussions, Evan consistently struggled with why students were not able to solve the "simple" problems presented to them in BIOL 1103L. For him, the students' inabilities to apply his instructional methods of giving simple instructions and of pointing out the multiple forms of guidance presented in the laboratory manual to develop experimental designs was incomprehensible. In his view, there was no inquiry involved in the laboratories he was teaching; each laboratory topic presented one problem that had one solution, and all students had to do was use what was given to them by him and provided in the manual to figure out that one solution. Evan and I debated at multiple points throughout the semester what inquiry meant in reference to his scientific work as a graduate student and in reference to the instructional labs he was teaching. His experience as a scientist was true inquiry to him: a problem to solve with many possible ways to solve it, so he would just jump in and try methods one by one. If one method didn't work (results did not answer his questions), he went back to the drawing board and tried a new method. He suggested that for the BIOL 1103 laboratories, there was no inquiry involved with solving the given problem; the materials and guiding questions provided laid out everything students needed. It was clear that Evan could not grasp that students' grappling with *how* to take all of the given hints and use them to help generate an experimental design was in fact a process of learning science. In this light, his instructional methods of teaching science as inquiry (e.g., giving some instructions and referring students to the laboratory manual) were not appropriate because in his view, BIOL 1103L laboratories were not inquiry-based and because students could not follow directions or apply hints.

The responses to the end-of-semester interview question of how science should be taught elicited substantial variation in the views of the four GLA participants. Tara indicated that the course design and goals determined how science should be taught. John and Cameron took opposite views: John felt that students at an introductory level should learn science through traditional teaching methods before attempting inquiry while Cameron indicated that students needed to learn science by experiencing the process of how to inquire and do science, no matter what level they are in college. A teacher's role in Cameron's view was to guide students through this inquiry process, perhaps acting as more of a "crutch" at the beginning but gradually moving farther back while students gained more independence in their learning (third interview, 12/09).

Finally, Evan's views suggest that he couldn't figure out how to teach students science in an introductory-level, inquiry-based biology laboratory course, perhaps due to his fundamental struggles to understand how the laboratories were even inquiry-based.

*Roles of teachers and students*

For this section of findings, I present analysis of two sources of data in which GLAs provided evidence of how the teaching preparation affected their views of teacher and student roles in biology laboratory courses experienced within this study The data sources included transcripts of all interviews as well as critical information given in pre-demographic surveys about this topic (see Appendix A).

Tara once again reverted back to the entire semester's experience of ongoing teacher preparation as having impacted her views of teacher and student roles when learning science in introductory biology laboratory courses. Reflecting on her experiences in *A&P* where her role was first to lecture and then quiz students throughout the laboratory class by having them identify parts of human anatomy and where students' roles were to take notes on her lectures and memorize the information, she enjoyed the newfound interactive nature of the inquiry laboratories. An example of this new teaching role and its impact on her and students was described in her second interview. In that interview, Tara admitted: "I feel more like a teacher now than I did before because actually I can tell whether they are learning it or not" (second interview, 10/09). She described her role in the classroom to be shifting to a teacher that probes *why* students were making the choices and drawing the conclusions that they were rather than just delivering information. This new role forced her to be prepared to trouble-shoot problems in students' understanding of their actions rather than in the mechanics of the laboratory activities. Students therefore needed to be actively involved in their decision making processes and articulation of their choices, to Tara and to one another. In her final interview, Tara explained that she "still felt like a parent and the students were her children," but she

> felt a bit more engaged doing the inquiry-based and that was pretty based on all of these different training components. All of them seemed to help quite a bit in the understanding of what inquiry was and then putting it into practice actually helped me (third interview, 12/09).

John did not feel that any preparation component affected his views on the roles of a teacher and a student in introductory biology laboratory courses; rather his views were based on past experiences as a student. The teacher is there to build conceptual and content foundations that will allow students to eventually work more independently from the instructor. Students must take in this initial foundation through memorization and practice and then learn to apply this knowledge to new situations. In his second interview, John explained his ideas of these roles:

> …I like the idea of teaching the raw information where they…as bad as it sounds….have to do the memorization and stuff. And then just kind of build on that. Because that seems to have a more logical flow and also seems to flow better. Just kind of from personal experience, just like jumping into something right in the middle throws everybody off if they don't have those building blocks behind it. So, besides teaching them the fundamentals to begin with, introducing them to methodologies and showing them how it works in one specific context and then letting them from there branch out and kind of design their own stuff. (10/09)

Cameron, on the other hand, felt strongly that defining inquiry science through the initial workshop and through the actual teaching of laboratories affected his views of the roles students and teachers should take in introductory biology laboratory courses, as described in his second interview:

> I guess going back to defining inquiry science it's I guess you are making it clear. Looking at it as students and teachers are I guess more… they're not way down here. They are more on equal footing with each other. They help each other out and I think that was helpful and I think just presenting an atmosphere where everyone feels confident you know. Comfortable talking in class. I know a couple of mine…that wasn't. I think that it's just, you know, the inquiry lab itself just promotes a better atmosphere. And I think that's what helps. Not necessarily a training component but maybe taking what you learn from this and applying to your own class. (12/09)

Evan did not provide a direct answer to this question, but reported at another point in the final interview that in this particular teaching assignment, his role as an instructor is to give students a backbone of a question to answer, rules and methods by which to answer it, and then "guide them on the bumper and help them get down the lane" (third interview, 12/09). He described this approach to teaching non-science majors as appropriate for this level of student and compared it to how he is currently being taught in a very different, but equally as appropriate, manner in graduate school: one where he is given a problem and little to no instruction on how to solve it.

In conclusion, aspects of the teaching preparation affected GLAs' views of the roles of teacher and students in introductory biology laboratories, but to varying degrees. Tara was able to draw on differences between her past teaching experiences and her current ones, noting that all aspects of the teaching preparation helped her develop as a teacher. She alluded to the fact that the inquiry laboratories themselves enabled her to gauge student learning, become more involved, and teach in ways that required her students to think critically about their work. John did not feel that the teaching preparation affected his views of teachers and students, but rather reinforced his ideas that he brought to this teaching assignment that were based on his experiences as a student. For Cameron, the teaching preparation only mildly influenced his ideas of student and teacher roles, but the application of the teaching preparation to his actual teaching was critical to establishing his views. Evan was able to compartmentalize his student and teacher views to his teaching assignment and to his actual experience as a graduate student; he did not refer to the teaching preparation as being important to defining these views.

*Other factors outside the teaching preparation that affected these same teaching characteristics*

In this final section of analysis, findings will be presented that arose from the analysis of data related to factors other than the ongoing teaching preparation that impacted the teaching characteristics already queried (e.g., teaching confidence, views of scientific inquiry). The main data source for these findings continues to come from interviews with the GLAs. The actual question presented to the GLAs about these other factors was presented in the final interview, but multiple piece of information from earlier interviews, post-observation feedback discussions, and discourse during weekly preparation sessions provided key exemplars of the GLAs' responses to this question.

Two themes emerged as the most prominent responses to this question: the actual teaching of the laboratories and peer and mentor observations (which I actually considered to be a major component of the teaching preparation). For the latter, a specific set of post-observation interview questions was used as a starting point for feedback discussion with GLAs immediately following an observation (see Appendix D). While these feedback sessions typically only took 10-15 minutes, I realized after the first week of data collection that it was rarely possible to conduct the interviews face-to-face as most of the GLAs taught at least two back-to-back laboratory sections or had classes that immediately followed their teaching assignment. Therefore, I resorted to a different method of engaging in post-observation feedback. The GLAs and I became accustomed to me working alongside them to quickly clean up and set up for the next laboratory section. In these cases we would carry on brief conversations about the laboratory that just occurred. Sometimes all of the interview questions were covered in these conversations and in other times only a few were. At the minimum, this on-the-spot dialogue allowed for both parties to discuss what worked and what didn't, and perhaps what to alter (if anything) in the next laboratory section. When the next section started I would quickly jot down notes of the conversation and later that day, type them up. These notes and my input into interview questions that were not discussed were emailed to the GLAs, and the GLAs responded with their thoughts about the interview questions when they had time.

A potential disadvantage to this system was the chance that GLAs would not respond to my emailed feedback since it required extra work for them to sit, read my messages, think about them, and then write responses. A second potential disadvantage was that handling post-observation interview questions this way did not allow for GLAs to give their input into a question without first seeing what I thought; this, in turn, could bias the GLAs' answers. It became readily apparent, however, that the GLAs were anxious for the emailed feedback because they would often email me to check that they would be receiving it before I even had time to send it! Every GLA responded to every email, and I found that the GLAs' responses indicated that they were not afraid to disagree with me, or at least present a side of a situation that differed from my interpretations. Therefore, it did not appear that my feedback biased the GLAs' responses.

For Tara, getting in the laboratory classroom and enacting the curriculum was as important as any teaching preparation method received. Throughout the semester, Tara emphasized how actually teaching the laboratories revealed the importance of interactions that she had with students, and these interactions were enabled by the design of the laboratory activities, e.g., group work, cooperative learning. The following dialogue from Tara's final interview brought together multiple reflective pieces of information regarding her views of the BIOL 1103L curriculum:

> …it's when you actually start interacting with the students and you realize the kinds of questions that you can ask to get them to think, that's where the inquiry-based really starts to work. That's when I first realized that it's beneficial, especially in this kind of a lab where they don't really care about the concepts because they are not going to be doing this, but I think that's what it was. It was more like getting in there and actually doing it. (12/09)

Tara also noted that "stuff that you picked up along the way" was beneficial to all the teacher characteristics discussed in the final interview, but what she cites as evidence is actually part of the teacher preparation (third interview, 12/09). As an example, she cites the post-observation feedback and discussions with me where I sometimes compared her teaching methods with those I observed in other GLAs' classes. These discussions enabled Tara to gauge the effectiveness of her chosen methods and how to potentially improve them. She also noted that while these discussions were valuable to her, she always felt that "for the most part I kind of knew what went well and what didn't" (third interview, 12/09). Peer observations were noted by Tara as being helpful as well because she "could pick up techniques that they used and try to apply them to my own. Like stuff that I like and then stuff that I didn't like about theirs I could try to avoid" (third interview, 12/09).

Similar to Tara, John noted that my observations were critical because the post-interview "feedback…made a difference because it gave me more of a focus on where I might need to spend more time" (third interview, 12/09). Peer observations were equally as helpful as they illustrated how *not* to teach something. John was careful to clarify that even though someone can be given all the preparation available, the experience of teaching is the greatest lesson.

Cameron was the one GLA who did not mention the actual teaching of the laboratories as being something that impacted the teacher characteristics discussed in the final interview. For Cameron, actually enjoying teaching had a major impact on all teacher characteristics discussed in the final interview. Equally as important was the fact he had experienced inquiry in his undergraduate introductory biology laboratory course in contrast to other science laboratory courses he took when an undergraduate; the inquiry biology laboratories were more relevant to his life while his chemistry and physics laboratories always left him with a question of why he was doing what the laboratories asked him to do. In response to the final interview question of what other factors besides elements of the teaching preparation impacted the teacher characteristics discussed, Cameron reiterated the importance of the preparation sessions and peer observations, and he acknowledged that a one-credit course called *Writing in the Disciplines* for which he was required to register for his teaching assistantship was helpful in managing the numerous writing assignments that students turned in. Cameron felt that peer observations should be a required part of holding a biology teaching assistantship with the Division of Biological Sciences.

Evan focused his response to what factors outside the teaching preparation affected the teacher characteristics discussed by emphasizing the importance of teaching the first laboratory section of the week since that is where all the mistakes are made. As he described, “the differences between his first and last section of the week were dramatic: …my third class was always the most efficient, fast. They finished with everything. They got some of the highest grades…it could be because of my explanations got a little bit better” (third interview, 12/09). He also discussed how his lack of content knowledge in certain topics affected his ability to teach effectively.

## *Conclusions*

When considering the rich data provided in response to the interview questions presented in this study, it becomes clear that teaching is an individualized experience, but one which can be positively impacted if ongoing discipline-specific teaching preparation is provided. This research study proposed to investigate how novice graduate student instructors reacted to a semester-long teaching preparation program designed to better enable them to teach an inquiry-based introductory biology laboratory curriculum with a writing intensive focus. By providing GLAs with ongoing teacher education and support as they embarked on their new teaching assignment, I hoped to ease some of the difficulties that first-time teachers experience such as classroom management issues or feeling overwhelmed with new responsibilities, but I also hoped to help the GLAs use their science content knowledge to achieve course curricular goals, namely teaching science as an inquiry process. The following conclusions can be drawn from this study:

1. Discipline-specific teaching preparation is beneficial for novice instructors, especially when the intended curriculum is written in a way that is unfamiliar to them. In this case, only one GLA reported having introductory biology laboratories taught in a means that emphasized the

process of learning science as inquiry. For all GLAs, multiple aspects of the preparation positively impacted their abilities to teach in ways that enable students to build understanding of science as inquiry and their confidence towards teaching (in general) and towards teaching biology as inquiry. The preparation also provided new means for the GLAs to consider how science should be learned; for most GLAs, it reinforced notions of the roles that teachers and students should take when teaching and learning science in a laboratory environment, but cases arose where new doors were opened for considering other ways to teach science as inquiry and to decipher what instructors and students should do in a classroom when learning science.

2. Within a teaching preparation program, time must be devoted for reflective practice. In this case, GLAs, both novice and experienced, were given opportunities on a weekly basis to discuss teaching experiences encountered in the classroom. Their reflective practice was therefore based in a social setting and was exercised within "communities" of teaching peers (McLoughlin, Brady, Lee, & Russell, 2007). Other forms of reflective practice could have been implemented such as responses to vignettes, written journal entries, or through web-based forums, but were not. Regardless, in many of the questions addressed in this study, the GLA participants referred to benefits (e.g., improved confidence in teaching) of discussing laboratories with peer GLAs during the weekly preparation sessions. This finding supports a substantial literature base in teacher education research regarding critical components for successful teaching, especially for new teachers (Loughran, 2002). For novice teachers to become professionals, they need opportunities to reflect with mentors and peers; as McLoughlin et al. (2007) stated: "professional growth requires engagement and dialogue with a community of like-minded peers, and it is a social and self-critical experience" (p.5).

3. When developing teaching preparation programs for novice teachers, the impact of the actual teaching experience should not be underestimated. Each of the GLA participants discussed the importance of "just getting in there and doing it" (Tara, third interview, 12/09) and how substantially the actual practice of teaching impacted the teacher characteristics discussed in this study. Studies have demonstrated that for preservice teachers, the student teaching experience can have a powerful influence on future implementation of teaching methods or even continuing to teach as a career (Fives, Hamman, & Olivarez, 2007). Likewise, the first three years of a teaching assignment for new K-12 instructors can be tenuous at best as teachers struggle with putting theory into practice while realizing the myriad nuances of teaching day to day, e.g., classroom management, behavior issues, accountability required through paperwork.

4. While a considerable time investment for both teacher mentors and teachers, multiple benefits arise from engaging in teaching observations. Observational feedback from an experienced mentor or from watching a peer's successes and failures in the classroom provides a powerful means of providing immediate feedback to instructors (Bell & Mladenovic, 2008; Campbell, Abd-Hamid, & Chapman, 2009). This structured feedback can not only help improve continued instruction but can also assist instructors to more adequately meet stated student learning goals (Luft, 2001) and improve teaching confidence (Bell & Mladenovic, 2008). As described by the GLA participants in this study, observations allowed the GLAs to develop as teachers as they were able to use the experiences of others to develop their own teaching habits, and my post-observation feedback was often readily implemented by GLAs in their next laboratory section.

The efficacy of a discipline-specific teaching preparation education program must be established by teachers involved. Without the teachers' use of the preparation given or their feedback on it, teacher educators should not have confidence that their well-meaning efforts are being received as such. This research study illustrates that a carefully planned teaching preparation program can positively impact needs of novice graduate student instructors.

Table 3.3
*Selected demographic information of Fall 2009 BIOL 1103L GLAs*

| **GLA** | **Gender** | **Ethnicity** | **Teach future Career** | **Become faculty Member** | **If faculty, % time teaching** | **Area graduate studies** | **Level course content knowledge** |
|---|---|---|---|---|---|---|---|
| John* | Male | Euro-Amer | Very Likely | Very Likely | 50% | Plant Biology | High |
| Wendy | Female | Euro-Amer | Unsure | Unsure | 20% | Entomology | Adequate |
| Evan* | Male | Hispanic | Very Likely | Very Likely | 60% | Biochemistry | High |
| Tammy | Female | Afric-Amer | Very Likely | Unsure | 80% | Science Educ. | High |
| Alice | Female | Indian | Very Likely | Very Likely | 50% | Public Health | High |
| Tara* | Female | Euro-Amer | Unsure | Unlikely | 70% | Food Science | Very High |
| Cameron* | Male | Euro-Amer | Unsure | Unlikely | 50% | Marine Science | High |
| Austin | Male | Euro-Amer | Very Likely | Very Likely | 30-40% | Plant Biology | Adequate |
| Carter | Male | Indian | Very Likely | Very Likely | 50% | Entomology | Unsure |
| Mike | Male | Euro-Amer | Very Likely | Very Likely | 40-50% | Biochemistry | Very High |
| Missy | Female | Hispanic | Very Likely | Very Likely | 50% | Fungal Biology | Very High |

Table 3.3 continued

*Selected demographic information of Fall 2009 BIOL 1103L GLAs*

| **GLA** | **# semesters teaching assistant** | **Previous teaching positions** |
|---|---|---|
| John* | 0 | Undergrad lab assistant/tutor |
| Wendy | 1 | BIOL 1103L |
| Evan* | 0 | NA |
| Tammy | 6+ | Middle and high school sci. teacher; adjunct biol. instructor; BIOL 1103L; sci. education teacher and TA positions |
| Alice | 4 | BIOL 1103L; TA in Poultry Science |
| Tara* | 4 | TA for Biology of Protists lab; TA for Anat. and Phys. Labs |
| Cameron* | 0 | NA |
| Austin | 5 | College biology lab instructor; summer science camp instructor |
| Carter | 0 | Tutoring; guest lectures; lab instructor in Entomology camp |
| Mike | 0 | Tutor; helped prep and teach in undergrad/grad course in biotechnology techniques |
| Missy | 4 | TA intro to biol.(non-majors); TA clinical micro lab |

Table 3.3 continued
*Selected demographic information of Fall 2009 BIOL 1103L GLAs*

| **GLA** | **How do you know if lesson includes inquiry activities?** |
|---|---|
| John* | Don't know |
| Wendy | Directions would not be step-by-step; they give list of materials and objective requiring student to think through how to get from A to B |
| Evan* | Don't know |
| Tammy | When step-by-step instructions are not given and students must determine what to do in order to answer a particular question or set of questions; When the instructor does not give answer but draws answer from students by helping to guide the students' thinking |
| Alice | Students are focus of lessons/activities; students have all freedom to do experiment by only the correct method to the objective will secure good learned results |
| Tara* | Lab wouldn't just entail memorization but would include critical thinking (e.g. short answer or essay type questions) |
| Cameron* | Group activities; hands-on labs |
| Austin | Lesson would require students to make observations about a particular topic and then require them to test their Observations |
| Carter | No step-by-step instructions from start to finish of lab; would require inquiry activities |

Table 3.3 continued
*Selected demographic information of Fall 2009 BIOL 1103L GLAs*

| | |
|---|---|
| Mike | NA |
| Missy | Type of assignments I have to give students especially in labs where they have to learn to research at some level |
| | |
| **GLA** | **Student teacher role in inquiry activity** |
| John* | None |
| Wendy | BIOL 1103L |
| Evan* | NA |
| Tammy | In all previous teaching experiences listed; also student in classes that were inquiry-based |
| Alice | BIOL 1103L |
| Tara* | None |
| Cameron* | None |
| Austin | None |
| Carter | None |
| Mike | None |
| Missy | None |

Table 3.3 continued

*Selected demographic information of Fall 2009 BIOL 1103L GLAs*

| **GLA** | **Student teacher role in inquiry activity** |
|---|---|
| John* | Don't know |
| Wendy | Student must think through what has been presented and provided in manual and teacher should discuss material with students by explaining concepts and answering questions initially. Then they help student think through the project by providing questions that would help guide the student to the correct answer. |
| Evan* | Don't know |
| Tammy | Inquiry activities require students think and plan; students must also have some prior knowledge; teachers must have strong grasp on content needed to answer questions upon which the activity is based; teacher guides the students' thinking and provides encouragement for the students; teacher often uses questions that provide student thinking |
| Alice | Student: reading pre lab and ready for newer challenge; be able to do some external reading like text book or articles; be able to run their imagination to get to the objective. Teacher: expectation to read the lab wheel and come up with satisfactory answer for that set; ready to explain the most difficult concept into the most simple words and pictures; be ready to put the same problem in different words/diagrams/pictures |
| Tara* | Student reads background material, performs lab, and answer follow-up question in lab; teacher goes over background material in a way that students can comprehend and then assistant students with the lab when needed |

Table 3.3 continued
*Selected demographic information of Fall 2009 BIOL 1103L GLAs*

| **GLA** | **Student teacher role in inquiry activity (continued)** |
|---|---|
| Cameron* | Students are active participants rather than passive listeners. Teachers provide general info but mainly step back to watch students find out information through activities. Teachers also serve to answer questions and help students understand why it is they are doing something. |
| Austin | Instructor role becomes more passive; instructor would save much more to engage the students' curiosity; students would be more active and inquisitive. |
| Carter | Teacher facilitates the inquiry activity through leading questions and the objective to the lab to guide them. Students should figure out the materials and methods to get the results of the intended activity |
| Mike | Student and teacher need to work too hard for a fully successful inquiry. |
| Missy | Teacher gives a short background of the activity; students research, "design" and interpret their results |

Table 3.4
*Interview items for beginning-of-semester, mid-, and end-of-semester interviews*

| **Interview Items** | **Beginning of semester** | **Mid-semester** | **End of Semester** |
|---|---|---|---|
| Here is a list of all of the training components that you experienced this semester. Did any impact your **knowledge** of how to teach science as inquiry? If so, how? | | | X |
| Using the same list, can you tell me if any training components affected:<br>a. knowledge of scientific inquiry and how to teach in ways that enable students to build understanding of science as inquiry<br>b. confidence towards teaching (in general)<br>c. confidence towards teaching inquiry<br>c. ideas of what science is and how it should be taught<br>d. views of the role of a teacher and of a student<br>e. ability to teach science as inquiry | | | X |
| What other factors, if any, impacted these same teacher characteristics, and how? | | | X |
| Describe how your science classes were typically taught. What did your professors do? What did students do? Why do you feel that both teachers and students took these roles? | X | | |

Table 3.4 continued
*Interview items for beginning-of-semester, mid-, and end-of-semester interviews*

| **Interview Items** | **Beginning of semester** | **Mid-semester** | **End of Semester** |
|---|---|---|---|
| How do you view “inquiry?” Is it a method? An epistemology? | X | X | X |
| What aspects of inquiry are in the following labs (list of labs)? Which did you anticipate and which did you observe or experience? | | X | X |
| What is science? How should it be taught? How would you define the role of an instructor in student learning? | X | X | X |
| What characteristics describe a “good” teacher of science as inquiry? | X | X | X |
| Give an illustrative example of an interchange you had with students this semester in which you feel they really learned something. | X | X | X |
| What were some of your biggest frustrations with teaching this semester? | | | X |
| How have your expectations for students changed over the course of the semester? | X | X | X |
| What do you think students needed most from you as their instructor? | X | X | X |

Table 3.4 continued
*Interview items for beginning-of-semester, mid-, and end-of-semester interviews*

| **Interview Items** | **Beginning of semester** | **Mid-semester** | **End of Semester** |
|---|---|---|---|
| If you were an instructor in charge of a laboratory course, would you be likely to teach an inquiry lab or one with a more traditional format and why? | | | X |
| What do you think the biggest difference is between labs taught using a traditional format with those that use inquiry? | X | X | X |
| Are there any areas where you feel you could have benefited from more instruction? | | X | X |

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# CHAPTER 4

# TEACHING NON-MAJORS BIOLOGY AS INQUIRY: THE DEVELOPMENTOF BIOLOGY GLAs' CONCEPTUALIZATIONS OF TEACHING SCIENCE AS INQUIRY[2]

[2]Miller, K.R. & Oliver, J.S. (2010). *Unpublished dissertation, The University of Georgia.*

Note to reader: This is the second of three chapters that are intended to be submitted as manuscripts to professional journals. The first manuscript presented analysis of the impacts of a teaching preparation program developed to help novice graduate student instructors (GLAs) teach introductory undergraduate biology laboratories with an inquiry focus to non-science majors. This second manuscript presents analysis of how these same GLAs came to conceptualize teaching science as inquiry over the course of their teaching assignment. The final manuscript will present an analysis of the GLAs' enactment of those conceptualizations.

