Chemistry Graduate Teaching Assistants' Experiences in Academic Laboratories and Development of a Teaching Self-image

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Chemistry Graduate Teaching Assistants’ Experiences in Academic Laboratories and Development of a Teaching Self-image

By

Todd Adam Gatlin

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy Department of Chemistry College of Arts and Sciences University of South Florida

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Dedication

To my wife, Sarah, and our family members who provided the support and encouragement to finish this dissertation.
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# Table of Contents

List of Tables \hspace{1cm} v

List of Figures \hspace{1cm} vi

Abstract \hspace{1cm} vii

Chapter One: Introduction \hspace{1cm} 1

Graduate Teaching Assistants in Chemistry \hspace{1cm} 2

Literature on chemistry GTAs \hspace{1cm} 3

Training and support provided to chemistry GTAs \hspace{1cm} 4

Evaluation of GTAs’ teaching and impact on students \hspace{1cm} 9

Benefits of teaching for GTA \hspace{1cm} 11

Research Goals \hspace{1cm} 12

Organization of this Dissertation \hspace{1cm} 13

Chapter Two: Experimental Chemistry Teaching: Understanding Teaching Assistants’ Experience in the Academic Laboratory \hspace{1cm} 14

Note to Reader \hspace{1cm} 14

Introduction \hspace{1cm} 14

Research Goal \hspace{1cm} 18

The Study \hspace{1cm} 18

*Context and design* \hspace{1cm} 18

*Data collection and analysis* \hspace{1cm} 20

Results \hspace{1cm} 22

*Outcome space and interpretation* \hspace{1cm} 22

*Doing* \hspace{1cm} 23

*Knowing* \hspace{1cm} 24

*Transferring* \hspace{1cm} 26

Discussion and Conclusion \hspace{1cm} 28

Implications \hspace{1cm} 31

Chapter Three: Factors Contributing to the Development of Graduate Teaching Assistant Self-Image \hspace{1cm} 33

Note to Reader \hspace{1cm} 33

Introduction \hspace{1cm} 33

Method \hspace{1cm} 36

*Study design and context* \hspace{1cm} 36

*Data collection* \hspace{1cm} 37

*Data analysis* \hspace{1cm} 38
Findings and Discussion

Proposition 1: GTAs’ teaching performance is associated with the way they see themselves as instructors, that is, their GTA self-image

Proposition 2: In the absence of any other factors, GTAs will base the construction of their GTA self-image on their perception and interpretation of prior experiences

Proposition 3: Training and staff meetings influence GTAs’ construction of their self-image

Proposition 4: GTAs’ beliefs about the nature of knowledge are associated with their construction of their self-image

Proposition 5: GTAs’ beliefs about the nature of the academic laboratory are associated with their construction of their self-image

Conclusions

Limitations

Implications for Laboratory Instruction

Chapter Four: Case study of two graduate teaching assistants’ self-images before and after teaching in a cooperative problem-based chemistry laboratory

Introduction

GTA Self-Image Model

GTA self-image

Beliefs about the nature of knowledge

Beliefs about the nature of the laboratory

Prior experiences

GTA training and support

Methods

Setting

GTA orientation

Participants

Data collection

Interviews

Surveys

Data analysis

Role of the Researchers

Findings and Discussion

Shea’s and Lyle’s pre-teaching background

Shea’s pre-teaching GTA self-image

Shea holds a GTA self-image as a manager and provider of knowledge (1.i)

Shea believes students obtain knowledge from teachers and by ‘doing’ (2.i) and Shea envisions students as physically active (3.i)

Shea believes the purpose of the General Chemistry Laboratory is to prepare students for future laboratory courses (4.i), and Shea values practical skills as the most important student outcome (5.i)
Shea’s Post-teaching GTA self-image

Shea holds a self-image as a guide and mentor for her students (1.f) 84
Shea views students as providing active exchanges and sharing views (2.f) 86
Shea values physical and mental activity (3.f) 88
Shea believes the general chemistry laboratory prepares students for future problems (4.f) and she values practical skills, scientific skills, general skills, and content knowledge (5.f) 89

Lyle’s Pre-teaching Self-Image

Lyle holds a self-image as a content expert and questioner (1.i) 90
Lyle views students as physically active (2.i) 93
Lyle holds an absolute view of knowledge (3.i) 94
Lyle believes the laboratory is a place to prepare for future laboratory courses, learn techniques and theory (4.i). Also, Lyle views laboratory learning as experiential (5.i) 95

Lyle’s Post-teaching self-image

Lyle holds a self-image as a content expert and questioner (1.f) 97
Lyle envisions students as physically active (2.f) 101
Lyle holds an absolute view of knowledge (3.f) 104
Lyle differentiated goals for majors and non-majors of chemistry (4.f) and Lyle views laboratory learning as experiential (5.f) 105

Cross-case analysis of Shea and Lyle

Limitations 111
Conclusions and Implications 113

Chapter Five: Conclusions

GTAs’ Experiences in Academic Laboratories 116
Impact and Benefit of Laboratory Teaching Experiences 117
Limitations 118
Implications 122
Implications for GTA Training and Support 125
Implications for Laboratory Reform 128
Implications for Graduate Education in Chemistry 129

References 131

Appendix A: Permission to Reprint 142

Appendix B: IRB Approval 143
<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Sample Case Narrative: Avery, a GTA from the expository program</td>
<td>145</td>
</tr>
<tr>
<td>D</td>
<td>Pre-Teaching Interview protocol</td>
<td>147</td>
</tr>
<tr>
<td>E</td>
<td>Post-Teaching Interview protocol</td>
<td>150</td>
</tr>
<tr>
<td>F</td>
<td>GTA Survey</td>
<td>152</td>
</tr>
</tbody>
</table>
List of Tables

Table 3.1 Distribution of participants by program type. 38
Table 4.1 Background characteristics for each case 76
Table 4.2 Pre-Survey Part II: Prior Laboratory Experiences 78
Table 4.3 Pre-Survey Part I: Views on Laboratory Learning 80
Table 4.4 Assertions about Shea’s pre- and post-teaching self-image and related factors 81
Table 4.5 Assertions about Lyle’s pre- and post-teaching self-image and related factors 91
List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Phenomenological outcome space</td>
<td>23</td>
</tr>
<tr>
<td>3.1</td>
<td>Data analysis scheme</td>
<td>38</td>
</tr>
<tr>
<td>3.2</td>
<td>Factors associated with GTA self-image development</td>
<td>40</td>
</tr>
<tr>
<td>4.1</td>
<td>Relative timeline of data collection and GTA orientation and teaching</td>
<td>70</td>
</tr>
</tbody>
</table>
Graduate teaching assistants (GTAs) play a prominent role in chemistry laboratory instruction at research based universities. They teach almost all undergraduate chemistry laboratory courses. However, their role in laboratory instruction has often been overlooked in educational research. Interest in chemistry GTAs has been placed on training and their perceived expectations, but less attention has been paid to their experiences or their potential benefits from teaching.