## *Introduction*

Teaching assistantships serve multiple purposes for graduate students: they provide a paycheck, often allow for a waiver of tuition and fees, and potentially provide valuable teaching experience. The assignments that result from being a graduate teaching assistant generally involve the education of undergraduate students. In the sciences this often, at a minimum, includes teaching laboratory sections within introductory level courses. But the assignments vary extensively across and within disciplines (Harris & McEwen, 2009); some require that the graduate student assume a "lecture teaching assistant (TA)" position where s/he may attend all lectures for a course, proctor exams, lead review sessions, and grade exams. In these cases the actual teaching experience is minimal. In other situations, graduate students might teach part or all of large lecture undergraduate courses.

Teaching preparation provided to these graduate students appears to vary as much as the actual teaching assignment themselves. If any sort of teaching preparation is provided, it most often occurs at the university level, meaning that it is not program or department specific (Gray & Buerkel-Rothfuss, 1991), and it tends to consist of a half-day or full-day session on administrative considerations for the classroom (Shannon, Twale, & Moore, 1998). Department-level preparation may only encompass the same administrative material as the university-level training or can be as in-depth as a teaching-mentor experience with a greater emphasis on subject matter content (Shannon et al., 1998, p. 441). Graduate students are often in need of teaching preparation if the subject matter content is unfamiliar, or simply not recently experienced, or if the course is designed with an unfamiliar pedagogical focus or curricula (Savage & Sharpe, 1998). The research being reported here is focused on teaching assistants who are not familiar with teaching introductory biology when the course structure is built around student inquiry. As will be shown, even establishing a definition for inquiry is not easy.

*Defining the word "inquiry"*

It is not uncommon for higher education science departments to attempt to reform their instructional practices by incorporating more "inquiry" into the lecture and the laboratories. A common path will include citations from the National Science Education Standards (*NSES*) (NRC, 1996) as the mandate for the reform. But it is clear that for many programs, enjoining this battle comes to be a formidable challenge. Consider these two reasons. First, higher education science instructors often have little to no teaching training (Sunal et al., 2001, p. 247). Two, if one takes a look at the immense literature base on science education reform in the last 20 years, it quickly becomes apparent that the word inquiry has been encumbered with many meanings. As Windschilt (2004, p. 483) described it, "ideas about inquiry are partly "in the head" (with different people understanding different aspects), partly embodied in the practices of the classroom, and partly codified in various community-wide discourses." Generally, however, Minner, Levy, & Century (2009) reported that inquiry appears to reflect:

> at least three distinct categories of activities—what scientists do (e.g., conducting investigations using scientific methods), how students learn (e.g., actively inquiring

> through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists), and a pedagogical approach that teachers employ (e.g., designing or using curricula that allow for extended investigations). ( p. 3)

These meanings may overlap or be kept as exclusive categories depending upon who describes them, and significant variation within each of these categories can be found within teacher education research literature (Anderson, 2002). However, a common feature of many of the descriptors is that they are based on the five "essential features of classroom inquiry" as defined in the *National Science Education Standards (NSES,* NRC, 2000). These five elements are:

> (1) Learners are engaged by scientifically oriented questions.
>
> (2) Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
>
> (3) Learners formulate explanations from evidence to address scientifically oriented questions.
>
> (4) Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
>
> (5) Learners communicate and justify their proposed explanations. (p. 25)

Within the activity category of inquiry teaching (or teaching inquiry), discussion has occurred as to whether teachers should teach science *by* inquiry or *as* inquiry (Anderson, 2002). This dialogue carries an important implication for how teachers enact inquiry in the classroom; the act of defining a pedagogical strategy may enable an instructor to more easily carve out student learning goals and therefore teach in pedagogically-sound ways to achieve those goals. As outlined by Chiappetta (1997, p.23), *teaching science by inquiry* (also referred to as teaching science through inquiry, or general inquiry) has a focus on helping students to discover science by allowing them to make observations and ask questions. This epistemological approach allows for students to choose questions that are interesting to them to investigate and implies that there is no set method to teach science. *Teaching science as inquiry* is what Chiappetta (1997) also refers to as scientific inquiry. In this case, students are involved in "active student learning and the importance of understanding a scientific topic. Here the content becomes a critical aspect of the inquiry (p. 23)." In order to teach science as inquiry, activities in which students engage and the teaching methods used to demonstrate those activities should show that science is a process of inquiry, similar to how scientists "do" science. Engaging students in this process can therefore draw a parallel in application to how students might approach problems in their own lives that need to be investigated (Flick, 2003, as cited in Abrams, Southerland, & Silva, 2008, p. xvi). A difficult task in teaching science as inquiry is that it requires that students utilize metacognitive skills to actively learn how to inquire (i.e., how to ask relevant questions and justify explanations or ideas). Metacognitive skills are often lacking in adult learners (Halpern, 1998) so it is imperative that when teaching science as inquiry, teachers work to develop these abilities in students. Lederman, Abell, & Akerson (2008) explained:

> At the same time that students are developing abilities for doing inquiry, they are building understanding about scientific inquiry…The understandings are often the result of metacognition in relation to inquiry-based activities…That is, good teachers help student think about the thinking processes that they have used and focus students on knowing how to improve. (p. 15)

*Teaching preparation at The University of Georgia (UGA)*

The faculty of the Division of Biological Sciences at the University of Georgia (UGA) are primarily teaching faculty and are therefore committed to providing undergraduate science education experiences that promote best practices in teaching introductory biology. In order to meet the call to reform in undergraduate education, these faculty and Division of Biological Sciences staff have gradually redirected the goals of all undergraduate introductory laboratory courses. This redirection has resulted in each laboratory course offering students opportunities to gain practice in the multiple phases of "doing" science including: (1) asking testable questions; (2) defining contexts for these questions; (3) defining methodologies; (4) collecting data; (5) justifying conclusions made; and (6) engaging in argumentation.

Upon the first few semesters of this conversion process, it became apparent that these graduate laboratory assistants (GLAs) were struggling with teaching a curriculum heavily linked to inquiry. During weekly preparation sessions, the GLAs freely discussed with each other and the Laboratory Coordinator that they themselves had never experienced being taught science in a way that allowed them to experience the process skills required to undertake a science investigation. Similar to preservice science teachers (Windschilt, 2004), our GLAs had taken extensive science classes as undergraduates but rarely experienced inquiry in the classroom i.e., what it means to learn science as inquiry in a classroom setting. They weren't sure what to do and would often ask the Laboratory Coordinator pedagogical questions such as: Do we tell the students how to design the experiments? Can we tell them anything? Do we tell them when their design is "wrong?"

In response to these feelings of being at a loss for how to teach introductory biology laboratories in what seemed to be an unconventional manner, a faculty and staff member of the Division of Biological Sciences developed a teaching preparation program that provides ongoing teaching support to the GLAs. This program, currently in its second phase of development, uses a variety of means to help GLAs transition into their teaching responsibilities as smoothly as possible and then continues to offer means of teacher support throughout the semester(s) in which they teach. This teaching preparation is completed through such means as a pre-semester workshop on the multiple layers of the word inquiry, opportunities for reflective discourse with peers and a teaching mentor, and mentor and peer observations using an observational tool designed to record frequency and quality of selected inquiry teaching and inquiry student behaviors. For a detailed list of these teacher preparation program components and to understand how the teaching preparation impacted specific teaching characteristics of the GLAs, please refer to Author, 2010a. During the years that the inquiry approach to teaching biology laboratory courses has been growing, it has become clear that greater understanding of the GLAs' approach to teaching was needed. Thus, the purpose of this research study is to understand how GLAs come to conceptualize teaching science as inquiry.

*Purpose and rationale*

As graduate students are learning to become teachers, they do not often have instructors to emulate. This is especially true when the teaching assignment requires them to use a curriculum with a pedagogical focus that is more uncommon than not in higher education. McKeachie (1990) reported that higher education instructors tend to have only slight familiarity with current teaching methodologies. The rationale for this study is based in attempting to understand how the GLAs came to conceptualize teaching science as an inquiry process. This information is critical to the efficacy of efforts being made to adequately prepare them to teach science as inquiry as well as how they actually convey science as an inquiry process to their students. A subsequent report will analyze if the GLA participants in this study actually enacted their conceptions of how to teach science as inquiry when the teaching opportunity arose.

*I*

*Novice teachers' conceptualizations of teaching science as inquiry*

While there appears to be a hole in the literature base of graduate student instructor preparation with regards to graduate teaching assistants in the sciences and how they come to conceptualize teaching science as inquiry, or even inquiry in general, there is important information to be gleaned on the same topics from the more ample literature available on K-12 preservice and inservice teachers. For example, studies indicate that for elementary school teachers who lack a science background, professional development efforts geared towards building a better understanding of the nature of science (NOS) are not always successful in long-term retention of proper notions of this topic (Akerson, Abd-El-Khalick, & Lederman, 2000), especially if they are given on a short-term basis such as one part of a teaching methods course or a workshop. However, providing ongoing teaching assistance while these teachers are actually practicing allows them to build, reflect upon, and teach appropriate conceptions of NOS using "inquiry science methods" (Akerson & Abd-El-Khalick, 2003). Kielborn & Gilmer (1999) reported that actually engaging preservice teachers in investigations that involved the process of science enables them to "…internalize and transform new information for their own use and understanding" (p. 93) and therefore have a greater ability to teach science as inquiry to their students. Citing work by Gallagher (1991) which demonstrated that preservice teachers tend to bring little actual experience of engaging in the process of science to their teaching experience and therefore hinders their abilities to "plan and implement lessons that will help the students develop an image of science that goes beyond the familiar 'body of knowledge'" (Gallagher, 1991, as cited in Akerson & Hanusein, 2007)," Akerson and Hanusein (2007) added that practicing teachers would likely have the same problems (p. 654). This can directly translate to first time graduate student instructors of science courses that center on science education reform efforts. A recent study by Park Rogers and Abell (2008) echoed this notion: "Not understanding inquiry teaching can make it difficult to translate one's beliefs about the nature of scientific inquiry into the practice of inquiry teaching" (p. 594).

Even when preservice teachers hold a science background, however, conceptualization of inquiry does not necessarily arrive any easier. In a study of 14 Master of Science students in a secondary science teaching program where all participants held science degrees, Windschilt (2004) found that when these students had to plan inquiry investigations and then later engage in them, the students struggled with enacting an empirical inquiry study that had theoretical grounding. He concluded that despite their science backgrounds, these students struggled with asking a good question and designing a study to test that question, and that these struggles with enacting "authentic" inquiry in the classroom must be taken into account when constructing preservice teaching courses:

> "From a constructivist perspective, we know that preservice experiences can be best designed only if we first understand the frameworks of knowledge that preservice teachers bring with them to the program and the broader culturally reinforced models that maintain everyday ways of thinking about the disciplinary activities of scientists (p. 508).

Windschilt also reported a number of additional factors that may influence how preservice teachers conceptualize inquiry including emulating their previous instructors in K-12 education, how their undergraduate laboratory courses were taught and the roles student took within these labs, and their undergraduate coursework in a teacher education program (Windschilt, 2003).

*Theoretical framework*

This study was framed under the epistemology of constructionism. Constructionism, as defined by Crotty (1998):

> …is the view that all knowledge, and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context. (p.42)

Additionally, my methods for this research study were directed through the lens of symbolic interactionism. These research design approaches allowed me to assume a role of a participant observer in order to collect data from GLA participants throughout their interactions with each other, with me, and with their students. Symbolic interactionist perspectives are often used in research studies having a constructionist philosophy as both are centered on the idea that knowledge is built through a social, interactive process between individuals and their surroundings. The three foundations of symbolic interactionist perspective include 1) "that human beings act toward things on the basis of the meanings that these things have for them"; 2) "that the meaning of such things is derived from, and arise out of, the social interaction that one has with one's fellows"; and 3) "that these meanings are handled in, and modified through, an interpretive process used by the person in dealing with the things he encounters" (Bulmer, 1969, p. 2 as cited in Crotty, 1998, p.72). In this research study, the GLAs' experiences as novice teachers in introductory, undergraduate biology laboratories are characterized by symbolic interactionism as posited by Benzies and Allen (2001): the meanings constructed and assumptions developed by the GLAs as they progressed through their teaching experience in inquiry–based biology laboratories were often revisited, reinterpreted, and then redefined.

## *Methods*

### *Researcher role in the study*

At the time of this study, I served as the Laboratory Coordinator for the Division of Biological Sciences at UGA. A significant portion of my job duties were spent supervising and providing teaching preparation to the GLAs who teach the introductory biology laboratories for UGA. Additionally, I was also a graduate student in Science Education. To account for potential bias in data collection and interpretation that could occur from assuming these multiple roles, I took copious notation of all conversations, both written and verbal, that I had with GLAs in order to evaluate if these discussions were somehow clouding my researcher role. For instance, it was not uncommon for me to need to take multiple roles in one interaction with a GLA: that of the researcher, a participant observer, a supervisor, a teaching mentor, and a graduate student. I then discussed and analyzed the notes with faculty within the Division of Biological Sciences as well as my research advisor in Science Education for compromises in data collection and analysis.

### *Data Collection Instruments and Analysis*

In a previous and related study (Author, 2010a), I analyzed the impact of the teaching preparation program on GLAs' teaching characteristics of 1) knowledge of scientific inquiry and how to teach in ways that enable students to build understanding of science as inquiry; 2) confidence towards teaching (in general) and towards teaching science as inquiry; 3) ideas of what science is and how it should be learned; 4) views of the role of a teacher and of a student; and 5) ability to teach science as inquiry. In that study, I described all elements of the program as well as the methods used to collect and analyze data on GLAs' perceptions of the effectiveness of it. In this study, I focused more intently on the same data to investigate how GLAs came to conceptualize teaching science as inquiry in their first time teaching assignment of introductory biology laboratories for non-science majors.

In the pre-semester workshop (prior to the onset of any teacher preparation), GLA participants were individually queried on their conceptions of the word "inquiry." This was done in multiple ways. One means was through a teaching vignette that described a biology laboratory instructor using teaching methods that one might employ if teaching science as inquiry (see Appendix B). GLAs were asked to respond to this vignette by explaining if and why (or not) they agreed with the teacher's instructional methods. Second, in a pre-demographic survey, GLAs were asked to respond to the following (among other questions): *How would you know if a lesson included inquiry activities? Describe any experience you have had with inquiry instruction. Describe the roles of a student and a teacher in an inquiry activity.* Finally, GLAs read five brief descriptions of laboratory experiments and were asked to indicate if these experiments were "inquiry experiments" and to justify their answers. All of these methods were designed to elicit what the GLAs brought to the onset of their teaching assignment in terms of attitudes towards and knowledge of inquiry. Then, at multiple points during the semester, GLAs were asked in quasi-structured individual interviews to explain their understanding of the word inquiry. These interviews (three per GLA participant) took place at approximately two weeks into the semester of the student, around the 8$^{th}$ week of the semester, and after the last laboratory of the semester. By using three interviews rather than a pre- and post-semester interview, I hoped to gather valuable information regarding GLAs' conceptualizations of their teaching experience as the semester was progressing.

In this study, the primary source of data for analysis was transcripts from the GLA participant interviews. I used a qualitative statistical software program (ATLAS.ti.6) to assist with coding data from interview transcripts. The coding process I used was the three-step data analysis model presented by Strauss and Corbin (1998). I began with the transcripts of one GLA participant and employed open coding methods in order to develop a first set of category labels to the data. I followed this same procedure for the other GLA participants' transcripts. After these initial categories were created, I reviewed them to determine if modifications needed to be made (i.e, elimination of some categories, merging of others). The next step of analysis was axial coding of the categories: I compared them to establish if causal relationships were present. Last, I used selective coding to settle on central themes of categories. I related all categories to these themes, so the themes became the main units of analysis in my dissertation.

In order to establish trustworthiness when collecting and analyzing data related to interviews, I engaged in member checking. Before conducting the second and third interviews, I reviewed the ones that had already taken place. Since I repeated many of the same questions across all interviews (see Table 3.4), I would let GLAs respond to each question and then would remind them of how they had answered the same queries in previous interviews. This enabled me to establish, with the GLAs' input, clarity of all responses across the course of the semester. It also allowed me to confirm with the GLAs any changes that I was interpreting in their responses.

Finally, themes from data analysis were triangulated with additional data sources including pre- and post-semester GLA surveys, behavioral observations of GLAs, relative comfort levels of content, reactions to a pre-semester teaching inquiry vignette, and informal discussions with GLAs.

*GLA Participants*

Participants in this study included a subset of four GLAs from the population of 11 GLAs assigned to teaching BIOL 1103L in fall 2009 at UGA. All 11 GLAs took part in the teaching preparation program described in a previous research study (Author, 2010a). BIOL 1103L is a one-credit introductory biology laboratory course for non-science majors; its content focus is cellular and molecular biology. The GLA participants were selected based on a subset of pre-demographic survey characteristics including gender, past teaching experience, past experience with inquiry, reported likelihood of teaching in the future, and initial “buy-in” to inquiry teaching methods i.e., response to the teaching vignette previously described. While all 11 GLAs agreed to participate in the study, I ultimately chose participants who had never taught BIOL 1103L before and who indicated the greatest variety of responses to these questions; it was my hope that having an extensive range of responses would allow for me to gain a wide range of understanding of the impact of the teaching preparation program. Students were also observed as part of the teaching observations portion of the teacher preparation program, but this study will not report on their data of student inquiry behaviors.

At the time of the study, Tara had recently completed her M.S. degree in Cellular and Molecular biology and was beginning a Ph.D. program in Food Science. During her previous tenure as a graduate student, she held two teaching assistantships. One was for an introductory *Anatomy and Physiology (A&P)* laboratory course for which she was the only instructor of her laboratory sections and the other was for an upper level undergraduate course, *Biology of Protists*, in which her instructor roles were more limited (faculty were the main instructors of the laboratory sections; she truly served the role of an assistant to students and instructors during laboratory activities). Tara indicated that she had no prior experience with inquiry but offered that if a lesson were to include inquiry activities, “the lab wouldn’t just entail memorization but would include critical thinking (e.g., short answer or essay type questions)” (pre-semester demographic survey, 08/09). She described the roles of instructors and students in a typical laboratory experience for undergraduates and in an inquiry activity as being the same: the teacher gives background lectures and helps students when they have questions, and students perform laboratories and answer follow-up questions. At the beginning of the semester, Tara reported that she would not likely become a faculty member in her post-graduate career and was unsure if her eventual career would involve teaching.

Cameron began his graduate student career after taking a year off from his undergraduate degree program; he was in his first semester of a Ph.D. program in Marine Sciences at the time of this study. Cameron had never taught before and indicated that he had never experienced inquiry. In the pre-semester demographic survey, Cameron proposed that a lesson with inquiry activities might contain "hands-on labs and group activities" (pre-semester demographic survey, 08/09). His description of a typical biology laboratory course experience for undergraduates included passive student and teacher roles: "Teacher goes over the lab for the day and then turns lab over to student to undertake. Teacher travels around answering questions and provides feedback" (pre-semester demographic survey, 08/09). His descriptions for inquiry activities reported in his pre-demographic survey reflected more active roles for students and teachers:

> …students are active participants rather than passive listeners. Teachers provide general info but mainly step back to watch students find out information through activities. Teachers also serve to answer questions and help students understand why it is they are doing something. (08/09)

Cameron indicated that he, like Tara, was unsure that a future career would involve teaching and that he was unlikely to take a faculty position.

Like Tara, John brought a M.S. degree (Plant Science) to the start of a Ph.D. program in Plant Biology. John had never taught before, reported having no experience with inquiry, did not offer suggestions as to what a lesson with inquiry activities might include, and did not attempt to describe what the roles of a student and a teaching in an inquiry activity might be. Unlike Tara and Cameron, John planned to obtain a faculty position in his future career. The likelihood that he would teach was high but he preferred to split his job responsibilities equally between teaching and research. Based on his experience taking introductory biology laboratory courses, students and teachers in these classes took passive roles: the student reads background material, listens to a professor give a general lecture, and follows a laboratory protocol. The teacher answers questions and points out things throughout the laboratory.

Evan was the oldest of the four GLA participants. He had worked in the medical field for several years after completing his undergraduate degree and was starting his first semester of graduate school, hoping to earn a Ph.D. in biochemistry. Evan gave the same responses to John in reference to future career goals, likelihood of teaching, and previous teaching experience. He indicated that he had had no previous experience with inquiry and like John, did not suggest what a lesson would be like if it included inquiry activities. Evan suggested that in typical undergraduate biology laboratory course experiences, the professor gives an introduction “that students should be prepared for” as well as additional information (e.g., warnings) before “releasing” the student to work (pre-semester demographic survey, 08/09). The professor’s role is to “monitor progress and help at any given point (pre-semester demographic survey, 08/09). Due to the extensive first year coursework required by his home department, Evan had two course overlaps with our weekly preparation sessions and therefore would usually arrive late and have to leave shortly after, thereby only staying for about 20-30% of any given preparation session. This became particularly stressful for Evan as he was assigned to teach the first laboratory section of the week; his personal course schedule was so full that we were unable to change his teaching schedule to avoid this.

## *Findings*

What follows are research study findings that arose from the analysis of data. All of these findings are related to GLAs' conceptualizations of teaching science as inquiry. The findings are presented per individual GLA and via cross-GLA analysis. The first set of findings presented considers the GLAs' initial "buy-in" to teaching methods that could possibly be used to teach science as inquiry. Then GLAs' views on differences between science laboratory courses taught using a traditional format and those taught with an inquiry format are presented. Third, GLAs' descriptions of what students need to "do" inquiry as well as what students need from their instructors are considered. These findings are followed by an extensive analysis of GLAs' views of a "good" teacher of science as inquiry and then a brief quantitative analysis of GLAs' comfort levels with content level that they were required to teach. Finally, findings of GLAs' recognition of inquiry science activities, how GLAs' views of the word "inquiry" changed over the course of their teaching assignment, and how the GLAs characterize teacher and student roles in inquiry or presented.