This work was designed to investigate GTAs’ experiences in and benefits from laboratory instructional environments. This dissertation includes three related studies on GTAs’ experiences teaching in general chemistry laboratories. Qualitative methods were used for each study. First, phenomenological analysis was used to explore GTAs’ experiences in an expository laboratory program. Post-teaching interviews were the primary data source. GTAs experiences were described in three dimensions: doing, knowing, and transferring. Gains available to GTAs revolved around general teaching skills. However, no gains specifically related to scientific development were found in this laboratory format.

Case-study methods were used to explore and illustrate ways GTAs develop a GTA self-image – the way they see themselves as instructors. Two general chemistry laboratory programs that represent two very different instructional frameworks were chosen for the context of this study. The first program used a cooperative project-based approach. The second program used weekly, verification-type activities. End of the semester interviews were collected and served as the primary data source. A follow-up case study of a new cohort of GTAs in the cooperative
problem-based laboratory was undertaken to investigate changes in GTAs’ self-images over the course of one semester. Pre-semester and post-semester interviews served as the primary data source. Findings suggest that GTAs’ construction of their self-image is shaped through the interaction of 1) prior experiences, 2) training, 3) beliefs about the nature of knowledge, 4) beliefs about the nature of laboratory work, and 5) involvement in the laboratory setting. Further GTAs’ self-images are malleable and susceptible to change through their laboratory teaching experiences.

Overall, this dissertation contributes to chemistry education by providing a model useful for exploring GTAs’ development of a self-image in laboratory teaching. This work may assist laboratory instructors and coordinators in reconsidering, when applicable, GTA training and support. This work also holds considerable implications for how teaching experiences are conceptualized as part of the chemistry graduate education experience. Findings suggest that appropriate teaching experiences may contribute towards better preparing graduate students for their journey in becoming scientists.
Chapter One:

Introduction

In recent years, graduate education in chemistry has been questioned and challenged. Since 2011, three national reports commissioned by the American Chemical Society (ACS) (2011, 2012) and the National Research Council (2012) have focused on ways to keep US chemistry graduate education competitive. According to Faulkner (2012), who chaired the most recent ACS task force (American Chemical Society, 2012), the current interest on graduate education is on “whether our programs are doing the most valuable things for graduate students in the most effective ways” (p. 63). While recommendations to improve graduate education range from new funding models to better tracking of graduate progress, one stands out for the purposes of this dissertation. The recent presidential task force of the ACS (American Chemical Society, 2012) recommended teaching assistantships should be viewed “more strategically as an opportunity (and an obligation of the program) to enhance the professional development of the student” (p. 34).

The stance taken by this work is that “professional development” of chemistry graduate students should be aimed towards scientific development. The goal of graduate education is commonly accepted as preparation of researchers (Golde, 2006; Gonzalez, 2001). Further, the ACS task force (2012) stated the main purpose of doctoral education in chemistry is “to teach graduates how to enter a new field, how to pose worthwhile problems, how to be productive in generating valuable new knowledge, and how to evaluate critically their findings and those of
others” (p. 7). This dissertation explores how teaching assistantships in chemistry might contribute to these goals.

The present work focuses on chemistry graduate students’ experiences while engaged in teaching assistant positions. This work evolved from research initially focused on students’ experiences in chemistry laboratories (Sandi-Urena, Cooper, & Stevens, 2012; Sandi-Urena, Cooper, Gatlin, & Bhattacharyya, 2011b). The qualitative inquiry on students’ experiences generated the hypothesis that GTAs who facilitated the laboratories may be developing problem-solving skills. In this regard, one study was carried out that focused on GTAs’ experiences within a problem-based laboratory (Sandi-Urena, Cooper, & Gatlin, 2011a). GTAs’ experiences promoted their metacognitive development as they engaged in modeling problem-solving behaviors. Through this work, GTAs were recognized as learners within the laboratory environment and led to questioning what GTAs learn or gain from their teaching experiences. Therefore, this dissertation work evolved from a larger research program focused on learning in laboratory settings, but it focused specifically on the graduate students who were asked to teach in the laboratories.

**Graduate Teaching Assistants in Chemistry**

Chemistry graduate students usually enter their programs with a Bachelor’s degree in chemistry. They are students; their purpose in graduate school is to earn a Ph.D. They are often going through big life changes, and they have entered their programs with their own expectations, fears, excitement, and anxiety. On top of all of this, they are usually required to teach during their first semester even though they may have no background or training in teaching. Thus, in graduate school they are expected to begin teaching before they begin research, which they are more prepared to do because of coursework and possibly undergraduate research experiences.
In tertiary chemistry instruction, GTAs teach virtually all laboratory courses at large research universities in the US. In a 2002 survey of chemistry Ph.D. recipients, 92% of respondents reported teaching at some point in their graduate program and over 60% reported teaching exclusively in laboratory settings (American Chemical Society, 2002). It is not surprising that the majority of chemistry graduate students teach, because teaching assistantships are part of the funding model in chemistry. As mentioned, chemistry graduate students are often expected to teach even before they choose a research advisor. This practice was encouraged in the recent ACS report (American Chemical Society, 2012) that recommended chemistry departments should strive to fund all first year graduate students through teaching assistantships rather than funds tied to an advisor or research project. Hence, it appears as if GTAs will continue to be prevalent in chemistry instruction for the near future. Although, as the next sections will show, literature has not offered many suggestions on how the use of teaching assistantships may benefit graduate students’ development, as scientists, which is the goal of the graduate programs.

**Literature on chemistry GTAs.** Chemistry GTA literature is dominated by descriptions of training materials and programs (Bauer, Libby, Scharberg, & Reider, 2013; Burke, Hand, Poock, & Greenbowe, 2005; Chen, She, Chou, Tsai, & Chiu, 2013; Garland, 1969; Herrington & Nakhleh, 2003; Lippincott, 1959; Mellon, 1971; Pentecost, Langdon, Asirvatham, Robus, & Parson, 2012; Robinson, 2000). Much of the work is opinionated or based on “good practices” while theory and research guiding the practices are often left in the background if present at all (Gorsuch, 2012). Overall, GTAs’ experiences and development have rarely been the topic of research in chemistry education. There are a few investigations into GTAs’ teaching skills and their impact on their students’ learning. In addition, a couple of studies have addressed benefits
of teaching experiences. Each of these areas—training and support, evaluation of GTAs, and benefits of teaching assistantships—are addressed separately to determine what if anything literature might suggest about using teaching assistantships as an opportunity to enhance professional development of chemistry graduate students.