### *Initial thoughts about inquiry teaching methods: response to teaching vignette*

This section will examine the GLAs' reactions to teaching methods that might be used when teaching science as inquiry. The data analyzed in this section comes from the GLAs' reactions to the teaching vignette previously described.

In response to the inquiry teaching vignette presented in Appendix B, Tara indicated that the teacher's method was adequate. She also reported that if she were the instructor in that situation, she would have simply asked students about using a control, so that she would "be sure they were going to perform the experiment correctly" (response to teaching vignette, 08/09). This would have also given students an opportunity to demonstrate to her why they should use a control in what it should be. Cameron's response to the vignette suggested that he appreciated some of the teacher's teaching strategies used to attempt to get students to critically asses their experimental plan; he specifically noted the teacher's strategies of redirection of questions, letting students say everything they needed without him interrupting them, and allowing students to make decision about what they needed to do. Cameron's one point of criticism was directed at the point in time in which the teacher in the vignette Tom, told the students to rethink their experimental design. Cameron stated: "I probably would not have asked the first question (in the vignette) and focused on the need to improve the control" (response to teaching vignette, 08/09).

John reported that the instructional methods described in the vignette were "appropriate" because "instead of just giving them the answer he (the teacher) asked them questions that got them to think of other possibilities. I would have done something very similar if not the same" (response to teaching vignette, 08/09). Evan described Tom's methods as being confusing to students since the students were silent after the question was asked. Evan reported that he would have just told the students they needed a control once the student group finished explaining their experiment.

In summary, two of the GLAs disagreed with the appropriateness of the teaching methods used by the teacher in the vignette while two agreed. This measure of initial "buy-in" to teaching using inquiry methods suggests that novice instructors who find these teaching strategies to be inappropriate may be less likely to try to use them and therefore may have more difficulty enacting teaching science as inquiry in the classroom. Those instructors who appear to more readily accept teaching methods that encourage the pedagogy of teaching science as inquiry may be more likely to try and use them and may therefore experience an easier time enacting teaching science as inquiry in the classroom.

*Traditional science laboratories versus inquiry science laboratories*

In this section, findings will be presented that arose from the analysis of data related to GLAs' perceptions of differences between traditional science laboratories and inquiry-based science laboratories. Specifically, this section will examine how the GLAs' views of this topic changed over the course of the semester. This section of findings provides analysis per individual GLA as well as cross-analysis of the group of GLAs. Examples from each GLA participant are provided as appropriate; these examples surfaced among the data as the most definitive and representative instances of how the GLAs distinguished between traditional and inquiry instructional science laboratories.

In the teacher workshop given at the beginning of the semester, I asked all BIOL 1103L GLAs to skim through the laboratory manual for their teaching assignment and verbally give their reactions to differences that they noticed between it and manuals that they had used when taking introductory biology laboratory courses. After the GLAs offered such responses that indicated the BIOL 1103L manual had a limited number of experimental protocols for each laboratory exercise and the inclusion of pages for students to record experimental design ideas for every laboratory exercise, we discussed what "traditional" science laboratories involve in terms of teacher and student roles as well as laboratory manual presentation of activities. This was then contrasted to what "inquiry" science laboratories involve for these same characteristics. Shortly after this workshop, the participants engaged in their first of three individual interviews with me. In those interviews, all four GLAs described their experiences taking introductory science laboratory courses as being traditional in how they were taught, how students were supposed to learn, and how the laboratory activities were presented in the manual. Tara exemplified everyone's responses with the following statements from her first interview:

> …for like basic bio and basic chem it was here's a protocol….like a little 10-minute spiel about here's a little background and then it was follow your instructions, do what you need to do, and ask me if you have any problems… then you write up a lab report, turn it in next week. (08/09)

When asked to suggest why students and teachers took the roles assumed in these traditional laboratory courses, reasons given included: 1) traditional and older faculty who don't want to change (John); 2) professor didn't know anything about what actually was happening in the class unless the laboratory class contributed to the lecture course grade and TAs only knew enough to write on the board but could not expand on anything (Cameron); 3) assumption that some TAs didn't want to be there because they didn't seem to like it (Cameron); and 4) the professors wanted to give students practice following directions which has helped in grad school (Tara). Evan did not provide any responses to this question.

The exception to this traditional experience was from Cameron who excitedly pointed out that his introductory biology laboratory course was inquiry-based (this could not be said for his other introductory science laboratory courses such as chemistry and physics). He explained that he never knew that style of teaching and learning laboratory activities "had a name" (first interview, 08/09). Experiencing a phenomenon first and then subsequently applying a name to it is one of Anton Lawson's (2004) main tenants for how students best learn new material. In his introductory biology textbooks for non-science major college students, Lawson uses research about how our brains work to learn material the most effective and efficient ways possible to guide his presentation of material. He grabs students' attention by presenting patterns to them that they are then able to link new terms; by doing this the "…new terms have something to connect within memory and are therefore more easily understood and remembered" (Lawson, 2004, p. vii).

One question posed to the GLAs multiple times over the semester asked them to differentiate between science laboratory courses taught using a traditional format from those taught with an inquiry format. The goal of this question was to ascertain how GLAs' perceptions of what happens in a science teaching laboratory with inquiry-based activities changes over the course of the semester, either in regards to the student and/or teacher roles. In her first interview, Tara described a traditional instructional laboratory format as teachers "telling you what to do" and students being given a protocol to follow while in an inquiry format students must figure out what to do and design their own protocol; in order to do this, students must "understand enough about it to decide how you test it" (first interview, 08/09). By half way through the semester, Tara had broadened only her ideas of what an inquiry science laboratory is about: it included group discussions and student participation to get through the laboratories, and students "had to put the work in" in order to finish the laboratory activities (second interview, 10/09). Traditional instructional laboratory courses were more passive for teachers and students: "… you are up at front, talking at them, answering questions along the way. But most students don't ask questions because they want to go" (second interview, 10/09). Tara's end-of-the-semester interview responses to this question reiterated that inquiry laboratory courses require more student responsibility and more interaction between students and teachers. However, Tara has also developed a deeper level of teacher development in relation to this topic: in her final interview, she was able to describe how the differences between traditional and inquiry laboratories are related to student learning. The interactive nature of inquiry laboratories allows teachers have a greater knowledge of student conceptual learning as compared to taking a more passive, traditional teaching role where:

> you don't know what students are learning until they take a test…with inquiry-based you sort of gauge their progress along the way whether they are actually understanding and you can help them understand because that is the way the lab is set up. (12/09)

Many of John's sentiments regarding differences between traditional and inquiry instructional laboratories were the same as Tara's, but John was able to verbally demonstrate a deeper understanding of what teaching science as inquiry actually requires from teachers and students. Initial impressions of differences included that traditional laboratories have everything laid out for students so that they can easily follow a protocol to get through an exercise while inquiry laboratories require thinking, including personal reflection on and previous experiences in school and in life. The information from these reflections helps fill in gaps of information that the laboratories are not providing. Similar to Tara, John (in his third interview) expressed that inquiry laboratories are harder for the reason that students are not always prepared for critical thinking:

> …it's kind of hard for some people who are used to just saying here's this do it…they don't know how to figure out for themselves what a good way to do something is….or even if it's not the best way just to get started…(08/09)

In his second interview (about half way through the semester), John was able to expand on his understandings of differences between traditional and inquiry instructional laboratories, noting that having students create methodology actually makes the process of learning science *easier* because it is their own work on which they can reflect, and this is close to the process of science:

> …the biggest difference is students basically make up their own methodology versus just being given everything…in some respects that makes it easier on the students later on…when stuff doesn't work that you can say "you made up this experiment, how can you do it better?" versus when you get a cookbook method professors expect you to get a certain answer because they've done it so long everyone gets the same answer, and if something comes up wrong, go back and redo it or something. In inquiry-based they don't necessarily have to do that, they actually see more how science actually works. If it doesn't work, how are you going to go back and fix it…( 10/09)

By the end of the semester, John described differences between traditional and inquiry laboratories in terms of his frustrations in trying to teach science as inquiry. He described how student and teacher expectations in traditional laboratories stay at a level of expecting a "right answer" and for everything to work because the laboratory activity has been done countless times (third interview, 12/09). The chance of getting a result that is not expected is slim unless steps are completely skipped; this assurance of correct answers creates a low-stress environment. For the inquiry biology laboratories in which John engaged with students, he struggled with how to dispel students' misconception that there isn't always a "perfect" answer in science, but that is how science works and how we learn in science. As I observed him tell students several times during the semester of data collection: "Sometimes it [science] just fails miserably" (third interview, 12/09).

In his first interview, Cameron indicated that defining an instructor in inquiry laboratories should start with removing the word instructor. He felt it was "misleading" because it implies telling students how to do everything (first interview, 08/09). This "telling" role is indicative of a traditionally taught science laboratory course where students only need to listen and follow directions to complete laboratory activities; teachers in these laboratories simply tell students what to do and answer questions if students have problems. For him, the learning experience in an inquiry laboratory should be more conversational for teachers and students so that teachers are not seen as overbearing authorities but rather as people on equal footing with students. Cameron held these views all semester, and by the end of his teaching assignment, he explained in more detail that traditional laboratories are monotonous because although students may change topics every week, they follow the same procedure every week: students come in, do what they need to do, leave, write a report and hand it in the following week. Inquiry laboratories actually require critical thinking about the entire process of science: "…you actually have to think about it and each week it's your mind is only on this one problem and you have to get all aspects of it" (third interview, 12/09).

In Evan's first interview, he did not try to distinguish between traditional and inquiry instructional laboratories because he felt that at the point of that interview, he had not experienced any kind of inquiry in the two laboratories that had taken place. By half way through the semester, Evan began to report differences between the two types of laboratories: traditional laboratories followed a process of students receiving a summary of the laboratory from their teacher and then the teacher letting them do the activities, only stepping in when there is an issue of safety or a potentially large error being made. Inquiry laboratories were interactive, and teachers needed to be pro-active about this interactive nature. Evan also began to describe his frustrations with enacting inquiry experiences with students, pointing out that inquiry laboratories were a "headache" (second interview, 10/09). He felt that students at an introductory level were not ready to engage in designing experiments for several reasons: they had no confidence in what they were doing, did not know enough content or about the process of science to adequately design methodology for an experiment, and had no idea how to predict results of their experiments. These combined factors made it difficult for students to then write about their experiments. Additionally, students were not ready to deal with mistakes in their experimental plans, even though Evan freely admitted that this is what happens in science all the time. For him, something in BIOL 1103L had to be limited; students should either engage in an inquiry-activity and then write a structured laboratory report on the experience or "go back to traditional laboratories where it is cut and paste at the top end and freely write about it" (second interview, 10/09). By the end of the semester, Evan emphatically decided (in his final interview) that inquiry was not for introductory biology laboratories:

> Inquiry is pure chaos. I see a structured lab as everyone in laboratory coats, and they're perfect on all their glassware…I picture inquiry labs as a monkey pen at a zoo. That's what I picture as an inquiry lab. Just monkeys hanging from the ceiling, some are in the rafters, in the air ducts, some are eating the microscopes, like it's just…what is going on? And you would think it shouldn't be like that because they still have a backbone. They just have a couple of variables. But to this unseasoned student, those few variables are everything. Absolutely everything. (12/09)

Despite the fact that Evan ultimately decided that engaging students in inquiry-based laboratories at an introductory level was nothing but an exercise in frustration, he was able to articulate some of the same differences between traditional instructional laboratories and inquiry ones that other GLAs described. Overall, all GLAs demonstrated a development of ideas of what happens in an inquiry-based science laboratory while reiterating their unchanging views of traditional instructional science laboratories.

*What students need to "do" inquiry and what students need most from their instructors in inquiry-based laboratory courses*

Another aspect of understanding the GLA participants' experiences teaching science as inquiry were my perceptions of how the GLAs' viewed their students' learning needs changing over the course of the semester. The GLAs were explicitly questioned in all individual interviews about what they felt that students needed from them most as instructors. However, although never directly asked, most GLAs shared in these same interviews and other written and verbal conversations some valuable information about what students needed to "have" in order to "do" inquiry, or engage in the process of science. The following findings are analyzed in the framework of these important pieces to the puzzle of what it means to teach science as inquiry. When appropriate, quotes from GLAs or situations described by them are provided to exemplify the findings from analysis.

Tara reported that content knowledge was critical for students to be able to design an experiment and then test it. They also need to be able to think critically about their work so that they could justify the decisions that they made throughout the experimental design process. John's response was almost identical: content background, and even "minor methodology" background was necessary in order to even approach inquiry as presented in the BIOL 1103 laboratory curriculum (second interview, 10/09). He also mentioned that they needed critical thinking skills to be able to make choices for themselves. Cameron often talked about how students needed encouragement and confidence that they could "do" science (third interview, 12/09). For Evan, content knowledge was critical, but he noted that equally as important for students was to have confidence to apply that knowledge to an experimental design process.

Interestingly, the student characteristics that were identified by the GLAs as important for students to be able to do inquiry did not always reappear when the GLAs were explicitly asked to identify what students needed from them as instructors. In other words, GLAs did always report that what students needed from them as instructors were the same things that the students needed to do inquiry. For example, Tara did not report that her students needed her to provide them with content or ways to improve metacognitive skills. Rather, she reported that her students needed information from her in how to write in the discipline of science (since they were all non-science majors and therefore did not necessarily know discipline-specific conventions of writing). One of the points she made is that science writing is concise, and concise writing is essential for the business world (first interview, 08/09). To her, this skill was directly applicable to many of her students even though they were learning it from a scientist in an instructional laboratory setting. Tara also reported that because of the interactive nature of the laboratories and the fact that the laboratory activities emphasized questioning to such a large degree, her students need her to be prepared for those questions. She admitted that she did a lot more preparation for these laboratories than her previous teaching experiences. Finally she mentioned that she learned by devoting more time to prepping students for approaching pre-laboratory activities, she recaptured a great deal of precious in-laboratory time that was being sucked up by going over problems with pre-laboratory homework, and the questions she got via emails were cut down dramatically. She also mentioned that with the extra strategies she gave for approaching the pre-laboratory homework assignments, the pre-laboratory grades increased a great deal from beginning to end of the semester.

However, when describing differences between traditional and inquiry instructional science laboratories in her first interview, Tara emphasized how important it was for her to help students learn to articulate their reasoning for decisions made:

> "in traditional you teach them something you just lecture here it is and now do it. In this it's like why is this? Why is this more concentrated than this one? Tell me *why* this is more concentrated. Tell me why the absorbance would be higher for concentrated one rather than for more dilute one. They need to know *why* they are doing things. I need to ask them why and get them to explain it and if they don't get it quite right I can clarify it. So I think that's what I am there for…to guide them. (08/09).

For Tara, this *"why"* aspect of the inquiry biology laboratories was essential to the success of the laboratory experience for her and students; she consistently revisited this theme in all of her interviews. Clearly, then, she did feel that helping students achieve critical thinking was one of her main responsibilities as their instructor.

In contrast to Tara, the characteristics that John reported students needed to have in order to do inquiry were essentially the same ones he identified when questioned about what students needed from him as an instructor. He needed to give them content knowledge and also more guidance or structure in how to approach the inquiry aspects of the laboratories since it seemed so foreign to students. He also felt that they needed reassurance and confirmation from him that they were doing the right thing, and this was frustrating to him that they could not seem to grasp, even by mid-semester, that he was not going to give them the answers to solve the problems at hand. He wanted them to understand that he would guide them in certain directions to allow them to think critically and make choices, but he would not explicitly tell them what to do. This sentiment remained throughout the rest of the semester.

Like John, Cameron reported that what students needed to do inquiry were things that they needed from him as an instructor. His students needed him to present a comfortable environment where it was safe to talk about or ask anything and that as an instructor, he was open and ready for questions at any time. He felt strongly that they needed an interactive atmosphere to create these levels of comfort, and that as an instructor he needed to remain open-minded about what the students were asking. Having pre-conceived notions about what they were asking would not benefit the students because he would likely not provide helpful answers. He felt that he needed to give students the assurance that they could successfully complete all laboratory activities and that he had to guide them more at the beginning of the semester but then could back off from that role as the semester progressed. This did not imply, however, that Cameron felt that open-inquiry (with no guidance) should take place: “I think part of the inquiry is that I have to be like a resource, not necessarily just someone who would watch everything happen” (third interview, 12/09).

Evan did not allude to what students needed to do inquiry, but what students needed from him as their instructor was almost entirely pragmatic in nature: his students needed him to be a fair grader and not “lax” in the classroom (third interview, 12/09). He also felt that he needed to reach a middle point with his students: somewhere between a professor and a friend. He needed to challenge them and stick to the rules. He did not elaborate on any of these responses except to recall that his students were seemingly like high school students: immature, not ready to take responsibility for being in college, and could not follow directions. While not expressed within the responses to this question, Evan mentioned in the end of the semester interview that content knowledge was important in inquiry laboratories. He described having difficulties getting through the *Mendelian genetics* laboratory activities because of his weak content knowledge in this area.

In summary, the GLAs expressed a range of ideas concerning what students need in order to do inquiry and what students needed most from them as instructors. To a large extent, John and Cameron expressed that what students needed most from them as instructors was for them to give students the tools needed to do inquiry (e.g., content knowledge, interactive atmosphere). Tara's perceptions of what students needed to do inquiry and what they needed from her as an instructor were less aligned with her peers, suggesting that she viewed her instructor responsibilities as somewhat separate from providing all the tools students need to do inquiry. Evan did not provide a sense of what students need to do inquiry but suggested that he needed to focus on classroom management issues for his students. However, the findings in this section of data analysis parallel previous findings of the GLAs' descriptions of what an inquiry laboratory experience entails for both students and teachers. The GLAs' reported qualities of what students need to do inquiry and from instructors are similar to their descriptions of student and teacher roles in inquiry biology laboratories.

*Recognition of inquiry laboratory activities*

In this section of the data analysis, I was interested in determining how GLAs recognized a laboratory activity as having an inquiry nature. I specifically analyzed two sets of data: one from sample laboratory activities presented in pre- and post-semester demographic surveys and the other from discussions of inquiry qualities of five of the six laboratory series that the GLAs taught in BIOL 1103L. Findings are presented that arose from the analysis of data related to how GLAs interpreted the sample laboratory activities and the actual laboratories they taught could be described as inquiry-based activities.

*Sample laboratory activities.* One means by which I made an effort to understand how GLAs recognized inquiry activities was through the sample experiments presented in Figure 4.1 (these are the same as found in question #22 in the pre-demographic survey, Appendix A, and #13 in the post-demographic survey, Appendix C). These experiments were presented to GLAs in a pre-semester demographic survey before any teaching preparation had been given. Therefore, the responses GLAs gave reflected their initial ideas about what inquiry experiments might entail. The same scenarios were given to the GLAs at the end of the semester to see if responses had changed after receiving a semester of teaching education. Table 4.1 summarizes these changes.

Table 4.1
*Pre- and post-semester responses to recognition of inquiry experiments*

| | Tara | | Cameron | | John | | Evan | |
|---|---|---|---|---|---|---|---|---|
| Experiment | Pre | Post | Pre | Post | Pre | Post | Pre | Post |
| 1 | Yes | No | No | No | No | No | No data | No |
| 2 | No | No | Yes | No | No | No | No data | No |
| 3 | Yes | Yes | Yes | Yes | Yes | Yes | No data | No |
| 4 | Yes | Yes | Yes | Yes | Yes | 50% Yes<br>50% No | No data | Yes |
| 5 | No | No | No | No | No | No | No data | No |

Tara, Cameron, and John only changed their opinions on one experiment as to whether it was an inquiry experiment or not, but in all three cases it was for a different experiment. Tara initially described Experiment 1 as an inquiry experiment because “it requires understanding of crosses to identify genotype and phenotype of progeny” (pre-semester demographic survey, 08/09). Her post-semester response of *No* to this experiment was justified by the following:

"students are told what to do" (post-semester demographic survey, 12/09). Cameron initially described Experiment 2 as an inquiry experiment because it was a "hands-on activity" but he noted that students are "not necessarily understanding why" (pre-semester demographic survey, 08/09). His post-semester response of *No* to this experiment was justified by the fact that it "tells them (students) what to do" (post-semester demographic survey, 12/09). In the case of John's changed response to Experiment 3, he only half changed his pre-semester answer from *Yes* to a post-semester answer of half *Yes* and half *No*. His pre-semester interpretation that Experiment 3 was an inquiry experiment was that "There is a goal or end result desired but students must come up with how to do it" (pre-semester demographic survey, 08/09). His reasoning for the change was that it was "cookbook for data collection but open-ended for interpretation" (post-semester demographic survey, 12/09). Evan failed to complete this section of the pre-semester survey so there is no pre-post comparison for him. However, Evan is the only GLA in the post-semester evaluation of the experiments who reported that Experiment 3 did not describe an inquiry experiment because there was "no variability – you cross the 2 seeds and that's it" (post-semester demographic survey, 12/09). By the end of the semester and having gone through the same teacher preparation but having individual teaching experiences, Tara and Cameron had 100% agreement on what experiments were inquiry ones. John had 90% agreement due to his 50-50 response to Experiment 3, and Evan had 80% agreement with the other GLAs due to his response of *No* to Experiment 3.

Overall it appears that for three of the four GLAs (Tara, Cameron, and John), initial identification of inquiry experiments was highly consistent, and post-semester categorization of these same experiments was even more consistent. Although Evan did not lend pre-semester opinions of the experiments in Table 4.1, his post-semester data revealed 80% agreement with all other GLAs on which experiments were descriptive of "inquiry" experiments. All together, a generalization can be made that all four GLAs appeared to have the same understanding of what inquiry activities reflect.

*BIOL 1103L.* Another means to ascertain how GLAs recognized inquiry activities was through discussion within the mid- and end-of-semester interviews. At these times, I asked the study participants to reflect on the laboratories that they taught and discuss what aspects of inquiry they had experienced with students. Responses reflected differences in opinions on levels of inquiry as well as aspects of inquiry experienced in the following five laboratory series: *enzymes (Carb Cutter), water quality, antibiotic resistance, Case It (genetic testing), and* <u>*C. elegans*</u> *(Mendelian genetics).* These laboratory topics were presented to students in the order just listed.

For Tara, the *enzymes* laboratories had "a lot of inquiry," and it was seen in all three weeks via the predominance of questioning that had to take place "to try to get them to figure out the ins and outs of the labs and *why* they were doing it as well as what should be happening" (second interview, 10/09). Both the *water quality* laboratory and the *Case It* laboratory had established protocols, so inquiry in these laboratories only occurred in data interpretation and justification of conclusions drawn. Tara anticipated that the *antibiotic resistance* laboratories would be somewhat cut and dry in methodological design (because the laboratory manual gave a firm idea of how to physically set up experiments to test the effects of different antibiotic discs and antibacterial products on gram positive and gram native bacteria) and similar to *water quality* and *Case It* for data interpretation and argumentation of conclusions, but she quickly observed a problem with her students' decisions of what to test. After her first laboratory section, Tara and I were ready to discuss what we had both seen happening: students' random selection of antibiotic discs and antibacterial products to test with no clearly articulated reasoning for their choices or predicted results. In subsequent laboratory sections when students approached Tara for her approval to proceed with their experimental designs, she required that they articulate to her reasons for their experimental design set-up and predicted experimental outcomes. Finally, the three-week laboratory series on *Mendelian genetics* was likened to the *enzymes* laboratory series: the process of inquiry was found in the experimental design (she emphasized her questioning students to justify their choices of experimental design plans…what their expected results would be and why) but much more so in data interpretation when students almost always had to interpret unexpected results in reference to their expected ones.

John described the *enzymes* laboratory series by comparing it to the *antibiotic resistance* laboratory series. In the *enzymes* laboratories, John recalled that "we kind of gave them ideas but didn't tell them what to do with it so they had to figure out what to do with what knowledge they had to answer specific questions" (second interview, 10/09). In order to do that, they had to "figure out how to think inside our little box," and John reflected that this was hard for students since it was the first laboratory series of the semester (second interview, 10/09). He then described the *enzymes* laboratory series as being more structured than the *antibiotic resistance* laboratory series where students were given "more room to branch out and think for themselves and get used to not having someone say *this is what you do*" (second interview, 10/09, emphasis in text added).  Like Tara, inquiry aspects of the *water quality* and *Case It* laboratory series were held to data interpretation. John felt the most inquiry was seen in the *Mendelian genetics* laboratories because students had more choices for how to set up their experiments and interpret results than in any of the other laboratories. These responses sparked me to ask if changing the order in which laboratory series were presented to students would better prepare them for the level of critical thinking needed for in order to engage in all aspects of designing an experiment. John could not say one way or another since to him all of the laboratory series has some aspect of inquiry.

When asked to describe aspects of inquiry that he and student experience in the following five laboratory series: *enzymes (Carb Cutter), water quality, antibiotic resistance, Case It (genetic testing), and* C. elegans *(Mendelian genetics*), Cameron responded by articulating that "different kinds of inquiry" were experienced (second interview, 10/09). The *enzymes* laboratories required students to engage in a great deal of critical thinking on their own and as it was the first laboratory series of the semester, they had no practice with engaging in that level of metacognitive skills before that point. They had to constantly ask questions to figure out where to go next, and they weren't used to doing that. Cameron was the only GLA that indicated (in his second interview) the *water quality* laboratories had:

> the most true inquiry because it wasn't something that was too much for them to understand… they could understand what they were doing…it wasn't me as an overbearing teacher. They were there doing everything themselves. I was just basically just walking around and if they had a problem they would just ask me questions. So, I wasn't telling them what to do. They were kind of going out …initiative and doing it themselves. (10/09)

The *antibiotic resistance* laboratories engaged students in the least inquiry compared to *enzymes* and *water quality* because he felt that in these laboratories, "it was pretty clear what students had to do" (second interview, 10/09). Cameron later compared the *Case It* laboratory series to the *antibiotic resistance* laboratories because students could figure how to do everything from what the laboratory manual gave them. They determined all of their answers for post-laboratory questions from interpreting data in one "correct" way, and this was "traditional" to him (third interview, 12/09). He did admit that the *Case It* laboratories required students to think about data and what it meant, but this was not inquiry-based to him. Finally, Cameron aligned the *Mendelian genetics* laboratories to the *enzymes* laboratories: very inquiry-based because they had to design their own experiments. Even though there was an overall "right" answer students had to get to attain on their own by "taking little bits of tools and kind of figuring it out on their own. I would give hints here and there" (third interview, 12/09). When asked if the order of presentation of the laboratory series should be changed so as to better prepare students for the level of metacognitive skills required for engaging in all aspects of experimental design, Cameron emphatically said no. He especially felt that as much of a struggle as the *enzymes* laboratory series was for students, it should stay where it is because it was a challenging laboratory series that showed students that they can "manage everything" (second interview, 10/09). *Water quality* was a great break from the intensity of *enzymes*, and it being outdoors, it was active and kept students' interest. He also noted that the *antibiotic resistance* laboratory series had the most relevance to students' lives.

Interestingly, when Evan was asked to describe aspects of inquiry that he and his students experienced in the same five laboratory series: *enzymes (Carb Cutter), water quality, antibiotic resistance, Case It (genetic testing), and* <u>C. elegans</u> *(Mendelian genetics*), he did not answer in terms of aspects of inquiry experienced but rather discussed aspects of the laboratory series that were applicable to students' daily lives or that were confusing to students. These responses re-emphasize how Evan struggled throughout the semester to conceptualize inquiry in a teaching context. For him, the *enzymes* laboratory series resulted in students getting lost in technical details of how to do the experiments. There was "a lot going on in these labs, and students have to apply information from week to week" (second interview, 10/09). The *water quality* and *antibiotic resistance* laboratory series were very applicable to students, and this made them want to ask questions, which for Evan made his "life a lot easier" (second interview, 10/09). He did not further expand on the types of questions they asked or how he responded to them. He reported that the *Case It* laboratories had no inquiry in them while the *Mendelian genetics* laboratories had some but were "a headache because students cannot follow directions" (third interview, 12/09). Inquiry could be experienced in the second week of this three-week genetics series if students did everything in the first week correctly and if they had mastered certain techniques that they needed to analyze their data. If both of these parts of the *Mendelian genetics* laboratories were accounted for, then students were left with a large task of interpreting data that was often not what they expected to get. When asked if he would change the order of the laboratories to better prepare students to engage in the process of inquiry, Evan's answer was vague: "Water quality comes out of nowhere but gives a break from intensity of enzymes. Antibiotics can be thrown in anywhere because it's a cool lab" (second interview, 10/09).

This section of data analysis indicates that most GLAs found two of the five laboratory series discussed (*enzymes, Mendelian genetics)* offered the most inquiry for students and teachers because they had the greatest emphasis on students fully exploring the experimental design process (including interpreting unexpected data, using previous knowledge to help solve problems, and being able to complete laboratory activities with only teacher guidance) and therefore greatest engagement in critical thinking skills. Two other laboratory series (*water quality, antibiotic resistance)* and their inquiry characteristics were more debatable per GLA. These laboratories held varying degrees of characteristics of inquiry, as described by the GLAs, but included such characteristics as interpreting unexpected data, articulation of experimental design choices, and justification of conclusions. The remaining laboratory series, *Case It*, was determined by all GLAs to have little to no inquiry characteristics. Overall, the GLAs appeared to have agreement upon what constitutes little or no inquiry as well as extensive inquiry, but laboratories that were determined to be more “middle ground” resulted in variations of interpretation of what inquiry was experienced by teachers and students.

*Defining a “good” teacher of science as inquiry*

When teaching science as inquiry, teachers must engage students in activities that involve experiencing the process of science. This can be achieved through partial inquiries, those that engage students in some of the “five essential features of classroom inquiry” (NRC, 2000, p.25) or full inquires that meet all five features (p.28). For the purposes of this study, I based my notions of qualities of a “good” teacher of science as inquiry on these five essential features of classroom inquiry. While I never held a specific conversation or instructional session that discussed these qualities in reference to being an effective teacher of science as inquiry, the mini-preparation sessions held throughout the semester, post-observational feedback, and instructional teaching notes reflected qualities sought in the GLAs that would enable them to achieve some or all of the essential features. For instance, instructional teaching notes given to GLAs often included questioning strategies to use so that students would have to communicate their process of thinking to the GLAs. These strategies were guidelines to avoid telling students the correct answer to problems but instead push them to articulate their thought processes. In most cases, using these strategies of redirecting student questions allowed students to solve their own problems.

In some instances of reflective discourse, the GLAs and I discussed the frustration that students expressed with inquiry-activity based laboratory activities and how satisfying it was for them and the GLAs when the students were able to reach the stated objectives of the laboratory exercise. The process of moving past these road blocks to success necessitated that the GLAs remind students of their capabilities of developing and using higher order thinking skills in a field that is not their preference. It also required that the GLAs allow for students to make some mistakes; one of Evan's comments synthesizes the comments of all four GLAs: "Let's face it, in science there are failures. We learn from them" (second interview, 10/09). Actually allowing that to happen in the classroom, however, might prove to be a difficult teaching task. Reflective discourse allowed for me and the GLAs to discuss these teacher qualities in a general setting and not as a specific discussion on characteristics of a good teacher of science as inquiry.

As the GLAs experienced teaching science as inquiry in BIOL 1103L, I attempted to capture how they described what they needed to do for successful implementation of the laboratory activities. This information was critical to my understanding how the GLAs came to conceptualize teaching science as inquiry because their responses could potentially give me insight into what they deemed important to offer as a teacher in order to teach science as inquiry. The following section of findings illustrates analysis of GLAs' conceptions of a "good" teacher of science as inquiry. The findings presented as a result of this analysis indicate high agreement amongst all GLAs regarding specific personality characteristics, class environment characteristics, and content knowledge that are needed to be a successful teacher of science as inquiry.

After a few weeks of teaching, Tara began discussing the importance of student participation. She described that for the inquiry laboratories to work, she needed to motivate students to participate because "they're supposed to get involved and learn how to do it" (first interview, 08/09). This simple statement indicates Tara's attitude towards student responsibility in this particular laboratory course. She noted that sometimes it seemed impossible to get students to participate and that she would resort to having to call names from the roll sheet if no one would volunteer.

A theme that emerged across most GLAs was that a good teacher of science as inquiry needed to have a personality characteristic of being approachable. In Tara's case, this was important for two reasons. One was so that students would be comfortable asking questions, and the second was so that they would see that she was comfortable answering the questions: ”I guess they'd have to be someone who says *Oh these people can talk to them*…students can feel comfortable talking to them…feel comfortable responding to their questions…" (first interview, 08/09, emphasis in text added). In this discussion of teacher personality characteristics, Tara also reiterated the importance of being comfortable with content in order to answer questions. At the end of the semester, one of her reflections on the entire semester demonstrated that she fulfilled this last characteristic of a good teacher of science as inquiry: "I was already pretty confident as a teacher. But I definitively feel more like a teacher now but I think that's more the whole basis of the lab…I feel pretty prepared in concepts" (third interview, 12/09).

By mid-semester, Tara described a good teacher of science as inquiry as someone who could effectively strategize questioning techniques in order to ask students questions that didn't give answers away. These probing questions needed to be carefully worded so that students would have to actively think through the steps they had taken to that point; this often would allow for students to answer their own questions. She also re-emphasized that getting students to participate was critical in inquiry laboratories, and she suggested that this might be easier for some GLAs than others due to personality characteristics: "Cameron is good at that because he's so friendly and so nice. He’s all over the place but they love it. I’m not that way” (second interview, 10/09).

In her final interview, Tara reiterated that a good teacher of science as inquiry needed to be able to ask the “right” questions to students so that they could critically assess their work (third interview, 12/09). Student participation continued to be a struggle but a necessity for the laboratories to flow well. Her discussion of this aspect of the laboratory course indicated that the class environment might actually affect student confidence and therefore willingness to participate: “…I think it’s easier to do it in small groups…because I think a lot of people are afraid in front of a class but when you are face to face they have to at least respond” (third interview, 12/09).

John began the semester describing a variety of characteristics of a good teacher of science as inquiry, and some of these overlapped with Tara’s responses. First, he indicated that a good teacher had to be ”passionate about the (students’) work and take interest in it” (first interview, 08/09). This personality characteristic conjures up images of a teacher showing excitement and overt enthusiasm for what is taking place in class, but I noticed throughout the semester that John’s personality tended to be reserved and at times stoic. He did, through his questions to students and discussions with me, clearly show interest in his students’ work. For instance, he asked thoughtful questions when teaching that allowed students to consider multiple avenues for their experimental plans. However, his quieted expression of interest may not have lead students to think he was passionate about their work.

For John, a good teacher of science as inquiry could not be passive. Noting his experience with hands-off instructors who left him feeling alone in the learning process, he did not have many fond memories of mentoring support as he never felt that he could approach most professors with questions or problems. He did talk about one of his past instructors who took an active role in discussing, planning, and evaluating John's work, and so John wanted his students to see him in that light: approachable, so that they would come and ask questions. He felt it was important to stay up to date with students' progress to keep them on track. John initially reported that many students came to him with questions, but as noted earlier, his students often wanted him to just tell them the answers to problems. Many eventually stopped coming to ask him for help, but the ones who persisted were ones that John described as "really wanting to know how to get to the right answer" (second interview, 10/09).

A difficult role to take, but a necessary one in John's opinion, was to let students make mistakes along the way of engaging in the process of science "because that is where students learn" (first interview, 08/09). Knowing that this had to be done within reason, John felt confident that if students were to experience authentic inquiry, they needed to go through the reality of making errors in science and then finding ways to fix those errors. For an inexperienced teacher, John took a bold step by potentially creating a frustrating learning environment where students might resent his not telling them the "right way" to do things in the first place and therefore feel that their time and energy were wasted.

By mid-semester, John reported good teachers of science as inquiry needed patience because inquiry can be "trying on students and they take that frustration out on the TA to some extent" (second interview, 10/09). This aspect of teaching science as inquiry is something he reported having talked about with all the GLAs and to which they were all in agreement. He also noted that content knowledge and a knowledge of the premise of laboratory activities, experienced through doing the same laboratory in a different course/setting or experiencing it in a research laboratory, was critical so that a teacher can troubleshoot problem and be able to answer questions: "…even though you understand the context, you may not be able to answer some of the problems that arise without having actually done something like it" (second interview, 10/09). John also mentioned that being able to rephrase questions was important because not everyone understands the same way; he felt that peer learning was means to achieve this goal if a teacher was unable to convey information to a particular student. John did not provide data in his end-of-semester interview about characteristics of a good teacher of science as inquiry.

Cameron, like the previous two GLAs, felt that good teachers of science as inquiry must have both content knowledge and contextual understanding of the laboratory activities "…because the minute you go up there and you really don't know what they are talking about, they'll see right through it (first interview, 08/09). He admitted, like Tara, that this takes extra effort on the teacher's part. I observed Cameron put this teaching characteristic into play throughout the semester. In Cameron's introductions for each laboratory section, he used different ways to present an overview of the laboratory activities, and they almost always pertained to the students' lives. He brought in terminology from different non-science disciplines and made parallels between those terms and the processes in which they were involved to terminology and processes the students were working within laboratory activities. An example comment that I wrote during my observations of Cameron in the first week of the *Mendelian genetics* laboratory series (week 12 of semester) exemplified this:

> Intro to laboratory: Cameron does a great job of explaining why it is important to study C. elegans for studies of genetic inheritance. Clearly did research on his own. Examples go beyond what is in the manual.

Similar to John's assertion that good teachers of science as inquiry should show passion for students' work, Cameron also discussed the importance of expressed enthusiasm for learning and questions. He felt that students should see that as a teacher, he enjoys questions and is willing to answer them. If he shows students that he is intimidated by questions, then the students most certainly won't ask them. He echoed Tara's stated sentiments that he needs a firm content based to answer the questions.

By mid-semester Cameron felt that to be a good teacher of science as inquiry, one had to listen to students carefully to make sure that their questions are being heard. He felt it was easy to only half listen and to answer students with pre-conceived answers. Cameron also discussed that in order to support the interactive format that is inherent to inquiry laboratories, a teacher cannot talk down to students but instead should create conversations with students so that everyone is kept on equal levels. The end of the semester found Cameron reflecting that patience is a virtue, and without it, the laboratory would fall apart: "…students are stressed and if you get flustered it all falls apart" (third interview, 12/09). Content knowledge was still deemed critical, as was being open-minded to seeing that to teach science as inquiry effectively, "… it's not just me talking to the class. It's students who are talking back" (third interview, 12/09).

Evan initially focused his thoughts on a good teacher of science as inquiry in reference to teaching characteristics noted by other GLA participants: not being introverted, showing excitement about what students are doing, and getting students to participate by taking on the role of a "game-show" host in order to motivate them (first interview, 08/09). He felt it was important to make sure students in these laboratories understand that they have to participate. By mid-semester, Evan discussed how important it was to not give answers to students because they don't end up learning anything: "…don't give answers…if I give it to you it's worthless…I have been there…you are telling me and I can do this on a test but I don't know what it means" (second interview, 10/09). He also noted, like Cameron, how important it was to listen to students' questions and not "write them off' " (second interview, 10/09). He likened questioning strategies to the profession of his sister, a defense attorney; in order to pull out what students know so that they can answer questions, you have to act as a lawyer and cross-examine them. This "brings students along" (second interview, 10/09) to the point where they can begin to start answering questions. Interestingly, these two interviews revealed two of several cases where Evan could verbally attribute aspects of the teaching preparation that the GLAs received to what needs to happen in his actual teaching experience, but when in the classroom, I frequently observed Evan telling students answers to questions and taking a passive rather than an active role in student interactions. Here are two examples of this dichotomy in intended curriculum versus practiced one as recorded in notes from observations of his teaching:

> 1. Evan tells students plate set-up choices and why each set-up would test certain parameters of *antibiotic resistance*. He needs to let student figure that out, or at least try. That is the point of the lab. (first set of observations, week 7 of semester; first week of *antibiotic resistance* laboratory series)
>
> 2. No use of demonstration scope and no demonstration of identifications of worms. Students must have technical, pragmatic instruction to identify worms and use microscopes. (first set of observations, week 12 of semester; first week of Mendelian genetics laboratory series)

At the end of the semester, Evan re-emphasized the need for a good teacher of science as inquiry to actively listen to student questions, citing himself as an example of what not to do: answering students' questions with pre-conceived answers when it could be conceptual issue they don't understand. The following excerpt from Evan's final interview described this experience:

> I only learned this because I have had to record myself twice, and then when I was watching the movies, I saw that students were asking me questions and I answer the wrong thing. I was like "oh they didn't ask what I answered. Did I even hear them?" Like it was actually the last lab, <u>*C. elegans*</u> *3*, I had to record that one. And one of the students asked me a question and I answered with the most obvious…I mean it wasn't a stupid answer. I was like "well let me look at your punnett squares." There was no reason for me to look at their punnett squares. I'm like why did I even say that? I didn't listen. I had already in my head what he asked, even though it's not what he really asked. So there was no help of inquiry there. Where I could have lead him to answer his own question. (12/09)

Evan also noted content knowledge was critical to being a good teacher of science as inquiry, noting his problems with answering questions during the three-week laboratory series on *Mendelian genetics* which he attributed to not being strong in that content area. He further explained that his lack of knowledge in this area was due to the fact that he memorized everything in his undergraduate class in order to pass tests, but that he never felt he really understood what he was doing. Finally, Evan discussed that making the laboratory activities relevant to students' lives was important for effective teaching science as inquiry because that was the job of a teacher in general – to make things relevant to students. Both he and Cameron discussed at several points during the semester that the *antibiotic resistance* and the *water quality* laboratory series were excellent examples of everyday relevance. Evan went farther in his third interview to discuss that the focus of the *enzymes* laboratory series (testing a diet pill on the market to see if it does as it advertises: blocks the digestion of starch) should have been more than relevant to students because “our county is obsessed, completely, with figure,” but felt that this laboratory series fell short of this because students got lost in technical aspects of the laboratory activities (second interview, 10/09). They had too much going on that was new to try and pull together that they lost the overall interest factor in the laboratory topic.

I found these interview pieces helpful in understanding how Evan was developing as a teacher within this laboratory course. Repeated incidences of hearing about and discussing, with Evan, his inability to define inquiry within the context of teaching and his seeming endless frustrations with the laboratory curriculum and his students were sharply contrasted by his less-frequent statements such as the ones described in this section of data analysis and findings. In this end-of-semester interview, Evan was not only able to articulate what he needed to be doing in the classroom to make teaching science as inquiry a successful experience, but he was also confident and honest enough to take those qualities and compare them to how he was actually teaching. This level of self-reflection is indicative that Evan has the cognitive ability to constructively self-evaluate his own teaching.

To summarize, the themes of approachability, strong content knowledge, taking active roles in student learning, showing excitement for student learning, and getting students to participate were teacher characteristics described by all GLAs as necessary to be a good teaching of science as inquiry. In this light, it is clear that the GLAs all shared similar experiences in the classroom. Beyond these characteristics, the GLAs described additional teacher attributes important to be a good teacher of science as inquiry; the characteristics may reflect individual struggles that the GLAs faced based on their personalities or those of students.

*Comfort levels with content*

In order to gauge how GLA participants felt about content that they were going to have to teach, question #9 in the pre-demographic survey asked GLAs to report their “level of content knowledge for the material covered in this course” (See Appendix A). John, Cameron, and Evan all reported “high” levels while Tara reported “very high.” Additionally, a one-question survey (see Figure 4.2) was given to all GLAs that asked them to rate their comfort level with material presented in pre-laboratory activities for three laboratory series (*enzymes, antibiotic resistance, Mendelian genetics)*. These pre-laboratory assignments were chosen to evaluate because I felt that they assessed a wide range of detail of content and conceptual-based questions. The score a GLA could choose represented their relative comfort level: low scores (e.g., “1”) indicated low comfort level answering student pre-laboratory questions without assistance and high scores (e.g., “4”) indicated high comfort level of answering pre-laboratory questions without any assistance. Table 4.2 displays the collected scores.

Table 4.2
*GLA participant pre-laboratory comfort levels with content in three laboratory topics: enzymes, antibiotic resistance, Mendelian genetics*

| | Evan | Cameron | Tara | John |
|---|---|---|---|---|
| Pre-laboratory topic | | | | |
| *enzymes* | 4 | 3 | 1 | 4 |
| *antibiotic resistance* | No data | No data | 3 | 4 |
| *Mendelian genetics* | 2 | 4 | 4 | 4 |

The results indicate that John always ranked his comfort level with content topics as being high while data collected for the other three GLAs demonstrated a greater mix of reported comfort levels. Only two laboratory topics had data from all four GLA participants (*Mendelian genetics* and *enzymes*), and the *Mendelian genetics* laboratories garnered overall higher scores than enzymes.

*How GLAs' views of "inquiry" changed over the course of their teaching assignment*

For most GLAs, their views of the word inquiry began with a limited (or non-existent in the case of Evan) position, but often developed as the semester progressed. In her first interview, Tara described the word inquiry as a teaching methodology: "inquiry is just a question... I introduce and idea, I ask what they think, why they think it, where they think we should go from there" (first interview, 08/09). She eventually built this view to include a means of learning: "…it is a method for me of how to get them to learn. And it's a method for them of how to learn….questioning them to make them think" (second interview, 10/09). Interestingly, John took the opposite progression in his conceptions of inquiry. He initially focused his notions of inquiry on learning, describing inquiry in broad terms: a means to find out information by asking questions. By half way through the semester, he only slightly clarified this conception of inquiry by adding that inquiry was a means for students to approach science. At the end of the semester, John described inquiry as a teaching methodology that varies per instructor. Recalling his experiences of having both passive and active science teachers, John noted that inquiry teaching roles depend on how much teachers get involved with what and how their students are learning.

Cameron probably held the most unchanging view of inquiry, but it was broadly defined throughout the semester as a both a mode of teaching and a mode of learning, inside and outside the science classroom and encompassed both sides of Chiappetta's (1997) views of inquiry.

Inquiry was a "responsibility" held by anyone interested in learning more about something, regardless of the discipline, to find answers to problems encountered It also allowed people to become more independent in their thinking and didn't require a set method (first interview, 08/09). As described by Chiappetta (1997), this line of thinking reflects teaching or learning *by* inquiry (not the expressed focus of the laboratory course Cameron was teaching); Chiappetta, of course, focused on learning *science* by inquiry, but Cameron applied this same theory to learning anything.