**Training and support provided to chemistry GTAs.** Chemistry training materials and programs began frequently appearing in the literature in the 1970s. At that time, GTA training was not a common occurrence across chemistry departments. Through a survey of 125 Ph.D. granting chemistry departments, Renfrew and Moeller (1978) found that only 48% offered some form of training for their GTAs. In a 1997 (Abraham et al.) survey of departments with ACS approved chemistry curriculum, 37% offered no forms of training. The 63% that offered some form of training varied greatly as to the nature and scope of the training they provided. Safety and grading techniques were covered most often. However, departments also reported discussing laboratory activities, learning theory and goals of laboratory education. Yet, of the departments that held departmental training, only 17% reported the training lasted longer than one day (Abraham et al., 1997).

The nature and scope of training programs and materials in literature also varied greatly. Some training materials were posed as “how to guides,” written directly to students who would take these assistantships. For example, the early *Handbook for Teaching Assistants* (1965) fit this description. Other training programs were designed to last between one and seven days. For example, Brooks et al. (1972) described a two-day seminar program that covered topics ranging from teaching techniques (maintaining eye contact, holding student interest, etc.), establishing authority, to grading papers. Likewise, Birk and Kurtz (1996) described a week long program that for the most part covered the topics found in the *Handbook for Teaching Assistants* (1965).
Today, these seminar and workshop approaches are still common according to recent reviews (Gardner & Jones, 2011; Seymour, 2005); however, as evident in recent programs (Bauer et al., 2013; Burke et al., 2005; Pentecost et al., 2012) they are more likely to contain discussions of learning theory. Although based on a small sample, it appeared that there is a correlation between including learning theory in GTA training and the use of inquiry-based laboratory practices.

While including learning theory seems to be a valuable goal, its inclusion in a week long training program raises some concerns. Each of the training programs referenced above take place immediately before GTAs are expected to teach, usually one or two weeks prior to the beginning of the semester. It seems unreasonable to expect great gains in understanding and internalizing of learning theory or teaching proficiency in one week or less, especially considering that most students enter graduate school without any formal training in pedagogy or learning theory. Even professional teachers undergo further mentoring and training after they begin teaching. Further, it has been shown that new GTAs are concerned with aspects of self and survival (Nyquist & Sprague, 1998), such as whether their students will like them and what they should do the first day. For chemistry GTAs, who usually start teaching their first semester, these concerns are coupled with the stress inherent of starting a new graduate program. Considering GTAs’ concerns, it is worth questioning the benefits of initial training that spends a considerable amount of time on learning theory.

Evaluation of training programs and GTAs’ experiences within them have not been a frequent component on chemistry education literature (Seymour, 2005). Seymour (2005) reviewed literature regarding GTA training in science, technology, engineering and math (STEM) fields and argued, “it is clear for this synopsis of research and evaluation studies […]"
that academe has not yet widely accepted either the importance of appropriate professional
development for their TAs or the importance of well-designed evaluations of those programs that
they offer” (p. 252). Further, when there has been evaluation of training programs, the evaluators
tended to be the program developers (Bauer et al., 2013; Bond-Robinson & Bernard Rodriques,
2006; Marbach-Ad et al., 2012; Nurrenbern, Mickiewicz, & Francisco, 1999; Pentecost et al.,
2012). Only Roehrig et al. (2003) evaluated a program for which they were not part of the
development team.

In a review of training programs across science disciplines, Gardner and Jones (2011)
only identified three studies that evaluated the effects of chemistry GTA training programs.
Based on the three chemistry evaluations that Gardner and Jones (2001) identified, chemistry
training programs that provided continuous support were found to have an impact on teaching
assistants’ pedagogical content knowledge (Bond-Robinson & Bernard Rodriques, 2006) and
their teaching behaviors (Nurrenbern et al., 1999). Roehrig et al. (2003) found that a weeklong
training program had little effect on the chemistry GTAs as their teaching behaviors throughout
the semester were still mainly based on their previous experiences as students. These findings
were consistent with programs in other sciences, and they led Garder and Jones (2011) to suggest
support should be continuous, focused on student learning, and embedded within the curricular
context for which the GTA will teach.

Suggestions of continuous support merged well with the theme of “professional
development” that appeared in GTA work in the 1990s. Educators began to favor this term over
“GTA training” as it recognized the potential of these programs to have lasting effects on
graduate students’ development as future faculty members (Seymour, 2005). Yet, both “training”
and “professional development” are in use today in chemistry education and usually point in the
same direction: the preparation of teachers. Pentecost et al. (2012) even promoted “training” that fosters “professional development.” “Training” usually focused on the immediate job responsibilities, and “professional development” added components for the preparation of future careers in academia. This is how the terms will be used here.

Programs that focus on professional development, preparation for future faculty careers, are usually not specific to individual departments. Perhaps the most well known was the Preparing Future Faculty program (Pruitt-Logan, Gaff, & Jentoft, 2002). This program sought to address all aspects of faculty roles such as teaching, research and service. Participating graduate students received feedback from research and teaching mentors. The program also clustered institutions across doctoral granting, liberal arts, and community colleges, to provide graduate students with the scope of options available. While this program is no longer funded on the national level, some universities continue to model the approach (“Preparing Future Faculty,” n.d.). Another advancement that is more recent came from the Center for the Integration of Research, Teaching and Learning (CIRTL) network (Austin et al., 2009). This program was designed to prepare the next generation of STEM faculty members and based its work on three core ideas: teaching as research, learning communities, and learning through diversity. This program brought together a network of faculty members, post-docs and graduate students across US institutions. Members of the CIRTL network developed online courses with topics ranging from diversity in STEM to scholarly teaching practices for its members (“CIRTL Network,” 2013).

Another approach for preparing graduate students for academic careers involved the use of workshops. For example, an upcoming Cottrell Scholars workshop will bring together a GTA and faculty mentor from twelve universities for a two-day workshop (“Cottrell Scholars
Collaborative,” 2013). The specifics of the two-day event are not posted online. However, the program hopes to promote interactive and evidence-based learning strategies. Another one-day, six-hour workshop was recently described (Bauer et al., 2013). Workshops were held at top chemistry departments and attended by chemistry graduate students interested in careers in academia. Each workshop involved five components: (1) out of chemistry learning event, (2) pedagogical and cognitive theories for novices, (3) argumentation analysis, (4) cooperative knowledge construction in laboratory, and (5) exploring students misconceptions via clickers. Workshop participants were surveyed immediately following the workshop and six months later; 89% responded favorably that the workshop had changed their perspectives about teaching and learning (Bauer et al., 2013). There are some potential explanations for why findings from this one day workshop were more favorable than findings by Roehrig et al. (2003) and Gardner and Jones (2011) in relation to short-term training. The workshop participants were self-selected; they wanted to prepare for future academic careers. Second, the favorable evaluation could have been an artifact of the self-report nature of the evaluation.

While these professional development programs offer one possibility for strategically using GTA positions, they are promoted for graduate students who self-identify as interested in academia. Their explicit goal is to prepare the next generation of faculty members; yet, the majority of chemistry graduate students will not work in academia. In a study involving graduate students at 27 institutions, only 36% of chemistry graduate students were considering a career in academia (Golde & Dore, 2001). Of all the disciplines surveyed, chemistry graduate students showed the least interest in academic careers. The same survey found that only 17% of chemistry graduates were in tenure track positions five years after graduation (Golde & Dore, 2001).
These broad professional development programs have an important but limited role due to the small number of graduate students planning for careers in academia. They are useful for preparing those students who would like an academic career. However, these approaches do not provide suggestions for how chemistry departments should frame teaching assistantships for those students who are not interested in academic careers.

In summary, although descriptions of training and support exist, few studies have evaluated the effects of training programs on GTAs’ teaching behaviors or skills. The studies that have evaluated training programs pointed towards the need for continuous support embedded within the department. Moreover, the programs conceptualized as preparation for future academic careers target a subset of chemistry graduate students. Therefore, the value of teaching assistantships for those students not pursuing academic careers remains unclear.

**Evaluation of GTAs’ teaching and impact on students.** Another area of literature involving chemistry GTAs has sought to evaluate their teaching behaviors, their perceptions of teaching and their impact on students. Miles Pickering started this line of work with a series of studies in the 1970s. In many ways, his studies and commentaries (Monts & Pickering, 1981; Pickering, 1978; 1988b; 1988c; 1988a; Pickering & Kolks, 1976) highlighted the need for training and support that was addressed in the previous section. For example, one study showed that GTAs’ evaluations of students’ laboratory skills were at times negatively correlated with students’ skills as measured by laboratory practical exams (Pickering & Kolks, 1976). In another study, Monts and Pickering (Monts & Pickering, 1981) attempted to investigate the impact of GTAs’ background on students’ performance, but recognized that while they found some GTAs had a positive effect on students’ performance, they could not identify the background
characteristics of an effective GTA. Nonetheless, this body of work set the foundation for future training programs and research.

Herrington and Nakhleh (2003) approached GTA effectiveness through students’ perspectives. Based on responses to a questionnaire and free-response instrument, their findings suggested effective GTAs, as perceived by students, could communicate clearly; had knowledge of the techniques, chemistry concepts, how students learn, and teaching; and they showed concern for students. These findings provide insight into how students view laboratory GTAs. However, it is not known if students’ perceptions of effective GTAs were influenced by the laboratory instructional style. Further, these findings, and focusing on GTAs’ teaching skills in general, offer little insight into what GTAs may receive from their teaching experiences.

One characteristic of this line of research is that GTAs were often treated as instruments of instruction. Within this instrumentalist approach, GTAs were viewed in function of the undergraduates they taught. For example, when describing their research objectives Bond-Robinson and Bernard Rodriques (2006) stated, “the underlying goal of GTAs gaining understanding […] is the undergraduates’ learning” (p. 313). In this objective, it is clear that undergraduate students’ learning rather than graduate students’ learning was the focal point. From this perspective, it is easy to lose sight of the fact that GTAs are also students within the chemistry program.

In this instrumentalist view, GTAs were not at the forefront of attention; they were not viewed as actual partners in instruction (Seymour, 2005). A less instrumentalist view of GTAs could be taken by recognizing them as learners within the laboratory environment. Research would then focus on what GTAs gained and learned from their laboratory teaching experiences rather than what their students took away. This change in perspective would assist chemistry
educators in determining how teaching assistantships could be strategically used for the scientific development of chemistry graduate students.

**Benefits of teaching for GTAs.** There was scant chemistry education literature that addresses benefits GTAs receive from their teaching experiences. This was unfortunate since understanding the benefits of teaching assistantships could have provided the most insight into strategically using them for graduate students’ development.

In chemistry, Seymour’s (2005) work with teaching assistants in three innovative programs was the only research study that analyzed the benefits GTAs receive from teaching. She found that GTAs stand to gain general content knowledge, teaching skills such as communication, and an appreciation for academic careers. These benefits were slanted to those interested in academic careers. However, content knowledge and communication could be valuable outcomes for all graduate students.

Two studies in related science fields suggested teaching experiences might impact GTAs’ research abilities. In biology education, French and Russell (2002) posed an intriguing question that has influenced the work presented in this dissertation, “Do Graduate Teaching Assistants Benefit from Teaching Inquiry-Based Laboratories?” GTAs self-reported that teaching had a positive impact on their research abilities. This study was relevant in that it specifically questioned the impact of teaching on graduate students’ scientific development, and it is the first that suggested teaching might be an integral component in graduate students’ journey of becoming scientists.

In a more recent study, that overlapped in time with this dissertation, Feldon et al. (Feldon, Peugh, Timmerman, & Maher, 2011), reported that teaching experiences of STEM and STEM education graduate students improved their methodological research skills. They analyzed
written research proposals for students who held teaching assistantships and those who did not. Their work shared a common theme with work by Seymour (2005) and French and Russell (2002). Each study treated GTAs as learners within the laboratory environment, and therefore, researchers were able to consider what benefits may be available to the GTAs through teaching experiences.

**Research Goals**

It is argued in this work that viewing teaching assistantships more strategically requires a shift from treating GTAs as instruments of instruction to recognizing them as learners within the laboratory environment. This calls for placing GTAs’ experiences and development, instead of their students, at the focal point of research. An understanding of GTAs’ experiences and benefits will lead to better answers as to “whether our [graduate] programs are doing the most valuable things for graduate students in the most effective ways” (Faulkner, 2012, p. 63).

To address this need, this work was guided by two broad questions:

1) What do chemistry GTAs experience in the academic laboratory?

2) What impact and benefits do teaching assistantships have on chemistry graduate students’ development?

The perspective taken by this research was that before we can fully understand the benefits available to GTAs we must first understand what they experience. In order to respond to the questions guiding this work, three objectives were undertaken. The first objective was to provide a rich description of GTAs’ experiences in an expository laboratory environment. This description would also provide access to the benefits available through the teaching experience. Further, providing a rich description of expository teaching experiences could provide an interesting contrast to previous work that investigated GTAs’ experiences in a laboratory
environment designed to involve more inquiry (Sandi-Urena, Cooper, & Gatlin, 2011a).

The second and third objectives were created as a corollary to the first: determine factors related to the GTAs’ construction of a self-image, the way they view themselves as instructors, and determine if GTAs’ self-images were susceptible to change through their teaching experiences. Understanding GTAs’ self-images could also provide considerable insight into why they teach the way they do. Further, a model for GTA self-image development would allow educators to reconsider current approaches to training and support and begin to consider whether the GTAs’ development of a teaching self-image is compatible and complementary to their development as researchers.