In the realm of teaching introductory biology laboratories, inquiry (to Cameron) presented a situation where students and teachers work together to solve presented problems. Teachers do not lecture at students but rather guide students with encouragement and clarifying questions in order to allow them to work through the process of science to solve the problems at hand. In this description of inquiry within teaching introductory biology laboratories, Cameron followed Chiappetta's (1997) vision of teaching science *as* inquiry.

Of the four GLA participants, Evan was never able to fully articulate what inquiry meant to him. He bounced back and forth in multiple conversations with me and in all of his interviews between a way to learn about anything of interest, a way to teach science, and a way that scientists do science; these are the same characteristics of inquiry summarized by Minner, Levy & Century (2009, p. 3) that describe the multitude of definitions provided in literature in inquiry. In most circumstances where this topic arose, Evan used his experiences working in a research laboratory as his point of reference. It became clear that Evan could easily view inquiry a process in which he engaged as a scientist, but could not conceptualize it in the context of teaching and learning in a biology laboratory course.

*How GLAs characterize teacher and student roles in inquiry*

Although never explicitly asked to articulate the roles of a student and a teacher in inquiry biology laboratories, pieces of information about this topic surfaced throughout the semester during interviews, email correspondence, and conversations when GLAs were trying to describe what inquiry meant to them. Tara initiated the semester by explaining that her role was to answer students' questions with a question in order for students to figure out solutions to their problems. When asked to explain that response in greater detail, Tara explained that she wanted students "to understand why they are doing it, so my questions are *why* questions. I want them to think critically…this questioning will apply to life" (first interview, 08/09). By half way through the semester Tara admitted that she liked that students had to develop their own procedures in some of the laboratory activities because she felt that this process should allow students to gain an idea of why they were doing what they were doing (although she added that they should also be able to implement it if they designed it, but that didn't always happen). Tara explained that the group work aspect of the BIOL 1103L curriculum better enabled students to develop heir own investigations: "I like that they work in groups so there's not the pressure of trying to have to figure it out yourself" (second interview, 10/09).

Cameron reported that students have greater responsibility in the inquiry laboratories because the GLAs were not "spoon-feeding" the answers to everything (second interview, 10/09). This called for students to encounter a given problem, understand it, and then create an experiment about it. In his mind, inquiry laboratories called for a role reversal in what students and teachers normally do: "And as time progresses you can kind of step back a little bit and then the student's responsibility is to step up" (second interview, 10/09). These sentiments carried throughout the semester. He even expanded his conceptualizations of the teacher role to explain that the teacher needs to create interactions with students in a way that helps students make their work and efforts their own (and not the sentiments of the teacher). Teachers also have to hold back answers, and this is frustrating to both students and teachers. The impact of these experiences can make the instructors look like “hard asses,” but it challenges students to do more independent work and thinking. Like Tara, he noted this is especially true if they have groups to work with (third interview, 12/09).

John also did not ever change is view of a teacher’s or a student’s role in inquiry. The teacher was there to help guide students down paths that will eventually lead them to where they need to go, but students had to make choices for themselves the entire time, and this required them to exercise critical thinking. In order to achieve that role, the teacher had to lay a foundation of content knowledge so students could build from it and attempt inquiry. Evan’s views on this topic were solely from an instructor’s position: “guide them…challenge them… stick to the rules” (second interview, 10/09).

For a summary table of the development of the GLAs’ conceptualizations of teaching science as inquiry, please refer to Table 4.3.

*Implications*

While science graduate students who are required to teach might be offered teaching education, it is often not discipline- or pedagogically-specific (Prieto, Yamokoski, & Meyers, 2007). This is a monumental issue considering that graduate students teach as many as two-thirds of undergraduate courses at some higher education institutions (Nelson, 1995, p.20). How can we assume that these novice teachers are accurately conceptualizing teaching science as inquiry, and therefore potentially translating this into their teaching, if they are not offered opportunities to develop these conceptions? As an example, Roehrig, Luft, Kurdziel, & Turner (2003) reported that chemistry graduate student instructors (GTAs) of guided-inquiry laboratories tend to teach as they were taught: through traditional means of lecturing to students and grading laboratory reports. Although given a four-day training session on topics designed to “inform GTAs about their responsibilities as instructors and to help them make the transition from student to teacher” (p. 1206), the GTAs were given no instruction in *how* to teach that content in this curriculum. Observations of these GTAs revealed that they did not have instructional skills to work with inquiry-based activities. They were unable to manage multiple student-designed experiments and so ended up spending too much time with some groups and not enough with others. They corrected students’ errors by telling them how to do things and were observed to sometimes take equipment from students and do the experiments for them. The researchers provided suggestions of how a training program for the GTAs should include means to prepare them to teach using inquiry teaching skills, but these proposals did not involve a means to understand the GTAs’ conceptions of teaching science as inquiry. Gaining an understanding of how the GTAs were responding to the training in terms of their understanding of pedagogical approaches would better inform future GTA preparation by allowing the researchers to see if new emphases should be placed on discourse or other means for the GTAs to articulate their conceptualizations.

This report presents an analysis of how science graduate students teaching introductory biology laboratory courses to non-science majors come to conceptualize teaching science as inquiry. Many of the factors that shaped the GLAs’ beliefs were elements of the teaching preparation program that they received throughout their teaching assignment (e.g., discussion of questioning strategies, discussion of consideration and validation of student ideas), but just as importantly, this research study demonstrates that factors outside of pedagogically specific teaching preparation brought to a teaching assignment can affect how conceptualizations of teaching science as inquiry are developed (e.g., knowledge of content inherent to lessons being taught, views of how science should be learning, past experience with inquiry). It is reasonable to assume that these conceptualizations may affect the actual teaching in which the GLAs engage. In a subsequent manuscript, I will analyze data presented in this research study and in a previous one (Author, 2010a) to determine if and how GLAs are able to enact their conceptualizations of teaching science as inquiry.

In light of both existing preservice and inservice teacher education literature on the numerous factors that may affect how teachers come to conceptualize inquiry as well as lack of research on this same topic as it is relevant to graduate student instructors, I did not attempt to pinpoint the GLAs' understandings of teaching science as inquiry to one or even two particular characteristics but rather opened the doors for the GLAs to provide as much data as possible about factors influencing their conceptualizations. For example, Windschilt's 2004 study of how folk theories of inquiry can be used to provide a context for how preservice teachers conceptualize inquiry provides evidence that a multitude of notions about inquiry:

> …exist not only "in the heads" of science teachers, but are codified in authoritative documents, reinforced by textbooks, broadcast in the media, and embodied in the practices of educator who promote the use of inquiry as well as those who favor more traditional methods. (p.484)

He also suggested that educational experiences help shape preservice teachers' ideas about "doing science" with the most formative part of this molding occurring from their undergraduate coursework. In these courses, the preservice teachers are exposed to science taught in a "confirmatory" fashion as it was in high school (Windschilt, 2004, p. 484). Some of Windschilt's earlier work suggests that while getting preservice teachers involved in authentic inquiry experiences can influence their conceptions of inquiry, it is not the sole factor for enacting these ideas in the classroom (Windschilt, 2003). Even when given these experiences, it was the preservice teachers who had actually been involved in "authentic scientific research" (p.485) who tended to enact more inquiry in the classroom (Windschilt, 2004).

The semester in which this study took place began with the four study participants reporting no or limited conceptions of "inquiry," but by end, three of the four had come to conceptualize what teaching science as inquiry in introductory biology laboratories meant to them as individual instructors. While examination of multiple data sources revealed that all participants described numerous similar attributes of what it meant to teach science as inquiry, analysis also revealed that some GLAs' conceptions continued to develop throughout the semester while some stayed more steadfast. One possibility for this is that some GLAs may have decided that when a particular teaching strategy worked, there was no need to change it. Considering the myriad responsibilities that each GLA carried in addition to their teaching assignment, it is reasonable to assume that a GLA would hold on to each and every success and try to rock the boat as little as possible. One GLA was never able to clearly articulate ideas of teaching science as inquiry but could only relate inquiry to what he did as a scientist. Additionally, analysis of data indicated that commonalities existed between GLAs' ideas of when laboratory activities offer little or great opportunity for students to engage in science as an inquiry process, but some laboratory activities that did not appear to have these clearly distinguishable "extremes" of involvement in inquiry caused the GLAs to identify different aspects of what constitutes an inquiry activity and interpret how it is actually experienced by students and teachers. This suggests that despite the fact that a group of teachers may undergo the same teaching preparation that has an emphasis on understanding of pedagogy, what they bring with them to their eventual teaching assignment (e.g., experiences, knowledge of a pedagogical focus), what they take from the preparation, and their experiences in the classroom all contribute to the development of personal beliefs about teaching science as inquiry.

The broad interpretation of the data in this study would have greater meaning in a richer research setting. However, the findings addressed in this study lay a firm foundation for further research into graduate student teacher education, not only in the considerations of what should factor into the design and implementation of a preparation program, but also what and how to assess what the graduate students are learning from that teacher education. This study will help build a literature base of empirical studies on graduate student teacher education as it relates to inquiry at a higher education level. As in the study noted above (Roehrig et al., 2003) being able to study the development of these instructors' teacher beliefs will enable a more sound development of pedagogically grounded teacher support.

Table 4.3
*A summary of the development of conceptualization of teaching science as inquiry*

| | |
|---|---|
| **Initial "buy-in" to inquiry teaching methods** | |
| Tina | No |
| Cameron | Yes |
| John | Yes |
| Evan | No |
| **Recognition of differences between traditional and inquiry laboratory activities** | |
| 1. All GLAs articulated differences between traditional and inquiry laboratory activities throughout the semester of their teaching assignment.<br>a. All GLAs shared some commonalities in these described differences.<br>2. All GLAs developed their ideas about what constitutes an inquiry laboratory exercise throughout the semester of their teaching assignment.<br>3. All GLAs' views of what constitutes a traditional laboratory exercise stayed the same throughout the semester of their teaching assignment. | |
| **What students need to do inquiry and what they need most from the GLAs as instructors** | |
| Tara | Students need certain tools to do inquiry but what they need from her as instructor are things other than these tools (e.g., need her to be prepared). |
| Cameron and John | Students need certain tools to do inquiry, and they need them [as instructors] to provide those tools. |
| Evan | No information given on what students need to do inquiry, but they need him as their instructor to work on classroom management skills (e.g., be fair grader, not be "lax"). |

Table 4.3 continued

*A summary of the development of conceptualization of teaching science as inquiry*

| **Recognition of inquiry laboratory activities** | |
|---|---|
| | *Sample laboratory activities* |
| 1. Tara, Cameron, and John demonstrated high pre-semester agreement on what sample laboratory activities could be designated as inquiry activities.<br>2. Tara, Cameron, and John demonstrated high post-semester agreement on what sample laboratory activities could be designated as inquiry activities.<br>3. Evan did not provide pre-semester data but had 80% post-semester agreement with the other three GLAs on  what sample laboratory activities could be designated as inquiry activities. | |
| | *BIOL 1103L laboratory series* |
| 1. All GLAs agreed that particular laboratory series either had no or very little inquiry (e.g., *Case It!*) or a lot of inquiry (e.g., *enzymes, Mendelian genetics*).<br>2. All GLAs found that particular laboratory series were more “middle ground” inquiry activities (e.g., *antibiotic resistance, water quality*). These laboratory series elicited a range of individual variation in reference to ‘levels” of inquiry experienced as well as when during the laboratory series the inquiry was experienced. | |
| **Defining a good teacher of science as inquiry** | |
| 1. All GLAs expressed multiple commonalities in references to characteristics of a good teacher of science as inquiry including approachability, strong content knowledge, taking active roles in student learning, showing excitement for student learning, and getting students to participate.<br>2. All GLAs individually described additional teacher attributes important to be a good teacher of science as inquiry. | |

Table 4.3 continued
*A summary of the development of conceptualization of teaching science as inquiry*

<table>
<tr><td colspan="2">Comfort levels with content inherent in the enzymes, antibiotic resistance, and Mendelian genetics laboratory series</td></tr>
<tr><td colspan="2">Tara, Cameron, and Evan reported a range of low to high scores across all laboratory series. John reported high comfort levels for all three laboratory series.</td></tr>
<tr><td colspan="2">How views of “inquiry” changed over the course of the semester</td></tr>
<tr><td colspan="2">1. All GLAs began the semester with little (vague and general) or no position on what inquiry described.<br>2. All GLAs developed views of inquiry over the course of the semester, but did so in different ways:</td></tr>
<tr><td>Tina</td><td>Began with view of inquiry as a teaching methodology. Developed into a view of modes of both teaching and learning.</td></tr>
<tr><td>Cameron</td><td>All semester viewed inquiry as modes of both teaching and learning. Demonstrated development of these modes throughout the semester of his teaching assignment.</td></tr>
<tr><td>John</td><td>Began with view of inquiry as a mode of learning. Developed into a view of modes of both teaching and learning.</td></tr>
<tr><td>Evan</td><td>Never able to articulate what inquiry meant in reference to his teaching assignment. Was able to articulate inquiry in reference to his work as a scientist in a research laboratory setting.</td></tr>
<tr><td colspan="2">Student and teacher roles in inquiry</td></tr>
<tr><td>Tina</td><td>Demonstrated development over the course of the semester of views of student and teacher roles.</td></tr>
</table>

Table 4.3 continued
*A summary of the development of conceptualization of teaching science as inquiry*

| **Student and teacher roles in inquiry continued.** | |
|---|---|
| Cameron | Demonstrated development over the course of the semester of views of student and teacher roles. |
| John | Views remained the same over the course of the semester. |
| Evan | Views only reflected instructor roles and did not change over the course of the semester. |

For the following list of lab activities indicate if you think it is an inquiry experiment or not, and indicate why.

| Assignment | Inquiry? yes/no | Why? Or Why not? |
|---|---|---|
| In a genetics laboratory exercise students are instructed to cross two true-breeding lines of fruit flies, then identify the correct genotype and phenotype of the progeny | | |
| Students are told to plant seeds and fertilize with a dilution series of fertilizer, then measure the effect on plant height, number of leaves, and number of seeds. | | |
| Students are given two seed stocks: one parent and its progeny. Students are challenged to generate a hypothesis about the second parent's genotype and design an experiment to test it. | | |
| Students collect data about the organisms, pH, and nitrate levels of a stream and are asked to research what these values indicate to make an overall prediction about the water quality. | | |
| Students are instructed how to make 10-fold dilutions of soil samples and apply each solution to a culture medium. After incubation, students count the number of colonies on each plate and calculate the number of culturable organisms in the sample. | | |

*Figure 4.1*
Sample laboratory activities

Name: ______________________________________

Date: ______________________________

Next week your students will have a pre-lab exercise due. The problems they are asked to solve relate to concentrations, standard curves, and dilutions, use of spectrophotometers, and concentration versus absorbance.

Please take 5 minutes to scan through these pre-lab questions.

What is your relative comfort level with answering these questions on your own:

______1. I am not comfortable answering these questions without some sort of guidance or tutorial.

______ 2. I could answer some of these questions on my own, but would need some sort of guidance or tutorial for the rest.

______ 3. I could answer most of these questions on my own, but would need some sort of guidance or tutorial for the rest.

______ 4. I could comfortably answer all of these questions on my own without any kind of assistance.

*Figure 4.2*
Comfort level surveys

Name: _______________________________________

Date: _______________________________

Next week your students will have a pre-lab exercise due. The problems they are asked to solve relate to antibiotic resistance.

Please take 5 minutes to scan through these pre-lab questions.

What is your relative comfort level with answering these questions on your own:

______1. I am not comfortable answering these questions without some sort of guidance or tutorial.

______ 2. I could answer some of these questions on my own, but would need some sort of guidance or tutorial for the rest.

______ 3. I could answer most of these questions on my own, but would need some sort of guidance or tutorial for the rest.

______ 4. I could comfortably answer all of these questions on my own without any kind of assistance.

*Figure 4.2 continued*
Comfort level surveys

Name: ________________________________________

Date: ________________________________

Next week your students will have a pre-lab exercise due. The problems they are asked to solve relate to genetic patterns of inheritance.

Please take 5 minutes to scan through these pre-lab questions.

What is your relative comfort level with answering these questions on your own:

______1. I am not comfortable answering these questions without some sort of guidance or tutorial.

______ 2. I could answer some of these questions on my own, but would need some sort of guidance or tutorial for the rest.

______ 3. I could answer most of these questions on my own, but would need some sort of guidance or tutorial for the rest.

______ 4. I could comfortably answer all of these questions on my own without any kind of assistance.

*Figure 4.2 continued*
Comfort level surveys

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# CHAPTER 5

# HOW GLAs ENACT TEACHING SCIENCE AS INQUIRY IN A NON-MAJORS UNDERGRADUATE BIOLOGY LABORATORY COURSE[3]

[3]Miller, K.R. & Oliver, J.S. (2010). *Unpublished dissertation, The University of Georgia.*

Note to reader: This is the third of three chapters that are intended to be submitted as manuscripts to professional journals. The first manuscript presented analysis of the impacts of a teaching preparation program developed to help novice graduate student instructors (GLAs) teach introductory undergraduate biology laboratories with an inquiry focus to non-science majors. The second manuscript presented analysis of how these same GLAs came to conceptualize teaching science as inquiry over the course of their teaching assignment. This final manuscript presents an analysis of the GLAs' enactment of those conceptualizations.

## *Introduction*

Sweeping reforms in K-16 science education have called for teachers to teach in ways that enable students to engage in "inquiry" learning activities (NRC, 1996); the goal of this pedagogical practice is to help students experience science in ways that connect them to the work of scientists. When undertaking inquiry as a frame for their instruction, teachers engage students in lessons that provide experience in how the process of science works i.e., the nature of science. The teachers move away from delivering traditional passive lectures and instead work alongside students who are investigating science topics. Students, in turn, are directed away from memorizing content provided by teachers and move towards learning *how* scientists come to know science and its inherent content. How to actually achieve these experiences is widely interpreted, however, and so what constitutes an inquiry experience can depend on the teacher, the students, the context of the learning experience, or a mix of these factors (Crawford, 2007).

The teacher population described in this research study consists of novice graduate student instructors. When studying how these instructors enact inquiry teaching experiences in the classroom, one must rely heavily on the research literature base of K-12 teachers. For this much larger teacher population, extensive research studies have been completed that examine a wide array of aspects of enacting science education reform in the classroom. However, few studies exist for graduate student instructors. Therefore, most of the literature discussed in this manuscript comes from findings of research studies of K-12 teachers.

With any reform effort, regardless of discipline, comes the hurdle of actual implementation. This claim is not just in reference to the actual teaching of reform but also includes the development of pedagogically specific professional development programs, textbooks, and teacher support materials (Roehrig & Luft, 2004). Literature on science education reform efforts abounds with studies undertaken to understand why implementing significant change presents so many difficulties to preservice and inservice teachers. These studies indicate that a multitude of factors can affect teachers' willingness and ability to implement teaching reform in this discipline and in most others. Some of the reasons include teacher belief systems (Tobin, Tippins, & Gallard 1994), inadequate pedagogical content knowledge, or PCK (Crawford, 2000), lack of support and mentoring (Huling-Austin, 1992; Luft & Patterson, 2002), change to an unfamiliar school setting, teaching responsibilities outside of the field, and lack of opportunities to reflect on their experiences (Luft & Patterson, 2002). Despite the fact that studies conducted over 20 years ago noted that science and mathematics teachers often get lumped together into one group even though they can face starkly different experiences in both content and pedagogy (Sanford, 1988), only recently was a distinction made between types of challenges that teachers in different disciplines must overcome (Luft & Patterson, 2002). Keys and Bryan (2001) acknowledged that research on "…the role and knowledge of teachers in the reform process has been minimal" (p. 641), perhaps due to the lack of attention that has been paid to this important component of the science reform movement.

In additional to succumbing to the difficulties just listed, it is often the case that teachers attempting to implement science education reform cannot lead by example; they have never been taught by teachers who used teaching methods or lessons that allowed them to learn science as a process of inquiry (Windschilt, 2003). Research documents that despite pedagogical training teachers might receive, they will often teach as they were taught (Grossman, 1991). Finally, "confusion about the meaning of inquiry, inadequate preparation in inquiry methodology, and viewing inquiry-based instruction as difficult to manage" (Welch, Klopfer, & Aikenhead, 1981, as cited in Akerson & Hanuscin, 2007, p. 654) can also hamper reform efforts.

Finally, views of the nature of learning and the nature of science can dictate how one teaches and therefore also have a powerful influence on how that individual's students learn; research has demonstrated that teacher beliefs about the content they are teaching, the methods by which they are teaching and assessing that content, and how students learn that content can affect teaching practices (Cochran-Smith & Lytle, 1999; Pajares, 1992). For example, implementation of inquiry curriculum can be hampered by teachers' beliefs that science exists as a body of facts to be memorized and that students can only learn science adequately if they memorize facts (Keys & Bryan, 2001). In other words, two different curricula can exist for the same teacher: an intended one and a practiced one. However, successful induction programs have been reported to improve teachers' confidence in teaching science as a result of improvement in ability to use inquiry as well as actively challenging teaching ideologies (Luft & Patterson, 1999, as cited in Luft & Patterson, 2002). Luft and Patterson (2002) stated:

> If we expect beginning science teachers to refine their beliefs, practices and knowledge in ways that are conducive to standards-based science instruction, then induction programs must attend to this process….Small group discussions, purposeful dialogue about

> demonstrated lessons, participation in science-rich lesson, observations of exemplary science classes, and feedback on one's teaching can further facilitate the process of refining beliefs and practices, and construction of knowledge of science and science teaching. (p. 271)

There have been considerable efforts made to provide inservice teachers with reform-based professional development, but these efforts often require substantial time investment on the part of both the practicing teacher and the supporting mentor, and results of these efforts indicate that teachers do not necessarily alter their practice even though they may report a change in their beliefs of how science should be taught (Schneider, Krojcik, & Blumenfeld, 2005, p. 285). However, studies have also demonstrated that when teacher education materials are generated and utilized with other forms of professional development (e.g., opportunities to reflect on enactment) teacher opportunity to enact reform is increased (Schneider, Krojcik, & Blumenfeld, 2005). Blanchard, Southerland, & Granger (2008) found that after engaging teachers in a science research experience designed to give both authentic science practice but also an analysis of the type of inquiry inherent to this research, the teachers "changed to be much more student centered, with a strong focus on students' actively conducting investigations" (p. 355). Penuel, Fishman, Yamaguchi, & Gallagher (2007) found that after inquiry professional development was given to practicing teachers, implementation was critically dependent on the teachers having time to plan how and when to implement it as well as having technical support during implementation.

The purpose of this research study is to analyze how graduate student instructors (GLAs) of a non-majors introductory biology laboratory course who are receiving pedagogically specific teaching training enact their conceptualizations of teaching science as inquiry. This study provides evidence that for this lesser-studied teacher population, pedagogically specific teacher preparation can positively impact reform efforts made in the classroom.

*The roles of graduate students in undergraduate education*

It has been reported that a high percentage of undergraduate courses are taught by graduate students. For example, a survey completed in 1991 of 118 public and private United States higher education institutions revealed that "…68 (93 percent) of the responding institutions said laboratory instructions is done primarily by graduate teaching assistants, however other personnel frequently are involved as well" (Sundberg and Armstrong, 1993, p. 145). These novice teachers have been considered by research-oriented colleges and universities as "cheap instructional labor" (Nelson, 1995, p. 19) and have filled the gaps in many higher education institutions of providing instruction of introductory courses when increasing budget demands have not allowed for full time faculty or instructors to be hired or when faculty at research intensive institutions give lower priority to teaching responsibilities. Sykes (1988) referred to this attitude by many research faculty as "THEFT… The Historic Escape From Teaching" (p. 36), and has been reported to be most likely to occur at research intensive institutions where the tenure of full-time faculty is based on grants obtained and published research (Boyer, 1991 as cited in Shannon, Twale, & Moore, 1998; Sykes, 1988).

Graduate students are often assigned graduate teaching assistantships at some point in their graduate career. For science graduate students assigned to teach undergraduate science courses for their teaching assistantship, implementing science education reform can be a formidable task. Consider the following reasons. First, these graduate students are often fresh out of their undergraduate degree programs and have rarely held a teacher role. Second, science faculty tend to teach in a more traditional format (Brainard, 2007), and so graduate students have no ideas how to teach other than by what they experienced as students. Third, science graduate students tend to hold academic backgrounds in science, not science education, and so they generally have not had any teacher education when they begin their first teaching assistantship assignment. Fourth, once they do start teaching, teaching education offerings for graduate student instructors are few and far between. If teacher training is offered, it tends to be half- or one-day workshops that are based on university policies and not on teaching skills specific to a prescribed pedagogy (Roehrig, Luft, Kurdziel, & Turner, 2003). Current literature appears void of studies that analyze how aspects of pedagogically specific teacher education for graduate student instructors are enacted in the classroom.

If the reality is that graduate students are expected to take teaching roles role in undergraduate education (Young & Bippus, 2008), then they should be adequately prepared to do so, and this is even more apparent when asking these graduate students to implement a science-reform curriculum. This paper describes how one such preparation effort was translated in the classroom. As GLAs engaged in a semester-long teaching preparation program designed to prepare them to lead an introductory biology curriculum that teaches science as inquiry, I sought answers to the following research questions:

1. Which aspects of the GLA preparation did the individuals who received it employ? In what ways did the GLAs enact the conceptualization of inquiry teaching that was associated with them across the semester's experience and their concurrent teacher development?

2. How did the students respond as a result of the employed GLA teaching strategies?

*Purpose and rationale*

K-12 teacher education literature contains a multitude of research studies that detail obstacles to implementing science-education based reform in the classroom. As detailed above, while some contend that different forms of professional and curricular development can enhance inservice teachers' abilities to implement reform, the verdict is still out as to when, how, and why this occurs. Current literature on science-education based reform does not appear to address how graduate student instructors implement pedagogically-based teaching training. Therefore, this research study fills a gap in higher education research on a topic that is *as* applicable, if not more, to first time graduate student science teachers as it is to preservice teachers. If undergraduates are likely to have graduate students teaching some of their courses, we want them to be taught by prepared instructors. We therefore hold the obligation to 1) prepare graduate student teachers to teach; and 2) document their teaching so as to improve teacher preparation efforts.

Two previous research studies (Author, 2010a; Author, 2010b) provided meaningful implications for enhancement of the GLA teaching preparation program referred to in this research study. However, they did not address another critical piece of the puzzle on how to best prepare graduate student instructors to teach inquiry science reform: when they get in the classroom, do GLAs who receive preparation in how to teach science as inquiry actually enact their conceptualizations of teaching science as inquiry? What prevents them from doing so? How do their students respond to this enactment?

Understanding which aspects of the GLAs' conceptualizations of inquiry teaching that they actually employ is worthy of investigation for several reasons. One, the flow of instruction as viewed by a participant observer may be something similar to or different from what a GLA reports experiencing. This could be an important realization for both parties. GLAs might gain insight into their teaching that can help them increase their abilities to teach science as inquiry while I might gain insight on better means of teaching preparation. For example, perhaps a GLA reports implementing one type of teaching strategy designed to elicit desired student behaviors when in fact, I actually observe her or him using a different one. I might need to consider how to better explain or demonstrate preferred teaching methodologies that enhance teaching science as inquiry to avoid this confusion. From this experience, both parties would potentially better understand relevance of intended curriculum versus the practiced one.

Two, immediate feedback to the GLA I observe on his or her employed “best practices” of teaching science as inquiry would allow for active reflection. Rather than waiting a period of time to discuss observations, thereby increasing the chance that crucial details of the teaching experience might be forgotten, immediate feedback helps to secure meaningful reactions about teaching science as inquiry in the minds of the GLAs and myself.

Finally, analyzing how students react to enactment of teaching science as inquiry can also provide valuable input into teaching preparation for graduate student instructors of science laboratory courses with an inquiry focus. For example, understanding if students’ classroom actions change to reflect desired characteristics of student inquiry learning when their laboratory teachers enact greater frequency of inquiry teaching strategies would allow me to continue with current teaching preparation elements, or perhaps enhance others. On the other hand, knowing if students act independently of the level of inquiry teaching strategies employed is equally as important as teaching preparation can be structured to enhance these student learning behaviors and improve teaching method.

## *Study participants*

### *GLAs*

In the fall semester of 2009, four graduate student laboratory instructors (GLAs) assigned to teach BIOL 1103L at the University of Georgia were selected out of a pool of 11 to participate in an in-depth analysis of benefits of a GLA preparation program designed to advance inquiry teaching in an undergraduate non-majors biology laboratory course. BIOL 1103L is a one-credit introductory biology laboratory course for non-science majors that focuses on cellular and molecular biology. At the time of the study, all GLA participants were first year graduate students in science Ph.D. programs; two had previously earned M.S. degrees in science fields similar to their new intended programs. The GLAs chosen to participate in the student were selected based on gender (i.e., desire to represent both males and females) and their range of variability that they provided in “past teaching experience, past experience with inquiry, reported likelihood of teaching in the future, and initial “buy-in” to inquiry teaching methods” (Author, 2010a, p. 60).

### *Students*

Within each laboratory section that I observed of the GLA study participants, a random group of students was observed. Groups consisted of at least two students, sometimes reaching as many as five. This randomization process minimized bias of collecting data from the same sample of students each week, and it also increased the population size of students observed. Conclusions drawn about changes in specific student behaviors over the course of the semester are therefore based on a larger and therefore more representative population. This selection process did, however, eliminate a more in-depth view of these same student behaviors within individual students. However, I felt that the categories within the observation protocol used were not designed for an in-depth study of student learning and therefore should not be used as such.

Additionally, the format of the laboratory curriculum is such that students change groups with every laboratory series topic. Therefore, multiple factors such as dominance of particular group members and comfort level with content and concepts could confound conclusions drawn about changes in learning that take place in any given student.

*Theoretical framework*

The GLA portion of this study was framed by a constructionist philosophy. Constructionism is a way of viewing how knowledge is built; this knowledge "comes into existence in and out of our engagement with the realities in our world" (Crotty, 1998, p.8). This epistemology assumes that individuals may build their knowledge in different ways, but always under the context of social interactions with the people and objects (the world) around them (Crotty, 1998).

In this study, the four GLA participants experienced a semester-long teaching preparation program while they simultaneously taught introductory undergraduate biology laboratories with a science-reform based curriculum. I used a multiple case study approach to analyze GLA data in order to elicit how GLAs enacted teaching science as inquiry in relation to their developing conceptualizations of this complex understanding and the ongoing teaching education. GLA cases are analyzed individually and then compared across all cases to determine parallels and differences among the four GLAs.

Qualitative and quantitative analysis of student behavior data served as supplemental yet important information regarding impacts of science teaching reform enactment. This study was not designed to evaluate student learning gains. Thus, student data reported in this study should be taken as a general indicator of levels of desired inquiry behaviors that can occur in an introductory biology laboratory taught by novice graduate student instructors who are receiving teaching preparation at the same time they are teaching.

*Methods*

*Researcher role in the study*

During this study, I filled multiple roles. Professionally, I worked full-time as the Laboratory Coordinator for the Division of Biological Sciences at UGA. In this position, my primary responsibilities included coordinating all introductory instructional biology laboratory courses. This included acting as supervisor and teacher mentor to GLAs who taught the sections of the biology laboratory courses just mentioned. I was also a graduate student during this study and the person in charge of carrying out this study. As four of the GLAs that I supervised were also my study participants, I needed to plan and carry out this study carefully, accounting for potential bias in data collection and analysis throughout and after they study. I did this by taking detailed journals that reflected all interactions that I had with the four GLAs so that I could assess if these relations were somehow creating partiality in my researcher role. Consider an example; this might occur as I was interacting with a GLA during one of the laboratory sections in which I was observing him or her. In that moment, I might have had to assume multiple roles: a researcher, a participant observer, a supervisor, a teaching mentor, and a graduate student. I brought the notes that I took about these situations to my research supervisor and the faculty member in the Division of Biological Sciences with whom I created the teaching preparation program described in Author, 2010a to discuss and analyze them for compromises in data collection and analysis.

*Data collection and analysis*

The primary source of data for this study came from the *TA-IOP* (*Teaching Assistant Inquiry Observation Protocol*) (Miller, Brickman, and Oliver, unpublished manuscript). This observation tool allowed me to collect qualitative and quantitative data on teacher inquiry instruction behaviors as they related to the "five essential features of inquiry" (NRC, 2000, p. 25), teacher classroom management skills, teacher content knowledge, teacher preparation, and desired student "inquiry" behaviors that could be affected by implementation of the inquiry teaching skills. Data for the teacher inquiry behaviors were recorded by marking observed continuum levels of five "inquiry instruction skills" (see Figure 4 from Miller, Brickman, & Oliver, unpublished manuscript) and were also taken from notes I made about demonstration of GLAs' pedagogical skills, classroom managements skills, content knowledge, and teaching preparation, conversations between GLAs and students, and conversations between the GLAs and myself after my laboratory observations were complete. The end of the continuum with higher scores indicated that students were more autonomous in planning, investigating, evaluating, interpreting, and justifying. The end of the continuum with lower scores indicated that the instructors were doing students' work in the same five categories (i.e., GLAs were telling students how to plan investigations or how to evaluate findings). Scores for the teacher characteristics of classroom management skills, content knowledge, and teaching preparation were recorded as scores between 0 and 4; the scores represented levels of a continuum of percentage of time that a behavior was observed (e.g., 0 = not observed; 3 = observed often (>50% of time); 4 = observed throughout (>75% of time)). His same scoring continuum was used to score the following three student "inquiry" behaviors:

1. Behavior 1 (staying on task): Students were actively engaged in thought-provoking activity and stayed on task.
2. Behavior 2 (procedural questions): Most student questions were reflective (asking about why they were doing something) rather than procedural (how they were doing it).

3. Behavior 3 (collaborative learning): Students actively shared ideas and problem solving strategies, including how they learned and what they learn, with each other rather than turning to the GLA for corroboration (refer to *TA-IOP* in Miller, Brickman, and Oliver, unpublished manuscript).

In a previous study (Author, 2010a) I described how observations of GLA study participants and students were carried out. The semester began with a plan to observe GLAs and their students in each of the three laboratory sections a GLA taught per week, and this was to occur for all weeks of three laboratory series: *enzymes (Carb Cutter)* (three weeks), *antibiotic resistance* (two weeks), and *Mendelian genetics (C. elegans)* (three weeks). I considered these laboratory series to engage students in more aspects of the experimental design process than the other three laboratory series presented during the semester and were therefore perceived by me to provide students and teachers in a greater engagement of the process of science (Author, 2010a). After all observations of the *enzymes* laboratory series were complete, I opted to observe fewer laboratory sections per week for each of the remaining two laboratory series due to the extensive time demand required of these observations and follow-up discussions. I attempted to observe the first and second laboratory sections of two GLAs and the first and third laboratory section for the other two GLAs for the *antibiotic resistance* laboratory series. The laboratory sections observed per GLA were then switched for the *Mendelian genetics* laboratory series. This worked well in all cases except when GLAs had unexpected reasons for not being able to teach their normal laboratory section assignments. In those cases, I attempted to capture the first and last laboratory section taught for these GLAs.

To begin data analysis, I reviewed all *TA-IOP* observations made of each GLA; this included revisiting the inquiry teaching scores that I marked for each GLA as well as observational notes I took while the GLAs were teaching and from post-observation feedback conversations between me and the GLAs (these conversations either took place in person or through email). This information gave me an initial overview of general trends for each GLA instructor (e.g., I consistently score a GLA with high scores for some or all of the five inquiry instruction skills; a GLA did not often demonstrate classroom management skills and therefore often received low scores from me). Then, I re-reviewed each *TA-IOP* reporting form for my comments that indicated why GLAs received the scores that were recorded. Finally, I looked for general trends in scores recorded for student inquiry behaviors per GLA and reviewed comments I made that indicated why students received the scores that were recorded.

The second data source in this research study came from previous analysis of the GLAs' conceptualizations of teaching science as inquiry (Author, 2010b). This previous analysis and original transcripts from interviews conducted with GLA study participants were reviewed for conclusions drawn regarding how the GLAs, individually and collectively, developed their beliefs of teaching science as inquiry. Finally, these conceptualizations were cross-referenced with the observational data in this research study to determine if evidence existed for enactment of the described conceptualizations.

Student data were summarized as mean scores within laboratory sections for each GLA and are presented later in the manuscript in Tables 5.1-5.3.

*Findings – GLA data analysis*

What follows are findings that arose from the analysis of data related to GLAs' enactment of teaching science as inquiry. The findings are presented using a case study approach; for each GLA case, an overview of the following information is presented: past teaching experience, experience with inquiry, views of the word inquiry, conceptualizations of teaching science as inquiry, and characteristics of a good teacher of science as inquiry. This overview is followed by an analysis of data that describes the degree to which GLA research study participants enacted their conceptualizations of teaching science as inquiry. Considerations for varying levels of enactment of teaching science as inquiry are provided.

*Tara*

At the time of the study, Tara was a first-year Ph.D. student seeking a degree in Food Science and Technology. She had recently completed a M.S. Degree in Cellular Biology, and during that time she held teaching assistantships in two instructional laboratory courses. For one course (*Anatomy & Physiology*), she was the only instructor for her laboratory sections and taught using a common format for science laboratories: she presented a pre-laboratory lecture, students answered questions in their laboratory manuals as they completed required tasks, and then she asked students questions throughout the laboratory period with questions about what they were seeing or doing. Her other teaching assignment (*Biology of Protists*) was more of an assistant to faculty who actually taught the labs. In this case, the laboratories were more open-ended such that students often engaged in field work on their own to sample for protist species, and then they brought their collections to their laboratory class to identify them. Tara's main responsibility was to help with this identification process.

Tara described herself as a being confident in both teaching abilities as well as content material. She reported having no previous experience with inquiry, either as a student or teacher. Tara's thinking developed across the semester in which this study took place in reference to conceptualizing the word inquiry, and she came to conceptualize teaching science as an inquiry process as involving effort from both her as the teacher as well as her students. As in instructor of introductory biology laboratories with inquiry-based activities, Tara felt that teaching science as inquiry required questioning strategies that didn't give students the answer to their questions but instead required them to rethink the process that they went through in order to get to the point where they were asking the questions. She often discussed with me that her goal using redirected questions as a teaching method was to address the "Why's" of the efforts that students were making; Tara wanted her students to always understand why they were doing something, especially why they were making the choices they were making, and they needed to be able to articulate these justifications to her and peers at any stage of the process of science in which they were engaged.

For Tara, the ability to ask questions that provoked critical thinking in students was dependent on having adequate content knowledge; without the content, a teacher of science as inquiry could not ask these types of questions. Tara also discussed the importance of her students viewing her as open to answering any questions because the laboratories themselves were based on students asking questions to move forward. Students needed to participate in these laboratories, and so she needed to get them to do so. The atmosphere of the laboratory needed to be interactive for engaging students in science as an inquiry process to work well. The preparation it took to achieve these goals was greater than past teaching preparation she had done because she need to be prepared for student questions and possible outcomes of student-designed experiments. Tara reported that inquiry laboratories were academically harder for students because it required that they think critically about information, and many were not used to doing this. Because of time, they were also harder for her as an instructor because the preparation for them was more intensive i.e., being more prepared for students questions.

When I observed Tara teaching her laboratory sections, I consistently scored her inquiry instruction skills with high values, within and across all lab series. In other words, it did not matter that she was only three weeks into the semester when my observations began or that it was the last three weeks of the semester when I observed Tara; she almost always received high scores for desired teaching science as inquiry characteristics. Tara also consistently demonstrated the teacher characteristics she described as being necessary to teach science as inquiry. Example *TA-IOP* observational comments that I made, marked by week of the semester, exemplify this:

> 1. Confident/prepared – thorough pre lab review. Great job building on student answers with her own input. Getting students to add or disagree with her = dynamic! Good job circulating and prompting students." (first set observations – week 3 of semester; first week of *enzymes* laboratory series)
>
> 2. Pre lab review started off well. Left bacteria choices and product choice completely up to them – no hints. Was a fun interactive lab with a lot of student-interest questions." (second set observations – week 8 of semester; first week of *antibiotic resistance* laboratory series)
>
> 3. Stayed firm in pre-lab review for participation and communication of student thoughts. (third set of observations – week 13 of semester; second week of *Mendelian genetics* laboratory series)

These efforts to enact her conceptualizations of teaching science as inquiry did not come without hurdles, however. One of Tara's greatest challenges as an instructor came from her time management skills. One more than one occasion I observed that she spent extraordinary time with students reviewing pre-laboratory homework activities because it was clear to Tara that the students were struggling with these assignments. While this effort left her feeling satisfied that she had gone though the pre- laboratory problems thoroughly with students, she inevitably became flustered with the lack of time it left for the rest of class. Tara worked hard all semester to adjust her teaching plans and strategies in order to diminish this problem. One way that she did this was by making time at the end of laboratory periods to prepare students for the next pre-laboratory homework assignment due. She would have students look at the upcoming assignment with her and then give suggestions on how to approach the problems. She felt that this effort cut down on the time spent in class going through pre-laboratory homework problems and on questions emailed to her about the pre-laboratory assignments.

Another means by which she addressed her time management issues was through implementation of post-observation feedback that I gave her. In her first week of the *enzymes* laboratory series, I emailed the feedback to Tara, and among the comments I wrote the following:

> Pre-lab review maybe too long. Lost them at the end with the discussion of using a blank and jumping back and forth between that topic, absorbance vs. concentration, the spec machine, and others. Smooth out and shorten this review. Trying to get too many "remember this" concepts in and losing students. Simplify. What are the main points you need to cover this week? (post observation feedback – week 3 of semester; first week of *enzymes* laboratory series)

Tara's written response to my feedback was:

> As with the every first lab of the week, working out the timing seemed to be the hardest part. Balancing the background for understanding and then time needed to discuss and implement the labs has been especially difficult in this section. (post observation feedback - week 3 of semester; first week of *enzymes* laboratory series)

In her next laboratory section, I noted that Tara gave a much more concise review of the pre-laboratory homework questions. My comments for this observation detailed the following:

> We also both noted after this lab that this particular class seemed to have a better overall grasp of content and concepts than the first lab, so this may have affected how detailed you felt you needed to go into during the pre-lab review. (post observation feedback – week 3 of semester; first week of *enzymes* laboratory series)

For Tara, time management and students' conceptual understanding in the second week of the *Mendelian genetics* laboratory series also posed significant issues with her ability to implement her conceptualizations of teaching science as inquiry. I observed these issues in both of her laboratory sections that I observed for this week of the semester, and I recorded Tara's inquiry instruction skills for planning investigations with lower scores, indicating that she was actually planning a significant portion of students' experiments for them rather than having them do this work. My *TA-IOP* observations recorded that Tara and I were able to talk about these struggles briefly after each of her laboratory sections that met this particular week and also documented that I emailed the following post-observation feedback to Tara: "you [Tara] seemed to make a lot of decision for students regarding next steps to take – their second set of crosses to make.' Tara provided me with a written response: "I agree somewhat, but for most groups, I asked them what students thought they should do next and gave them some options (even though they didn't provide the options) because I was pressed for time." I suggested that a way to potentially deal with this time issue was to trim time spent on the pre-laboratory exercise review. For the students who did not understand the pre-laboratory assignment problems, I suggested that Tara announce that individual students with continued problems come see her at office hours because the class as a whole needed to move on. Tara struggled with this suggestion because she felt that no student could move forward without a solid understanding of the concepts of the laboratory. She didn't think any one question took too long to answer, but that she could instead shorten her discussion of a grading rubric. I observed these time management issues in both of her laboratory sections that I observed for this second week of the *Mendelian genetics* laboratory series, and I recorded Tara's inquiry teaching skills with lower scores which indicated that she was doing more planning work than students.

Overall, I observed Tara to enact many of her conceptualizations of teaching science as inquiry on a consistent basis. While she did have some difficulties with this enactment, I felt that she effectively demonstrated the ability to practice her intended teaching methods and goals.

*Cameron*

Cameron was a first year Ph.D. student in Marine Sciences at the time of the research study. He did not have any teaching experience and also reported having no experience with inquiry, although a few weeks after classes began he realized that the introductory biology laboratory course that he took at his undergraduate institution was inquiry-based. Cameron appeared to be able to conceptualize teaching inquiry as science in some of the same ways as Tara (e.g., him needing to appear approachable so students would ask questions, to provide a comfortable and interactive atmosphere, and to have rich content and conceptual understanding), but he was also able to expand upon his beliefs of inquiry and student and teacher roles in inquiry-science classrooms more fully than Tara (perhaps due to his past experiences with inquiry as a student). Teaching science as inquiry required that he convince students that they could do inquiry, and equally as important, that the playing field between his role and theirs was even. He did not want the students to view him as the "overbearing teacher" but as someone ready to guide them through science challenges that they could accomplish (second interview, 10/09). For him to achieve this particular goal, Cameron explained that having pre-conceived ideas about what students were lacking or asking was self-defeating. Something he had to actively work on in order to keep a congenial, "conversational" (first interview, 08/09) class was to block out his ideas of what students were asking and "listen when they're asking questions" (second interview, 10/09). Good teachers of science as inquiry also needed to have strong content knowledge and to be able to get students to participate. Cameron's view of inquiry never changed throughout the semester; inquiry defined a way of teaching and a way of learning that complimented one another in teachers' and students' conquests to solve problems.