Organization of this Dissertation

The structure of this dissertation takes the form of five chapters, including the present introduction. Chapters Two through Four are studies presented in the order they evolved. Chapter Two and Chapter Three have been published and are reprinted here with permission (Appendix A). Chapter Two focuses on the lived experiences of GTAs in an expository, laboratory program. Chapter Three presents a model for GTAs’ self-image construction through a multiple case study involving GTAs in two different laboratory settings: expository and cooperative problem-based programs. Chapter Four extends the work by exploring two GTAs’ self-image development over the course of their first semester teaching in a cooperative problem-based laboratory. Finally, Chapter Five addresses contributions made by this research, limitations, and implications for GTA training and support, laboratory reform and graduate education in chemistry.
Chapter Two:
Experimental Chemistry Teaching: Understanding Teaching Assistants’ Experience in the Academic Laboratory

Note to Reader
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Introduction
There is little doubt that chemistry educators and researchers regard introductory chemistry laboratory instruction as an indispensable component of tertiary level education. Although many benefits have been attributed to experimental instruction, debate about its purpose and its effectiveness in accomplishing desired learning outcomes might be as old as the assumed merits. This is reflected by the publication almost a century ago of reports underlining the “Problems in the experimental pedagogy of chemistry” (Spear, 1915) and calling attention to the need for systematic investigation of experimental learning outcomes (Wiley, 1918). This timely special issue of *Educación Química* is evidence of the persistent need to examine research in this field and to make strides to address the issues and concerns expressed in multiple review reports (Hofstein & Lunetta, 2004; Nakhleh, Polles, & Malina, 2003; Reid & Shah, 2007).

Entry-level college chemistry courses without a laboratory component would probably be unacceptable for most chemists and chemistry instructors. However, as Elliot, Stewart, and.
Lagowski (2008) sharply pointed out, this stance may be more the product of a deeply entrenched assumption than that of scientific understanding of the role that the lab plays in learning. In these authors’ words “precious little evidence exists that such instruction provides a useful function in the way(s) students learn chemistry” and yet “almost everyone has an opinion or a theory” on this topic (p. 145). Similar statements have become staple comments in reviews of science laboratory instruction (Hodson, 2005; Hofstein, 2004; Hofstein & Lunetta, 2004; Lazarowitz & Tamir, 1994; Nakhleh et al., 2003; Reid & Shah, 2007). From another standpoint, this controversy puts forth the need of sound research that will significantly increase understanding of the role of laboratory instruction in learning chemistry. Higher education institutions continue investing considerable resources sometimes in an apparent act of faith that as a consequence of the laboratory activities something, somehow, at some point happens that leads to significant chemistry learning improvement. In some way, this assumption is analogous to the illusion of learning held by so many students who think that keeping themselves busy studying will necessarily translate into learning. Not surprisingly, the question of the inherent merit of laboratory instruction has been reported previously in the literature (Hawkes, 2004; Hilosky, Sutman, & Schmuckler, 1998; Reid & Shah, 2007).

Notwithstanding, in avoiding confusion, we second Hodson’s (2005) clarification that criticism of laboratory instruction is “not so much an attack on practical work per se as a criticism of the kind of practical work we choose to do, and the way in which we implement it” (p. 30). Ironically, quite often those directly involved with general chemistry laboratory instruction seem unaware of this profound controversy. In our view, the inherent merit of laboratory instruction is not challenged where challenging is needed the most: from within the General Chemistry Laboratory programs. In the US, large research institutions hire
(post)graduate chemistry students to serve as laboratory graduate teaching assistants (GTAs) whereas liberal colleges tend to have faculty in these instructional positions. This set up is not universal, and in other countries, even at large, research-oriented institutions it is faculty members who actually instruct students in the introductory laboratories. Likewise, in some other countries institutions of similar characteristics utilize undergraduate teaching assistants throughout their undergraduate curriculum. US laboratory instructor or GTA coordinator positions rarely encompass expectations such as formal educational background and training and acquaintance with current pedagogies or educational research literature. Under these circumstances, it is understandable that instructional decisions—including instructional design—may be based on personal experiences and naïve assumptions that may perpetuate counterproductive practices in lab instruction. Recently, Bruck, Towns and Lowery Bretz (2012) investigated faculty perspectives of undergraduate chemistry laboratory and reported instructors’ goals, strategies, and assessments for different kinds of institutions (community colleges, liberal arts institutions and research universities). Even though the authors did not investigate where the interviewed faculty drew from to make those decisions, it is apparent that the reported goals and objectives were not entirely consistent with reference sources such as the National Research Council America’s Lab Report (Singer, Hilton, & Schweingruber, 2006).

A majority of papers in chemistry laboratory literature engages in the introduction of innovative ideas and laments the use of expository style of laboratory teaching. Domin (1999) exposes a more holistic perspective and gives more weight to instructional design over fashionable trends. In his view, each style of laboratory format may have value for different learning outcomes. For example, expository labs provide procedures; therefore, they are probably better suited for teaching procedural and technical skills than other non-traditional
approaches. Another apparent assumption in the scant college chemistry laboratory literature is the ubiquitous perception that the proposed curriculum and what happens in the laboratory are the same or as suggested by Briggs (2011), the idea “that students will undergo specific experiences when certain information is or is not provided” (p. 1034). This assumption has led to an overemphasis in research that has focused on the designed curriculum rather than what is enacted. Furthermore, the use of GTAs introduces an additional level of complexity in the enactment of the designed curriculum (Roehrig, Luft, Kurdziel, & Turner, 2003). In response to this reality, our research program pursues the study of learning in the laboratory as it occurs and not as it is meant to happen. In this naturalistic view, we conceive the GTAs not as mere facilitators or intermediaries of student learning but as active participants in the learning environment. Underlying this view is the principle that GTAs are the single most influential factor affecting laboratory instruction (Lazarowitz & Tamir, 1994) and that failure to consider their role prevents progress in advancing learning in the laboratory (Herrington & Nakhleh, 2003; Pickering, 1988b). The importance we place on the GTAs, however, is not in function of the students or instruction as has been customary (Birk & Kurtz, 1996; Harris & McEwen, 2009; Kurdziel & Libarkin, 2003; Luft, Kurdziel, Roehrig, & Turner, 2004; Roehrig et al., 2003). In our approach, the GTAs are not instruments of instruction but engaged agents in the learning process.

In light of this view, where others refer exclusively to the students in the laboratory we include GTAs as well. Such is the case of Hodson’s (1990) proposal that “we are unlikely to have a definitive answer to our questions about the pedagogic value of laboratory work” if we don’t focus more sharply on what students are actually doing in the laboratory (p. 39). Hodson’s (1990) emphasis on the need to understand the actual experiences is echoed by Casey (2007) in
her proposal of a methodological approach to inquire about college chemistry learning: “Perhaps if we could understand the meaning of the students lived laboratory experiences, we would be able to clarify what purpose the laboratory currently serves” (p. 130). We strongly agree with this stance, however, consider its scope incomplete in the case of tertiary science education laboratories unless GTAs are also considered in clarifying the pedagogical value of laboratory instruction. To that purpose, we have already reported an investigation that addressed GTAs’ epistemological and metacognitive development when they engaged in a cooperative, problem-based General Chemistry Laboratory program (Sandi-Urena, Cooper, & Gatlin, 2011a).

**Research Goal**

The purpose of this study was to use a phenomenological approach to generate a rich description of a General Chemistry Laboratory learning environment as lived by GTAs. By means of this description, we intended to enhance understanding of the GTA experience and how it influences the pedagogic value of academic laboratory work. In turn, this description will allow access to factors that may be necessary to consider in designing instruction in this kind of setting.

**The Study**

**Context and design.** This study took place at a research-intensive university in the United States of America; it is part of a larger research program whose ultimate objectives are to enhance understanding of learning in the academic chemistry laboratory and to ascertain gains accessible to students and GTAs through varied approaches to laboratory instruction. We have decided to use phenomenology (Moustakas, 1994; Patton, 2002) to investigate diverse laboratory learning environments. We make the methodological case here for this approach based on its distinct ability to provide access to understanding of “the meaning of a chosen human experience
by describing the lived experience or phenomenon as perceived by the participants” (Casey, 2007, p. 118). In synthesizing this idea, van Manen (1990) proposed that “phenomenology asks for the very nature of a phenomenon, for that which makes a some—‘thing’ what it is—and without which it could not be what it is.” Phenomenological methods intend to uncover the internal and invariant structure of the phenomenon not in its empirical individuality but in its essence (Patton, 2002). Although phenomenology was proposed by Casey (2007) as potential research tool to study the academic laboratory experience, it has only rarely been utilized for this purpose (Sandi-Urena, Cooper, & Gatlin, 2011a; Sandi-Urena, Cooper, Gatlin, & Bhattacharyya, 2011b).

According to the course syllabus, the General Chemistry laboratory in this study is “the first semester of a beginning course in laboratory methods and techniques” that is concerned with teaching “how to analyze information working in a group or alone, how to organize data and methods of problem solving”. In addition, it is intended to facilitate “understanding of the lecture material and support the concepts taught in the lecture course.” The General Chemistry program serves approximately 1500 students per semester and employs about 30 chemistry graduate students acting as teaching assistants. GTAs were invited to volunteer for this study via email. Confidentiality was stressed at all times. The GTA coordinator, chemistry instructors and faculty advisers did not have access to the data collected for this study and participants were not identified. Eleven GTAs volunteered: Six participants were male, six were US-born, the age range spanned from early 20’s to early 30’s and five of the GTAs were teaching for the first time. Each GTA taught two lab sections with up to 24 students. GTAs attended weekly staff meetings led by the GTA faculty coordinator. The meetings provided a venue for discussion of logistics and contents of upcoming experiments. First time GTAs also attended a two-day campus wide
workshop before the semester began. Additionally, first time GTAs were required to attend weekly meetings in which they would complete the upcoming experiments as if they were students. These meetings were optional for returning GTAs due to their familiarity with the experiments. The laboratory course used weekly experiments in which students worked in pairs or groups of four depending upon availability of equipment. Based on the reading of the laboratory manual, students were expected to generate questions that could frame their experimental work. GTAs were required to facilitate a discussion of each group’s questions at the beginning of the period, and help the class decide on the most appropriate question to frame their work. Once a question was chosen, students began work following the general procedure provided in their laboratory manual. Students were expected to answer the question in their weekly written reports. These reports were required to follow the guidelines of the Science Writing Heuristic (Poock, Burke, Greenbowe, & Hand, 2007). GTAs, in turn, assessed students’ reports as well as students’ pre-lab questions and laboratory notebooks. In addition to the responsibilities involved with the two lab sections, all GTAs were required to proctor during the General Chemistry exams and be available for weekly tutoring sessions.

Members of the research team did not have any direct interactions with instructors, GTAs and students other than the collection of data and did not participate at any level of course design, implementation or evaluation. For all practical purposes, the research team is not only independent from the investigated laboratory program but also unaffected by its success or failure.

**Data collection and analysis.** Data collection used a semi-structured interview protocol divided into three main parts. First, participants were asked to describe their own experience as general chemistry students and any previous experience as GTAs. Next, the GTAs were
prompted to describe their students’ experience in the laboratory and their own experience as a GTA. Finally, they were invited to share ideas they had about how students learn in a general chemistry lab. Interviews were conducted at the beginning of the second semester to assure that all GTAs interviewed had completed at least one full semester of teaching. Three participants met with both co-authors while the remaining eight participants met with one co-author. Each participant was aware of the IRB approval (Appendix B). Interviews lasted for approximately one hour, were audio recorded and archived using pseudonyms. Transcription took place once all interviews had been completed.

The data analysis protocol followed the modified phenomenological methodology proposed by Moustakas (1994) and is the same we have used for other reported studies (Sandi-Urena et al., 2011). The main steps are (a) analysis of the transcribed interviews to identify significant statements; (b) clustering of significant statements based on their meaning to create invariant constituents to which we refer as codes; (c) collapsing of codes based on thematic similitude to generate ‘themes’; (d) validation of themes by checking against transcriptions; (e) categorization of themes into dimensions by means of imaginative interpretation; (f) construction of an outcome space to describe the meanings and essence of the experience representing the group as a whole.

For the first three interviews, both researchers worked independently identifying significant statements, and clustering the statements into codes. Weekly meetings were held to discuss the relevance and terminology of the codes, and eighty-two codes resulted from this process. The first three interviews were re-coded and future interviews were coded using the agreed upon terminology. In subsequent meetings, our discussions focused on the thematic experience of the GTAs and led to the creation of a first draft of the outcome space that
integrated the textual and structural description of the experience as lived by the participants. The outcome space presented here was refined through subsequent research discussions.

Results

**Outcome space and interpretation.** Phenomenological reduction and analysis of the data produced the outcome space shown in Figure 2.1. This outcome space, representing GTAs’ experience, consists of three core dimensions: Doing, Knowing, and Transferring. These dimensions revolve around a central interconnecting factor: GTAs’ Role. Structurally, this interconnecting factor is the one element that holds the model together and without which the experience is no longer ‘what it is’. The centrality of this factor sheds light on the essence of the GTAs experience: They see themselves as central and indispensable; they orchestrate the functioning of the laboratory and without them the experience crumbles, it ceases to be. Another relevant aspect, but inherently difficult to represent graphically, is the time component. In this case, the description of the experience is static in the sense that snapshots taken at different times during the semester-long experience would be mostly indistinguishable. By this we mean that a progression of the nature or qualities of the lived experience did not surface to participants’ awareness when describing it. Interviewees made not explicit or implicit references to changes over the course of the experience. Trajectories of change are associated with opportunities for learning and reflection and we have observed them in non-traditional laboratory programs that challenge GTAs’ beliefs about learning (Sandi-Urena et al., 2011). The core dimensions of the outcome space are discussed separately in the sections below.
Figure 2.1 Phenomenological outcome space