I scored Cameron's inquiry instruction behaviors with high scores through the semester. Cameron enacted his conceptions of teaching science as inquiry on a continual basis from the first week of observations and through the last week. My *TA-IOP* observations that I made of Cameron's inquiry teaching skills repeated themselves in most observations:

> 1. Fantastic re-direction of questions. Good real-world examples. Discussions with students allowed them to figure out what they need for their experiments. Constant tie-in of pre-lab questions to what they would be doing in lab. Getting students to answer their own questions and figure out what they need to do or what they are missing. (first set of observations – week 3 of semester; first week of *enzymes* laboratory series)
>
> 2. Cameron is showing clear, concise confidence during pre-lab and making connects to lab objectives. Great use of demonstration microscope to help students with pragmatics of lab. (third set of observations – week 12 of semester; second week of *Mendelian genetics* laboratory series)
>
> 3. I loved the constant integration of pre-lab review with what students will be doing in lab. GREAT student participation and effort. Great sense of humor Cameron – do you realize you are using it?! (third set of observations – week 12 of semester; second week of *Mendelian genetics* laboratory series)

Some of Cameron's challenges specific to his enactment of teaching science as inquiry were pragmatic in nature: he tended to talk fast, and his exuberant effort made to help students understand material by explaining concepts in many different ways sometimes ended up just confusing them. To make matters more difficult, when time pressures mounted, he talked even faster and tried to rush students through the remaining time in a laboratory period. While he stuck to his guns and did a good job of not giving answers to students (one of his described qualities of a good teacher of science as inquiry), he ended up firing off multiple considerations for students to guide them through the rest of their laboratory period, and this only created frustration and confusion with students as they were unable to quickly process all of the guiding points coming from Cameron at one time. Additionally, Cameron appeared to have a difficult time spending equitable time with all student groups. I observed that he sometimes would spend long periods of time trying to help one group work through some problems, and this ended up leaving little time to respond to other groups that needed his attention. This led to student frustration and eventual off-task behavior such students talking about social events and text messaging. Finally, Cameron focused a great deal of effort on his value of a congenial classroom environment (another of his described qualities of a good teacher of science as inquiry), and he and I commiserated half way through the semester that perhaps he seemed "too" nice because it became a common theme that his classes engaged in loud discussions with group members rather than listen to him. It was difficult for Cameron to be more assertive in getting students' attention.

In summary, Cameron was comparable to Tara in his abilities to enact most of his conceptualizations of teaching science as inquiry. Perhaps due to his past experience taking an inquiry-based undergraduate biology laboratory course, he did not seem to think about student and teacher roles in his BIOL 1103L course in any ways other than those that support an inquiry-based pedagogy. Also like Tara, he experienced pragmatic teaching struggles, but I believe this is normal to any first time instructor or experienced instructor teaching a new course.

*John*

Similar to Cameron, John entered this study without teaching experience or experience with inquiry (Author, 2010a; Author, 2010b). He was starting his first year as a Ph.D. student in Plant Biology, and had already earned a M.S. degree in Plant Science from a different higher education institution. John's beliefs of the word inquiry began as a learning method but eventually included a teaching methodology that can be put into place in varying degrees depending on how involved an instructor is with what and how students are learning (Author, 2010b). He believed it was essential for instructors teaching science as inquiry to lay foundations of content for students in order for them to even attempt inquiry; these teachers therefore needed to be confident in their content knowledge. John enacted this conceptualization in all three laboratory series that I observed as I often noted that he took more time to traditionally lecture about content than the other GLAs that I was observing. John also expressed that instructors teaching science as inquiry needed to provide students with more guidance up-front on approaching inquiry laboratories before they could step back and let students have more control over their learning. In other words, teachers would likely need to help students more in the beginning of a teaching experience with the inquiry instruction skills scored in the TA-IOP before letting students have more say in those instruction categories; a conceptual understanding of the premise of the laboratory, gained either from actual laboratory research experience on the topic or having done a version of the laboratory at some point in time, was important to have in able to help trouble-shoot problems or answer student questions.

John took a firm stance that he communicated to his students all semester: he was *not* there to give students answers to solve the laboratory problems they were given, but he would "guide them along paths that will eventually lead them to where they need to go as long as they are making choices for themselves" (second interview, 10/09). John also believed that an instructor of science of inquiry needed to be "passionate about the (students') work and take interest in it" (first interview, 08/09). I reported in an earlier study (Author, 2010b):

> This personality characteristic conjures up images of a teacher showing excitement and overt enthusiasm for what is taking place in the lab, but the observer noticed through the semester that John's personality tended to be reserved and at times stoic. He did, through his questions and thought processes clearly show interest in the students' work. He asked thoughtful questions that caused students to consider multiple avenues for their experimental plans. However, this expression of interest may not have lead students to think he was passionate about their work. (p.151)

I encouraged John to develop more of a rapport with his students, namely by building on their offered responses so that they would continue to contribute to the class. Early in the semester, I often observed John providing either negative feedback or feedback that did not support the students' attempt to attempts to answer questions. If their answers were wrong, John might simply say "Nope" or "Not quite" and then ask for another response. It became clear to me that this was shutting down students' willingness to share ideas and opinions, and so I suggested that he try to communicate more with students about their ideas. I gave suggestions such as putting incorrect student answers in the context of what related question an answer did address and also crediting effort, especially if students were partially correct (e.g., "You are on the right track…"). John did try this and appeared to receive small positive results: students continued to offer answers when they heard they were on the right track. However, it was clearly awkward for John to attempt this encouragement, such that I noted in my *TA-IOP* observations of John's teaching that his efforts appeared forced and not genuine.

Finally, for John, a good teacher of science as inquiry could not be passive, must be patient, must demonstrate questioning strategies that help students to develop critical thinking skills, must be approachable so that students would be comfortable asking questions, and must allow students to make mistakes in order to experience true science.

If John implemented any of his beliefs of what it meant to teach science as inquiry, it was that he refused to simply tell students the answers to their experimental design problems. He was extremely patient with students questions, and he allowed students to carry out experiments as long as they could reasonably justify their choices to him (i.e., he allowed them to make minor "mistakes"). John redirected their questions to by asking them to consider particular aspects of their experimental designs or to walk him through what they had done to the point of their questions for him. Unfortunately, students often became frustrated with this consistent redirection of their questions, and part of this frustration could have been due in part to his seemingly stand-off personality. John did not have a dynamic persona, although he did recognize the importance of interactions in these lab classes in relation to getting inquiry to "work." I consistently observed him to circulate amongst groups, check in on their progress, and attempt to guide them through struggles they were experiencing. One of my *TA-IOP* observational comments described these efforts:

> John is approving experimental designs with scaffolded questions to correct big picture problems. BUT he is allowing wiggle room on parts of the designs that could be done

different ways. This allows for students to make non-crucial errors and even catch them. (first set of observations, third week of *enzymes* - week 5 in semester)

Notably, my comments documented multiple times at half way through and at the end of the semester that ”students (were) working in their groups a lot before approaching John” (second set of observations - week 5 of semester; first week of *antibiotic resistance* laboratory series). Perhaps John’s relentlessness paid off; his students were thinking within groups to solve problems and not relying on him.

John also spent a great deal of time working through pre-laboratory assignment problems with students; this suggested that he did attempt to ensure that they had an adequate understanding of content involved in the labs (another of John’s described characteristics of a good teacher of science as inquiry). John also experienced what all GLAs and I referred to as the “group” or “class effect.” This situation describes the common teaching dilemma of “What do you do with the class/group/student that just doesn’t get it?” For John, this was unfortunately his first section of each week, and it created a very frustrating way to start a new weekly teaching experience. In my observations of John’s second and third sections of each week, I marked his inquiry instruction skills with high scores (either “3” or “4”). But for the first class, it was more common for me to assign lower scores (often “1” or “2”) to John’s inquiry instruction skills.

In summary John was able to enact many of his conceptualizations of teaching science as inquiry, but they appeared to receive a less favorable response from students than I observed in the laboratory sections of Tara and Cameron. John held firm to his conviction of how a model of teaching inquiry should be enacted between students and a teacher. This conviction led students to feel that his teaching techniques were not supportive, but rather exclusionary.

*Evan*

At the time of the study, Evan was a first year Ph.D. student in biochemistry with no teaching experience and no reported experience with inquiry. Of the four GLAs, Evan had the most difficulty conceptualizing inquiry (Author, 2010b). In fact, Evan's experiences teaching and with the teaching preparation grounded his notions of inquiry as they pertain to his role as a scientist, but he could never fully articulate what they meant to relation to teaching and learning. He was able to see that what his students were supposed to do was a simplified experience that a scientist would undertake, but it was difficult for him to take this conceptualization and determine what he should do as a teacher to lead this experience and what students should be able to do in the role of novice scientists. Evan referred to inquiry laboratories as a "headache," and he felt that his students needed him to be on top of things in the classroom and "to challenge them and to stick to the rules" (second interview, 10/09). He discussed characteristics of an inquiry laboratory in relation to transference of information from one laboratory session to another and in terms of applicability to students' lives. The former characteristic appears to describe the format of BIOL 1103L laboratories as each topic covered takes two to three weeks. The latter characteristic may describe what Evan felt came through to the students as they followed through the sub-sections of the broader laboratory inquiry topics; for example, he discussed in his second and third interviews how the *water quality* and *antibiotic resistance* laboratory series were relevant to students' lives and interested them. The interest led them to want to ask questions and that made his "job easier" (second interview, 10/09).

Interestingly, Evan reported many of the same necessary characteristics as the other GLA research study participants when discussing teaching science as inquiry: instructors needed to get students to participate, be excited about student work, listen carefully to student questions, use questioning strategies that helped students answer their own questions (i.e., not giving them the answers), make laboratory activities applicable to students' lives, and have adequate content knowledge. However, of the four GLA participants, Evan was the least consistent about implementing these characteristics.

It is important to mention that Evan was at a distinct disadvantage from his fellow 1103L GLAs; his demanding course schedule allowed him to normally attend only 30-45 minutes of the weekly instructional preparation sessions, and he also taught the first laboratory section of the week. Therefore, he was not able to engage in the same level of teaching preparation as the other GLAs, and he did not have the opportunity to observe another GLA before he taught. Evan reported to me in the first week in which I observed him (week 3 of the semester): "I like to memorize the teaching notes…I can only teach by constant repetition of re-reading." Evan was unable to adequately process and reflect on the teaching notes before he stepped in the classroom, and this often resulted in Evan not knowing nuances of a laboratory series, not being able to answer some student questions, and often running behind. To compound this difficult situation, Evan and I both noted that this his first class of the week was generally unprepared for class, resistant to working independently, and difficult to motivate i.e., the "class" effect.

Evan's enactment of teaching science as inquiry reflected his uncertainly of what that concept meant to him as an instructor and to students, and he more than other GLAs was observed to struggle with fulfilling his limited ideas of what it takes to teach science as inquiry. In a previous study (Author, 2010b), for example, I noted how Evan realized when he watched a video of himself teaching near the end of the semester that he was not doing a good job listening to students' questions and was actually responding to the questions with pre-conceived answers. Also, Evan's first set of observations in the semester elicited comments from me that were similar to ones I made in the last weeks of the semester regarding his use of questioning in the classroom:

1. Evan told them they had to do dilutions for part 2…this is what students have to figure out on their own" (week 3 of semester, first week of observations of *enzymes* laboratory series). *Evan's response to this comment: "Thought it would take too long for them to do it, so I just told them." After the researcher explained that this is part of the experimental design process we want students to work through, Evan replied "what do you want me to say?" Observer noted this reflects the "just tell me" mentality that many of his students share when having frustrations with figuring out the "correct" answer.*

2. Student: how will we know what it looks like without antibiotics?

Evan: you will need a control.

Students: So we get an extra plate?

Evan: Each of you gets one plate and you will need to decide how to do a control. You have distilled water discs and plain paper discs (week 8 of semester, first week of *antibiotic resistance* laboratory series).

3. Evan told them the plate set-up choices with what bacteria to use and told them what that set-up would test (week 8 of semester, first week of observations of *antibiotic resistance* laboratory series).

4. Tells students how to measure zone of inhibition and what to do with data. Evan does all the work (week 9 of semester, second week of *antibiotic resistance* laboratory series).

5. Evan did a fair amount of data interpretation for students (week 13 of semester, second week of *Mendelian genetics* laboratory series).

Evan often noted to me that BIOL 1103L students were incapable of inquiry because they did not listen and follow his directions, they did not take college seriously, and they were still of a high school mentality and maturity level. My observations of Evan's inquiry instruction skills suggested that he began the semester with attempts to implement his ideas of a good teacher of science as inquiry (i.e., reflected in higher scores) but by half way through the semester, he had begun to let go of some of those efforts (i.e., reflected in lower scores). For example, in the first laboratory series in which I observed Evan, the scores that I marked for his inquiry instructions skills were consistently the highest or second highest scores that could be marked ("3" or "4") except for cases where he directly told students how to set up parts of their experimental designs. In his next laboratory series in which I observed Evan, the scores that I marked for his inquiry instructions skills demonstrated greater variation and fell between the next to highest score ("3) to the lowest possible score ("0"). In the last laboratory series in which I observed Evan, the scores that I marked for his inquiry instructions skills generally fell in similar patterns as in the *enzymes* laboratory series but indicated a sharp drop in recorded scores from week 1 to week 2. These scores then jumped back up to scores of "3" and "4" from week 2 to week 3. Overall, lower scores seen in the second and third laboratory series could have been influenced by mounting frustrations with his students' seeming inability to "do" the laboratory activities in combination with a demanding personal course load and not being adequately prepared to teach his students.

This is not to say that Evan did not share victories throughout the semester. He advocated multiple times to his students that what they were doing was like what he did in his research laboratory; the process of science does not have simple answers, and for them to experience science, they were going to have to work with unexpected findings. In this light, Evan fully enacted his conceptualization of inquiry. While Evan did try a variety of teaching suggestions given by me that would enable his students to work more independently, Evan also advanced as an instructor independently of my advice, demonstrated by strategies that he borrowed from fellow GLAs on how to teach material in different ways to students and tweaked to meet his needs. For example, he took advice given by other GLAs during discourse sessions about teaching strategies and began implementing peer learning in his laboratory sections. He stopped "giving" a pre-lab review and instead had students lead the rest of the class through pre-laboratory problems. During the peer learning, Evan happily found himself only need to ask for clarifications because other students in class would challenge the presenters if something seemed amiss. Evan also demonstrated a consistent effort to circulate amongst student groups to check on their progress and brought multiple real-life tie-ins to what students were doing in class.

Additionally**,** despite Evan's teaching struggles, he demonstrated that he was developing as a teacher. He was able to self-reflect on whether he actually, implemented some of his conceptualizations of teaching science as inquiry. I cited (Author, 2010b) one example of how Evan found himself answering students' questions with pre-conceived ideas of what they were asking; in effect, he answered them with information that had nothing to do with their question. In the case of the *Mendelian genetics* laboratory series, Evan described in post-observation dialogue that his content knowledge in genetics was poor and that he was trying to review and re-teach himself material before he taught. He admitted that his affected his abilities to help students with predictions and analysis of data.

In summary, Evan was able to enact his conceptualization of the word inquiry in relation to his work as a scientist, and was able to articulate this to students, but it appeared be a much more difficult task to enact his limited conceptualization of teaching science as inquiry within the context of his teaching assignment. While Evan was able to enact some conceptualizations, it was done to a more limited degree than the other GLAs. Evan was able to verbally describe some of the same characteristics of teaching science as inquiry that an instructor needed to have, but perhaps due to his lack of confidence in this conceptualizations, he struggled to enact them.

*Findings - student behavior data analysis*

Tables 5.1-5.3 show a compilation of the data analysis related to student behaviors. Student behavior scores taken from my *TA-IOP* observations were collapsed across individual behaviors and all weeks for each laboratory section. For example, consider the reported score of 3.33 for Tara, B1, Section 1. This score represents the averaged score for Behavior 1 that came from all students I observed across all three weeks of the *enzymes* laboratory series for Tara's first laboratory section of the week. In all tables, the letter "B" in stands for Behavior while NDC refers to No Data Collected. Scores marked with an asterisk represent only one week of data collected. Scores marked with two asterisks represent only two weeks of data collected.

Data indicate that none of the GLAs consistently had students with the highest or lowest scores; the averaged student scores varied within laboratory series and science as well as across weeks for all GLAs. Lower scores may be accounted for the fact that in some circumstances, half of a group's members were doing all the work in a given laboratory. So as individual students, the "workers" received high scores while the "non-participants" received low ones. Therefore, averaged across group members, a reported mean for a laboratory in a given week could be middle range, indicating a score between 1.5 and 3. This same trend was seen in the *antibiotic*

Table 5.1

*Average student behavior scores for each laboratory section in the enzymes laboratory series*

| *enzymes* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Section 1 | | | | Section 2 | | | | Section 3 | | |
| | B1 | B2 | B3 | | B1 | B2 | B3 | | B1 | B2 | B3 |
| Tara | 3.33 | 3 | 2.97 | | 3.33 | 3.44 | 3.44 | | 3.67 | 3.25 | 3.33 |
| John | 2.92 | 2.33 | 2.58 | | 4 | 3.33 | 3.83 | | 3.78 | 2.39 | 2.81 |
| Cameron | 3.83 | 1.33 | 2.67 | | 3.58 | 2.08 | 3.17 | | 3.5 | 1.92 | 2.34 |
| Evan | 3.83 | 1.14 | 2.02 | | 3.67 | 2.97 | 3.13 | | 3.67 | 3.16 | 3.83 |

Table 5.2

*Average student behavior scores for each laboratory section in the antibiotic resistance laboratory series*

| *Antibiotic resistance* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Section 1 | | | | Section 2 | | | | Section 3 | | |
| | B1 | B2 | B3 | | B1 | B2 | B3 | | B1 | B2 | B3 |
| Tara | 1.5 | 3 | 1 | | 4* | 4* | 4* | | 0* | 2* | 0* |
| John | 3 | 2.75 | 3 | | 4 | 3.67 | 3.5 | | NDC | NDC | NDC |
| Cameron | 1 | 0 | 0 | | NDC | NDC | NDC | | 3.5 | 1 | 1.5 |
| Evan | 2.5 | 2 | 3.5 | | NDC | NDC | NDC | | 2 | 3 | 2 |

B1 (behavior 1): staying on task; B2 (behavior 2): asking reflective questions; B3 (behavior 3): collaborative learning
NDC: No data collected; * = only one week of data collected; ** = only two weeks of data collected

Table 5.3
*Average student behavior scores for each laboratory section in the Mendelian genetics laboratory series*

| *Mendelian genetics* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Section 1 | | | | Section 2 | | | | Section 3 | | |
| | B1 | B2 | B3 | | B1 | B2 | B3 | | B1 | B2 | B3 |
| Tara | 3.33 | 2.67 | 2.67 | | 4** | 3** | 3.5** | | 2.5* | 1* | 1* |
| John | 4 | 3.67 | 3.33 | | NDC | NDC | NDC | | 4 | 3.25 | 3.5 |
| Cameron | 4 | 2.67 | 3.33 | | NDC | NDC | NDC | | 4 | 3.33 | 3 |
| Evan | 3.33 | 3 | 2.67 | | 4 | 3.33 | 3.33 | | NDC | NDC | NDC |

B1 (behavior 1): staying on task; B2 (behavior 2): asking reflective questions; B3 (behavior 3): collaborative learning
NDC: No data collected; * = only one week of data collected; ** = only two weeks of data collected

*resistance* laboratory series see Table 5.2) and the *Mendelian genetics* laboratory series (see Table 5.3).

Within these same tables, it is clear that for the *enzymes* laboratory series, highest scores were seen for staying on task (Behavior 1), then collaborative learning (Behavior 3), and finally asking procedural questions (Behavior 2). This trend was not seen in the next observed laboratory series, *antibiotic resistance*; no trends were found for high or low scores being associated with any particular behavior. In these laboratories, focus groups were always comprised of groups of two, so these low numbers on which means are calculated can greatly affect scores presented, especially if only one week of data was collected. Finally, student data collected for the *Mendelian genetics* laboratory series indicated that the student behavior of staying on task always had the highest scores, but the student behaviors of asking procedural questions and staying on task were fairly split on which had a higher score than the other.

In summary, no distinct trends were seen in students' scores when compared across GLAs. Additionally, for two of the laboratory series, *enzymes* and *Mendelian genetics*, Behavior 1 (staying on task) received the highest scores while the other two behaviors did not follow any trends within these laboratory series. The *antibiotic resistance* laboratory series resulted in the least consistency in high or low scores across all behaviors. These results suggest that Behavior 1 may have been the most readily achievable behavior in the laboratory series that I observed in BIOL 1103L, and this may be due to the fact that the laboratory activities are designed such that students must actively work the entire time they are in class in order to finish the laboratories. The other behaviors of asking procedural questions and collaborative group work may have been more difficult for students to achieve since the former is indicative of advanced thinking skills that may not have fully developed in students, and the latter is indicative of a learning context that may be unfamiliar and uncomfortable for students.

*Implications*

*GLA behaviors*

Kielborn & Gilmer (1999) report that when preservice teachers take part in investigations that involve the process of science, something they rarely experience, it becomes possible for them to "…internalize and transform new information for their own use and understanding" (p. 93) and therefore have a greater ability to teach science as inquiry to their students (Author, 2010b). A more recent study by Park Rogers and Abell (2008) echoes this notion: "Not understanding inquiry teaching can make it difficult to translate one's beliefs about the nature of scientific inquiry into the practice of inquiry teaching." For three of the four GLA participants in this study, these theories seem to hold true. Tara, Cameron, and John were able to fully engage in the teaching education preparation program provided in the semester that they were teaching; part of that experience was conducting the same laboratory experiences in which their students engaged. These same GLAs were also able to convey their ideas about teaching science as inquiry at the same time they were receiving the teaching preparation, and they were able to enact many of these pedagogically appropriate beliefs in the classroom. All three tended to demonstrate high levels of inquiry instruction skills as seen by the high scores that were recorded for their inquiry instructions skills on the *TA-IOP*. These results support existing literature which demonstrates that teachers are able to describe developing conceptualization of teaching science as inquiry and enact them in their classrooms (Windschilt, 2003).

In contrast, Evan did not have the opportunity to experience the weekly instructional preparation sessions to the same degree and therefore could not experience what his students were going to do in class each week. While Evan clearly articulated his role as a scientist in research laboratory setting as one which engaged in the process of science on a daily basis, he experienced difficulty translating that into the classroom within the context of student and teacher roles. This does not imply, however, that real world experience should be discounted as a factor that influences demonstration of inquiry instruction skills. Windschilt (2003) found that after preservice teachers engaged in inquiry experiences in a science methods course, the ones who enacted the most inquiry teaching in the classroom were not those whose conceptions of inquiry were most greatly aligned with what the science methods class taught, but were those who had experienced being part of actual science research experiences. As noted above, Evan was able to enact a small proportion of his conceptualizations of inquiry teaching skills. Perhaps with more time and a less intense personal schedule, Evan would have been able to demonstrate a greater understanding of what it means to teach science as inquiry and potentially demonstrate a greater enactment of these characteristics.

As a whole, interpretation of results indicate that despite carefully planned teaching preparation, individual instructors will enact different levels of the desired teaching skills. Crawford (2007) found that

> Despite being immersed in a cohort experience in learning about, and working with, aspects of how to teach science as inquiry, and despite having Mentors well acquainted with the goals of the preservice program, these prospective teachers demonstrated widely varying practice. (p. 634)

In Crawford's study and in this one, it is apparent that even the most carefully crafted teaching preparation cannot produce the "perfect teaching plan." In fact, a demonstrated strength of the novice teachers in this study is that they enacted their teaching in unique ways; this indicates that they were responsive to their individual teaching contexts. While both studies demonstrate that new teachers can enact teacher reform, preparation of those teachers should attempt to account for the multitude of factors discussed in this manuscript that may affect reform implementation. Even then, teacher educators should bear in mind that the individual teaching experience may have a heavy influence on eventual enactment. While it appears from data analysis in this study and in previous ones (Author, 2010a; Author, 2010b) that enactment of developing conceptualizations further reinforced those beliefs, it would be interesting to research this topic further.