**Doing.** This dimension reflects GTAs’ engagement in a series of actions that are directed at fulfilling their perceived role. Most of the things GTAs do are related to basic chemistry content or technical laboratory procedures. They read the manual, perform the laboratory experiment ‘as students’ the week before their own students perform it, and do their students’ lecture homework. Underlying these actions, is a deeply held premise that ‘*doing is knowing*’. Undoubtedly, GTAs engage in conscientious preparation; however, further analysis reveals that the motivation behind these actions is to master the contents and procedures so that they can provide them as flawlessly as possible to their students and thereby eliminate possible ‘errors’ that may delay the appropriate performance and completion of the laboratory exercise. The following quotes are examples of statements directly related to the purpose of *doing* in this dimension:

> Like when you do that practice lab, you know what to expect from the student’s point of view so if something does happen. You know, they get something that is only supposed to
take 11ml to titrate and its taking 22 mL. If I had that experience or some other TA had that experience, “well did you clean out your burette?” Oh yeah, you know, 20/20 hindsight. (Jaylen)

...you [GTAs] already do the experiment so you will understand or realize...when your student [is] doing the experiment, what kind of difficulty they will meet. Or what kind of result they will have. I mean even the experiment is already designed for some kind of subject, but maybe it has some fault you know. (Hayden)

The GTA becomes a source of information comparable to reading a book chapter whose role is to provide information to the students so that they are not held back by having to ‘figure out’ what to do next:

If they already know what... what’s going to happen, they just come in and... or you can tell them, you know, read this chapter and come in and do it. And, they don’t spend a lot of time sitting there, trying to figure out “what I’m going to do next”. (Dylan)

Clearly, Bailey agrees with this view when referring to their duties as GTAs:

My overall duties, I think, are to make sure that they’re getting, you know, I think is to make sure they’re doing the experiments accurately, make sure the experiments are running on time, get them to learn how to do time management and keep them safe.

The premise that doing is knowing translates into how GTAs view students’ actions and judge students’ understanding based on whether they are doing the experiments “correctly” and “accurately”:

Knowing. The Knowing dimension involves the things GTAs feel they must know in order to be successful in their role in the laboratory environment. The focus of GTAs’ thoughts gravitates around knowing procedural, technical, and conceptual information related to each
week’s experiment. Evidently, this dimension is intimately related to the first one, *Doing*, and sometimes participants’ statements show that relation; we acknowledge the occasional overlap in the meaning behind the quotes. The motivation for knowing this information is the desire to answer students’ questions during the laboratory exercise. Avery explains this in referring to doing the experiments and writing reports pretending to be students before teaching a lab session:

   *And there are numerous questions they can ask. Some students ask such weird questions. They come from different things. So, you [GTAs] need to accumulate all the knowledge and then come for the class, so it is a huge thing. I think it was really good. It was a good process.*

Avery identifies the purpose of their preparation as an opportunity to ‘accumulate’ knowledge that can then be transferred to their students and that is *really good*. There were occasions though where GTAs did not have all the answers and those occasions were seen as a source of frustration, as indicated by Casey: “*For the TA that… that's frustrating, especially for the TA, because I don't know what the answer [is]***”

In many cases, GTAs justify their desire to *know* as a way to overcome students’ lack of understanding. Dylan provides an example of this when he address taking on responsibility of making sure students has the data they need:

   *Also, some... at the end of the lab... making sure that everyone has gotten the data and they've processed it. Because my experience has been that a lot of people, when they leave the lab, don’t necessarily know what to do with what they did. They don’t know... They don’t know how to think about what they did.*
Efficiency is another driving factor in GTAs’ preparation. GTAs feel that if they know of the problems that may arise, they may better assist their students or remove the obstacles altogether, thus allowing for a more efficient laboratory experience:

*I just let them go, and I usually stand off and look and watch and I don’t really interact unless I think something’s going wrong.* (Bailey)

*If you go in to teach the lab, and this group over here that has something that’s not working out and that’s your first experience with that, I think a lot of people would feel anxious or stressed like oh my gosh how are we going to fix this. Where as if you know that that might happen [due to performing the lab as a student], you can be like... I don’t know, its less stressful... maybe warn the kids before they do lab... now don’t do this, do this.* (Jaylen)

**Transferring.** This dimension is representative of GTAs’ interactions with students and what GTAs do with the knowledge previously discussed. This transferring or ‘providing’ is a driving force for what GTAs feel they must do and know as part of their being a GTA. As noted before, GTAs feel it is their responsibility to know all the answers. The instructional interactions represented by this dimension seem to be shaped by the purpose of transferring knowledge. GTAs resort to strategies such as answering questions, demonstrating procedures, creating handouts and even going to the extent of lecturing at the beginning of the lab session:

*... now I try to be really, really thorough about saying everything. And that helps, I think. They... They really kind of need, like, before the lab almost like 30 to an hour... 30 minutes to an hour of really describing what they’re going to do before they do it.* (Dylan)
Having the answer to students’ questions and intervening if problems arise was another common practice:

*If they seem to be having trouble, you know, trying to correct them and show them what to do. Always asking, being there for… If they have questions, they always come up with questions and ask.* (Dylan)

Some GTAs such as Casey seemed to struggle with helping the students as much as possible without actually doing the experiments with or for them:

*they [the students] are supposed to do the experiment, I give them guidance. I… I try to help them as much as I can for their own experience and for my experience to… to step-by-step guide them through, but I’m not doing the experiments with them… for them, you know, that’s what I mean.*

Emerson, a veteran GTA, seemed to have found the solution to the challenge faced by less experienced GTAs. He was comfortable enough with his position to fix where, in his view, the manual fell short and provide the students the information they needed that was not readily available otherwise: “*So I found… I… I have my own little hand-out now… heh… heh… telling them precisely what I would like, that I think is not being conveyed by the lab manual.*” (Emerson)

We must stress that the GTAs were not necessarily trying to cut corners or shortchange the students in any way. Quite the contrary, they demonstrated willingness and desire to help their students the best they could. *Transferring* just happened to be their best way of doing so:

*I like interacting with the students. And… I like to think that I… you know, that I… that I’m sort of helping them along in this, you know not to be cliché but like this journey, or whatever, you know?* (Dylan)
... I tried my level best for my students, to do it the same way [compared to own experience as student]. My professors helped us in everything that we did. If we had a doubt, we went up to them, and they were there to tell us. (Avery)

Evidence for the three emergent dimensions—Doing, Knowing and Transferring—can be found throughout the data for all participants. And as we pointed out, quotes sometimes overlap in serving as evidence for these dimensions. Interestingly, however, we came across a single statement from a participant that in retrospective exemplifies all three dimensions and essentially condenses them into the view of the experience as lived by the GTAs:

_We basically do the entire experiment including the analysis part so that it is easier for us to explain it to the students because there are... there might be a couple of things which we might not... so that... so that everybody [GTAs] knows that looks... this is what we have to do... and it’s good because when I went into the class and I taught my students, I could explain everything to them, it was much easier for me._ (Avery)