*Student behaviors*

The goals of the BIOL 1103L curriculum are to improve student communication in the sciences, both orally and through written means; to understand that science is a process rather than a prescribed method; and to realize that science is not completed without cooperation and collaboration of peers. Division of Biological Sciences faculty and staff at UGA want students to understand that science involves collaboration of ideas and interpretations and consequently, a reliance on cooperative learning with peers. This learning requires trial and error processes, argumentation of ideas, and a partnership with peers to solve problems. Therefore, it is essential to judge how students are responding to employed inquiry teaching strategies designed to meet these goals. This would give a sense of how students are reacting to different levels of enactment of inquiry teaching. Observational data of student behaviors can lend evidence for appropriate structure of the teaching preparation program; modifying certain instructional components might assist in better reaching intended student outcome goals of the BIOL 1103L curriculum.

It seems logical that teachers who implement conceptualizations of teaching science as inquiry that are aligned with teaching preparation in this pedagogy would potentially have a student body that demonstrates the most, or the highest level of, inquiry student behaviors. The data presented indicate that this is not the case. While I can only draw broad generalizations from the student data collected in this study due to sample size and due to the fact that the design of this study was not intended to thoroughly study how GLA enactment of science education reform impacts student learning, the data from this study suggest that demonstration of student inquiry behaviors is unrelated to enactment of conceptualizations of teaching science as inquiry. For example, Tara and Cameron demonstrated the greatest ability to enact their conceptualizations of teaching science as inquiry, yet in some of my *TA-IOP* observations that took place half way through and near the end of the semester, students showed a high reliance on both of these GLAs to get through the laboratories. For example, in both the *antibiotic resistance* and *Mendelian genetics* laboratory series, students were not consistently observed to work independently of the Tara and Cameron (e.g., not working as a cooperative, cohesive group), and their questions were ones that reflected mainly pragmatic aspects of the laboratories rather than reflective questions about what they were learning. In fact, there were times in every set of observations (i.e., beginning, middle, and end of semester) throughout the semester that I observed students barely communicating within groups. John also appeared to enact a large proportion of his conceptualizations of teaching science as inquiry than Tara and Cameron, although with more difficultly, and Evan the least, yet data indicate that their students did not consistently receive middle to low scores for their inquiry student behaviors (i.e., scores that range between 0 and 2). In fact, there are multiple occasions where their students' scores rivaled those of Tara's and Cameron's students.

One potential reason for these varied student score results may fall to group dynamics. As noted earlier, I often observed one or two group leaders running the show (often happily) while other group members (equally as happily) turned over the reins to these group leaders. While I observed all GLA study participants emphasize to their sections that all group members needed to actively engage in the laboratories in order to understand what was going on and to be able to demonstrate that knowledge on graded assignments, this aspect of group work fell short of GLA and my expectations. After the first set of observations that I made in the *enzymes* laboratory series, I noted to all BIOL 1103L GLAs the lack of equitable work load in many groups that I observed. Despite the fact that I reminded them that they needed to find ways to check on cooperative effort within student groups, I did not see any change in any of the GLA participants' efforts to communicate with students about this issue, and therefore, no notable changes in this student behavior were observed.

In addition to these "go-getter" personality characteristics that could have influenced group leadership, student comfort levels with content knowledge could have also played a role in which group memberspulled more than their weight in laboratory activities. Students who felt they had a better understanding of enzyme kinetics, for instance, would have likely fared better on pre-laboratory homework problems and could have potentially carried that knowledge to their group when groups started designing their experiments. I found it interesting to witness a great deal of peer instruction during the course of the laboratory sections that I observed; students were struggling with the same thing the GLAs were: finding different ways to help others understand content material.

It was pleasing to see the abundance of high scores for the student behavior of staying on task and engaging in thought-provoking activity (Behavior 1). The BIOL 1103L laboratory curriculum was designed to do just that: engage students in interesting problems to tackle rather than in passive learning activities. It is not surprising that students almost always consistently received (from me) the highest scores for this behavior as the other two behaviors, especially asking reflective questions (Behavior 2), required intensive metacognitive skills. As several of the GLA study participants mentioned in previous studies (Author, 2010a; Author, 2010b), students are not used to thinking on their own. They *are* used to being "spoon-fed" directions and answers, and so asking them to take a much more independent role as learners, in the context of a field that is outside their disciplines of interest, was inevitably going to pose significant challenges.

The degree to which students experience science as a process can depend on their instructor. More thoroughly presented views of science may lead to greater student engagement (Dunbar et al, 2008) and perhaps a shift in students' willingness to read or comprehend science phenomenon. This greater sense of "I *can* do science!" is an integral part of students' perception of how well they perform in a science course (self-efficacy). Research has documented correlations between this student self-efficacy with attitude toward careeer choice (Lent, Lopez, & Bieschke, 1991) and enrollment in future courses (Zimmerman, 1995). It is therefore critical to understand the degree to which GLAs are presenting science as a process of inquiry to their students. A fruitful further study would be to ascertain how the recorded levels of inquiry enactment affect students' self-efficacy towards science.

*Conclusions*

There is hope of meeting science education reform at a higher education level. While the teaching preparation program for graduate student instructors of undergraduate introductory biology laboratory courses described in a previous study (Author, 2010a) was a time intensive process for me and for the GLA participants, it positively impacted GLAs' abilities to conceptualize teaching science as inquiry (Author, 2010b) and eventual enactment of those conceptualizations. Higher education faculty and administrators need to consider that if they are willing to allow a substantial portion of undergraduate education to fall under the direction of new graduate student instructors, they must provide these novice teachers with discipline specific teaching preparation. Without this vital step in the development of future faculty, graduate student instructors are left to experience the “live and learn” mentality while undergraduates are left with poor instructional quality (Savage & Sharpe, 1998).

This study and its related counterparts (Author, 2010a; 2010b) open the doors to a range of further research into the preparation of graduate student instructors. How are these instructors developing as teachers during the time that they teach? Do they carry their conceptualizations of teaching science as inquiry to other course assignments? What impacts student learning in introductory science laboratory courses with a reformed curriculum? How can the preparation given to graduate student instructors help demonstrate achievement of course goals in student learning? In light of the diminishing budgets available to hire full time faculty, higher education research must address these valuable research topics so that graduate student instructors are prepared to meet increasing teaching challenges.

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# CHAPTER 6

# CONCLUSIONS

Through the process of conducting this dissertation research study, I became aware of many of the important nuances of undertaking and carrying out research that involves human subjects. I believe that conducting research without being significantly influenced by my own biases to be imperative, but I found that maintaining this essential researcher quality during data collection and interpretation to be a difficult one. The GLAs (graduate laboratory instructors) in this study were hard working, driven graduate students struggling with new responsibilities beyond the teaching assignment with which I was involved. They trusted me to be non-judgmental in my researcher observations as related to their future employment and to help them resolve difficult teaching situations. They allowed me to have an in-depth, behind-the scenes look at both their work as novice teachers in the classroom and their ideas about their teaching experiences. Through these events and the countless emails, interviews, observations, conversations, and phone calls I shared with the GLAs, I became a companion in their journey, and I had to always remember that in order to draw unbiased conclusions from data analysis, I needed to step back from emotions that I shared with them and view data from an objective prospective. As difficult as this challenge was, I feel that I was able to be successful, and this allowed my research study to illuminate the impacts of both broad and fine details related to preparing novice graduate student teachers to teach for the first time.

The results of this dissertation were presented in the form of three manuscripts for publication. The first of these three manuscripts conquered two purposes. First, it detailed the elements of a teaching preparation program implemented in the same semester that novice graduate students taught introductory undergraduate biology laboratories with an inquiry-based curriculum. Three of the four GLAs were completely new to teaching while the fourth had taught undergraduate science laboratory courses for science majors (*Biology of Protists)* and non-science majors (*Anatomy & Physiology)*. However, all four GLAs were new to teaching a curriculum focused on inquiry-based learning. Second, in this manuscript, I analyzed transcripts from multiple individual interviews with the GLAs, pre-demographic survey information, and observational notes of the GLAs while they were teaching. This analysis allowed me to draw conclusions as to how these data as well as other sources of insight illuminated participants' views of the impacts of the teaching preparation on their 1) knowledge of scientific inquiry and how to teach in ways that enable students to build understanding of science as inquiry; 2) confidence towards teaching (in general) and towards teaching science as inquiry; 3) ideas of what science is and how it should be learned; 4) views of the role of teachers and of students; and 5) ability to teach science as inquiry. From a practitioner's standpoint, the program description provides a valuable tool for higher education teacher educators, and the subsequent analysis of its impacts can help enable decisions as to whether the teaching preparation program should be undertaken with a particular group of graduate student teachers or other new teachers.

A broad lesson that I learned from this analysis was that all GLAs found particular elements of the teaching preparation to be beneficial to some or all of the teacher characteristics just listed; therefore, there did not appear to be justification for me to eliminate any elements of the preparation program. A finer lesson I learned, however, indicated that perhaps some elements needed to be more strongly emphasized than had previously been during semester of the study. For instance, each GLA discussed the benefits of being able to talk about laboratory teaching experiences with me and especially with fellow GLAs. This was particularly important with regard to improving their confidence in teaching the laboratories. One recommendation to emerge from the first manuscript is a prescription for intermittent occasions set aside for GLAs to engage in reflection, co-generative dialogue, and co-teaching. Additionally, I believe that building a resource of quality video clips of GLAs and students engaged in BIOL 1103 laboratory activities would be an excellent additional tool that would be used during meetings to examine appropriate and inappropriate teaching. Finally, the GLAs in this research study discussed how beneficial it was for them to observe experienced and novice GLAs teach. I would like to find a way to have all BIOL 1103L GLAs (and those in other introductory biology laboratory courses under my direction) conduct some peer evaluations during the course of their teaching assignment, but this would have to be done in such a way that they don't see it as more work added on to their already crowded schedules.

Another significant broad finding described in this manuscript was that the actual experience of teaching holds a strong impact on a teacher's development, beliefs, and experiences. All of the GLA study participants, at some point, discussed how "just getting in there and doing it" was the best preparation there was for teaching. I think this is important to consider when developing teaching preparation because while the "trial and error" experience of teaching is in itself a form of learning, formalized teaching preparation should be constructed such that it moves teachers beyond this low level of learning about teaching. Additionally, this broad finding blends with a finer one: the actual teaching experience is a substantial compliment to existing preparation methods that I am employing. It informs my approach taken towards discourse topics and preparation elements and therefore should be used as a catalyst for such.

While commonalities existed across GLAs in discussions of the teaching preparation and other factors that impacted the teacher characteristics listed above, these shared views were actually highlighted by the variety of responses that emerged within individual GLAs. This is a benefit of conducting qualitative research with a small number of human participants; the process of spending extensive time with a small group of GLAs allowed me to gain insight into the experiences of each of them in extraordinary detail. This personal realization led me to further consider the impact of individual experience. For my second and third manuscripts, I chose to more finely analyze the same data sources considered in this first manuscript for even richer analysis of the GLAs' experiences of teaching science as inquiry.

In the second of my three manuscripts, I presented analysis of data that arose from transcripts of individual interviews with the GLAs, pre-demographic surveys, a one-question survey on comfort levels with the biology content being taught in specific laboratory series, and notes I made from my observations of the GLAs teaching in order to gain an understanding of how the GLA study participants came to conceptualize teaching science as inquiry. Little literature exists that analyzes how novice science graduate student instructors develop their conceptualizations of teaching science as inquiry, but informative literature in K-12 teacher education research provides valuable insight into this topic as it relates to preservice and inservice teachers. For example, elementary school teachers who are given short-term professional development experiences designed to help them develop pedagogically specific understandings of inquiry are sometimes unable to carry these beliefs for extensive periods of time (Akerson, Abd-El-Khalick, & Lederman, 2000), but if provided with more in-depth, long-term professional development, teachers are able to build, develop, and retain more of these beliefs (Akerson & Abd-El-Khalick, 2003). Additionally, it is common for K-12 preservice teachers to have few experiences of engaging in the process of science, and this has been found to diminish their skill in designing and applying pedagogically specific inquiry lessons “that will help the students develop an image of science that goes beyond the familiar ‘body of knowledge’” (Gallagher, 1991, as cited in Akerson & Hanusein, 2007). Therefore, I was particularly interested in the research on how instructors who are new to enacting the teaching of science as inquiry develop their conceptualizations of this approach to teaching. Understanding how the GLAs developed these beliefs could better assist in my perceptions of what those beliefs are (and if they are pedagogically appropriate) and potentially understand what the GLAs might eventually enact in the classroom.

In my research study, I provided intense, multi-dimensional professional development over the course of the semester in which the GLAs taught. This preparation had the potential to positively impact the GLAs’ abilities to develop pedagogically appropriate beliefs of teaching science as inquiry and therefore also positively impact their students’ understanding of science as a process of inquiry. However, based on the results presented in the first manuscript which alluded to the impact of the individual experience on the teacher characteristics studied, it became clear that my well-intended efforts to adequately prepare BIOL 1103L GLAs to teach science as inquiry could not account for the total preparation that they need. I was therefore interested in analyzing if the GLAs developed the same conceptualizations of teaching science as inquiry since they all received the same teaching preparation or if their conceptualizations were developed on a more individual basis.

My findings indicated that there were commonalities among the group of GLA study participants in development of pedagogically appropriate conceptualizations of teaching science as inquiry. Further and most importantly, they described many of the same teaching preparation elements as having impacted these beliefs. However, variation existed in GLAs' explanations of how those elements did so. Additionally, the impact of teaching preparation on development of conceptualizations of teaching science as inquiry was not superseded by the impact of other teacher qualities including what a teacher "brings to the table" (e.g., personality, experience with inquiry) and what a teacher actually experiences in the classroom (e.g., student interactions, time management issues). Understanding the importance of these three elements of teacher development is valuable to efforts to adequately prepare novice graduate student instructors to teach science as inquiry because understanding how the teachers develop their beliefs about this topic allows for teaching preparation that is grounded in pedagogical reasoning (Roehrig, Luft, Kurdziel, & Turner, 2003).

In the third manuscript, I chose to further analyze data from the second manuscript to determine if and how the GLAs enacted their conceptualizations of teaching science as inquiry. Research in K-12 education has demonstrated that if a teacher is unable to conceptualize inquiry teaching, they may have trouble enacting it (Park Rogers and Abell, 2008). In the research study being reported here, this notion was supported. GLAs with stronger conceptualizations of teaching science as inquiry were able to demonstrate greater enactment of these conceptualizations than GLAs with less firmly grounded conceptualizations. The results suggest that even with pedagogically specific teaching preparation, the enacted teaching experience is still individualized by teachers, and they will therefore demonstrate different degrees of preferred teaching behaviors.

One could theorize that teachers that enact greater degrees of pedagogically appropriate conceptualizations would have students who demonstrate greater degrees of preferred student behaviors. I found that desired inquiry student behaviors did not depend on level of enactment of conceptualizations of teaching science as inquiry. In general there was no difference demonstrated between the frequency or development of desired student behaviors in any of the GLAs' laboratory sections that I observed. This suggests that factors other than a teacher's teaching methodologies impacts students' abilities to engage in science as a process; this is a worthy topic for future research.

The process of beginning analysis of data from this research study on a broad scale allowed for me to draw conclusions based mainly on commonalities between GLAs, but it also allowed for me to more finely analyze data in the second and third manuscripts to understand individual experiences of GLAs in their development as teachers. This research study has grounded my beliefs in the importance of sustained, pedagogically specific teaching training for the graduate student whom I work. The benefits of the preparation may be common or individualized, but they are clearly better than no preparation at all. I will take lessons learned from this study and provide greater emphasis on particular aspects of the teaching preparation that were found to be beneficial across all GLAs, and I will also devote time to individualize preparation per GLA. A research study as in-depth as this one is not possible every semester, but understanding the findings of this study allows to me consider why GLAs might be struggling with their development of conceptualizations and eventual enactment of them as well as why defined student outcomes may or may not be met. I think most importantly, this study has demonstrated to me that teaching preparation goes beyond prepared elements and needs to involve teacher input into the preparation and teaching experience as well as a rich reflection on this information. Defining the relative success of teaching preparation is not just about the process of preparation, but involves the accounting for the role of each of the components that make up the act of teaching and the individual who is teaching.

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# APPENDICIES

# APPENDIX A

## PRE-DEMOGRAPHIC SURVEY

Name: ________________________________________________

1. What is your gender?

   Male Female

2. What is your ethnic background?

   African-American Asian American Euro-American Hispanic

   Other:

   If you were born in a foreign country, what is that country?

3. Are you a native English speaker? (i.e. English was the primary language you spoke and learned at home?).

   Yes No

4. What is the likelihood that you will teach in your future career?

   Very Likely Unsure Unlikely

5. How realistic is it that you will become a faculty member?

   Very Likely Unsure Unlikely

6. If you did become a faculty member and you were given a choice, what percentage of your time would you like to spend teaching?

   100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%

7. What area of Biology are you studying for your degree?

8. Circle the lab course you are teaching this semester:

    1103L – Cellular/Molecular Biology for non-majors
    1104L – Organismal Biology for non-majors
    1107L – Cellular/Molecular Biology for majors
    1108L – Organismal Biology for majors

9. Rate your level of content knowledge for the material covered in this course:

    very high   high   adequate   unsure   inadequate

10. Rate your level of confidence in writing:

    very high   high   adequate   unsure   inadequate

11. Rate your level of confidence for providing feedback on written assignments:

    very high   high   adequate   unsure   inadequate

12. How many semesters have you been a teaching assistant?

    >6   6   5   4   3   2   1   0 (this is my first semester)

13. Please list any prior teacher-training experiences you have had (including university orientations sessions for TAs or GRSC7770.)

14. Please list any and all previous teaching positions you have held.

15. What is the main reason <u>aside from making money</u> that you are teaching this semester?

16. How do you anticipate teaching this course will benefit you?

17. How would you know if a lesson included inquiry activities?

18. Describe any prior experience you have had with inquiry instruction.

19. Describe a typical lab experience for an undergraduate taking a biology laboratory course. Include a description of student and teacher roles.

20. Describe what a typical biology lab would look like in a lab manual (e.g. what would be included in the format of the lab presentation).

21. Describe the roles of a student and a teacher in an inquiry activity.

22. For the following list of lab activities indicate if you think it is an inquiry experiment or not, and indicate why.

| **Assignment** | **Inquiry? yes/no** | **Why? Or Why not?** |
|---|---|---|
| In a genetics laboratory exercise students are instructed to cross two true-breeding lines of fruit flies, then identify the correct genotype and phenotype of the progeny | | |
| Students are told to plant seeds and fertilize with a dilution series of fertilizer, then measure the effect on plant height, number of leaves, and number of seeds. | | |
| Students are given two seed stocks: one parent and its progeny. Students are challenged to generate a hypothesis about the second parent's genotype and design an experiment to test it. | | |
| Students collect data about the organisms, pH, and nitrate levels of a stream and are asked to research what these values indicate to make an overall prediction about the water quality. | | |
| Students are instructed how to make 10-fold dilutions of soil samples and apply each solution to a culture medium. After incubation, students count the number of colonies on each plate and calculate the number of culturable organisms in the sample. | | |

# APPENDIX B

## TEACHING VIGNETTE

**Name: ___________________________________________________________**

**Date: __________________________________________**

**Instructions:** Please read the following interaction of a GLA and a group of students taking an introductory biology laboratory class.

Tom is a graduate student laboratory instructor for an introductory laboratory course for non-science majors. He is using a laboratory curriculum that requires students to design their own experiments within given parameters. This week, they are studying the whether the amount of starch in their samples changes in the presence of amylase. To do this, students must work in groups of 3 or 4 and design a way to test the effects of amylase on varying concentrations of starch. They may only use the available equipment for their experiment. All groups show Tom their experimental plans before they start their experiment.

Group 1 tells Tom they are ready, and a group leader explains their experimental design to Tom. Noting to himself that the group has not included an appropriate control, Tom waits until they are finished telling him their plans.

Tom: I think this sounds pretty good. What are you going to do with your starch concentration measurements when you are done?

Group Member: Compare them to see if some have less starch in them than others.

Tom: Makes sense. How are you going to know your results are accurate?

Group members are quiet.

Tom: In other words, how will you know if the enzyme affects starch at all?

Group member: Well, if we add amylase to the tubes that have different starch concentrations and then wait 30 seconds, then we can stop the reactions, put the tubes in the spec machine, take absorbance readings, and then get relative starch concentrations. If the starch concentrations are different from the original ones, then we know that amylase broke some starch down.

Tom: Is it possible for starch concentrations to change even without enzyme being present? How would you know for sure? I think you need to consider this before starting your experiment.

**Describe your reactions to Tom's methods of teaching. Do you think that they were effective in helping students think about an appropriate control? Why or why not? What would you have done in his situation? Use the back if you need extra room to respond.**

# APPENDIX C

## POST-DEMOGRAPHIC SURVEY

Name: ________________________________________________________

Date: _____________________________________

Course Taught: _____________________________

1. Besides money, in what ways have you benefited from teaching this year?
2. What is the likelihood that you will teach in your future career?

   Very Likely    Unsure    Unlikely

3. How realistic is it that you will become a faculty member?

   Very Likely    Unsure    Unlikely

4. How has being a TA influenced your final career goals?
5. If you did become a faculty member and you were given a choice, what percentage of your time would you like to spend teaching?

   100%  90%  80%  70%  60%  50%  40%  30%  20%  10%  0%

6. Rate your level of content knowledge for the material covered in this course:

   very high    high    adequate    unsure    inadequate

7. Rate your level of confidence in writing:

   very high    high    adequate    unsure    inadequate

8. Rate your level of confidence for providing feedback on written assignments:

   very high high adequate unsure inadequate

9. Rate your level of satisfaction with the e teacher training you got while teaching this course.

   very high high adequate unsure inadequate

10. Please describe your experience with inquiry instruction.

11. How would you know if a lesson included inquiry activities?

12. If you were an instructor in charge of a laboratory course, would you be likely to teach an inquiry lab or one with a more traditional format and why?

13. For the following list of lab activities indicate if you think it is an inquiry experiment or not, and indicate why.

| **Assignment** | **Inquiry? yes/no** | **Why? Or Why not?** |
|---|---|---|
| In a genetics laboratory exercise students are instructed to cross two true-breeding lines of fruit flies, then identify the correct genotype and phenotype of the progeny | | |
| Students are told to plant seeds and fertilize with a dilution series of fertilizer, then measure the effect on plant height, number of leaves, and number of seeds. | | |
| Students are given two seed stocks: one parent and its progeny. Students are challenged to generate a hypothesis about the second parent's genotype and design an experiment to test it. | | |
| Students collect data about the organisms, pH, and nitrate levels of a stream and are asked to research what these values indicate to make an overall prediction about the water quality. | | |

| | | |
|---|---|---|
| Students are instructed how to make 10-fold dilutions of soil samples and apply each solution to a culture medium. After incubation, students count the number of colonies on each plate and calculate the number of culturable organisms in the sample. | | |

14. Can you give an example of an inquiry activity you have taught or been taught with that was particularly effective?

# APPENDIX D

## POST-OBSERVATION INTERVIEW QUESTIONS

1. What do you think went well in the lab?

2. Can you give an example of an interchange you had with the students that you felt went particularly well? Why did it work well?

3. What did you feel did not go well with the class?

4. What is the reason you think these problems happened?

5. How would you modify your teaching next time to deal with this problem?

6. Are there any materials or instructions you felt would have helped you better prepare to teach this lab?

7. If you could teach this same class over again, what would you do differently? (In particular any interactions you had with the students during class.)