**Discussion and Conclusion**

This study documents the experience of chemistry graduate students engaged in laboratory instruction in a General Chemistry program. Deep textual analysis of the interviews led to the construction of an outcome space (Figure 2.1) that describes GTAs’ experience in terms of three fundamental dimensions: Doing, Knowing and Transferring. Overall, from the perspective of the GTAs the experience is consistent with a verification type laboratory (Domin, 1999) where for all practical purposes the students have access in advance to the expected outcomes of the laboratory experience and to the procedures. Furthermore, the experience is centered on contents, procedures and techniques. Our phenomenological approach is aimed at elucidating “the meaning, structure, and essence of the lived experience” (Patton, 2002, p. 482)
and it is not pre-occupied with the designed curriculum or achievement of professed goals. Although it is not our immediate intention to use our methodological approach as an assessment tool, identification of an apparent mismatch in this study suggests its suitability for this kind of purpose: in principle, the designed curriculum was meant to be an inquiry-based experience. Roehrig and collaborators (2003) have reported qualitative evidence of instances in chemistry laboratory instruction were a presumed reformed inquiry-based curriculum defaults mostly to an expository style experience for GTAs and students. These authors identified as probable reasons (a) GTAs’ prior experiences as students, (b) GTAs’ lack of instructional skills to facilitate the learning environment and (c) GTAs’ ill-formed conceptions about learning.

We put forth that in our case, the methodological approach moves us closer to understanding the underlying causes of this occurrence. Through the structural analysis of the experience we suggest that the interconnecting factor without which the experience is no longer ‘what it is’ is precisely the GTA’s perceived role. The conjuncture of the GTA experience is very unique and by no means do we intend to equate it to that of professional teachers. However, we may still borrow some of the understanding of teachers’ development of professional knowledge for teaching. Teachers develop their understanding and knowledge through experience and reflection and drawing from their coursework (Carter, 1990). In teachers’ case, this is a process that evolves over a period of years (including college training) and is supported by skilled mentors and an educational infrastructure. In this study, chemistry graduate students structured their GTA self-image in a very short period of time and with very limited resources from which to draw and typically insufficient support (Stacy, 2000). Their instructional practice in the laboratory did not allow time or adequate opportunities to reflect about their views of themselves as instructors. Constraints in terms of time and resources in face of a daunting task pushed them
to operate on pedagogical emergency mode. Instead of risking a conflict or dilemma that might have triggered their reflecting, they tailored their experience to conform to, and thereby strengthen, their GTA self-image. This is reflected in their “Doing” to achieve “Knowing” of everything to anticipate anything that may create an unexpected situation. “Transferring” through detailed lecturing and direct responses of questions seem to serve the same purpose. In summary, the learning environment is shaped to adjust to the GTA self-image and not necessarily to achieve desirable learning outcomes.

In their central role, the GTAs viewed themselves fundamentally as providers of knowledge (procedural and conceptual) and managers (of grading, time and safety) thereby relegating the potential learners to consumers of knowledge and laboratory clerks responsible for performing the experiments. Interestingly, Hofstein and Lunetta (2004) suggested this detrimental behavior, in their review of the laboratory in science education, when they stated that instructors “spend large portions of laboratory time in managerial functions, not in soliciting and probing ideas or in teaching that challenges students’ ideas” (p. 44).

The learning environment instantiated in this study grants an opportunity for GTAs to enhance content mastery, communication skills and personal satisfaction, all traditional gains (Seymour, 2005). However, it is important to note that teaching labs is not indispensable for content mastery or technique refinement; both could be accomplished in the graduate research experience. Communication skills could be developed in research group meetings or through teaching lecture classes. Therefore, the gains accessible to these GTAs are not exclusive to teaching in a laboratory setting. The experience itself offers few, if any, opportunities for epistemological doubt, a necessary precursor for the adoption of more sophisticated views of knowledge and science (Bendixen, 2002). In fact, the experience may be counterproductive in
this regard (Hammer, 1994). The lived experience of these GTAs reflected little to no sign of cognitive or affective challenges compared to those identified in GTAs who participated in a less traditional learning environment, cooperative problem-based laboratories (Sandi-Urena, Cooper, & Gatlin, 2011a). Perhaps a more cognitively challenging and engaging environment may help GTAs view themselves more as participants in the learning process and less as transfer of knowledge agents and managers of time and safety.

Implications

Calls for laboratory reform are not new; however, the focus of reform efforts is usually the undergraduate students. Chemistry graduate students typically teach labs before they start their own research, and for most future faculty, laboratory teaching is the only form of teaching experience before securing a faculty position. With these facts in mind and the current findings in light of previously reported benefits of less-traditional laboratory teaching (Feldon et al., 2011; French & Russell, 2002; Sandi-Urena, Cooper, & Gatlin, 2011a), it would appear a case can be made that reform is in the best interest of undergraduate students and the graduate students who facilitate the labs. These findings may be a step in that direction and may ultimately inform the reform of laboratory instruction and GTA training.

Although GTAs may base their teaching on their own experiences as students, it may be over-simplistic to think that just presenting them alternate instructional approaches will modify this behavior. This study shows that there is something more entrenched that needs to be addressed and that providing the (pedagogical) knowledge may not be enough. That is, it may not be sufficient to just tell chemistry graduate students what to teach and how to teach it. GTA preparation may need to consider a less surface-level approach and aim at holistically prepare the chemistry graduate student for a responsibility that in principle was not what they signed up for.
when they decided to become scientists. On a larger scale, this view may entail for laboratory instructors and decision makers “rethinking our own views of teaching and learning so that we are better able to serve all the students” and GTAs (Stacy, 2000, p. 77). Additionally, we maintain that this reflecting about the self as instructor is indeed a contributing factor in the journey of becoming a scientist in which students embark when entering their graduate programs. In concluding, we see the role of the GTA as central in the general chemistry laboratory experience but not in the same sense that GTAs in this study viewed themselves. GTAs are essential in that they can promote an environment in which students advance in a trajectory of becoming independent and autonomous learners.
Chapter Three:
Factors Contributing to the Development of Graduate Teaching Assistant
Self-Image

Note to Reader

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Introduction

Chemistry laboratory instruction has been viewed as an integral component of the chemistry curriculum since Liebig’s introduction of the apprenticeship model of student training (Elliott et al., 2008). Perhaps no area in chemistry education has seen as much attention, particularly in the past half century with the appearance of science curricula that emphasize the processes of science and the development of higher order cognitive skills (Meester & Maskill, 1995). In spite of this thriving interest, learning in the college chemistry laboratory continues to be an under-investigated topic (Hilosky et al., 1998; Hofstein, 2004). Certainly, articles addressing the pedagogic value of laboratory instruction and implementation and design of experiences are abundant as are reports of novel laboratory experiments, often dating back to times preceding the creation of this *Journal*. However, in our opinion, this historic interest in laboratory instruction has not effectively translated into comparable educational research endeavors. In 1998, Hilosky, Sutman and Schmuckler stated that “reporting on research related to the impact of laboratory experiences on student learning and attitudes seems minimal in light
of the level of funding” available to advance reform in college chemistry. Moreover, the role of graduate teaching assistants (GTAs) in chemistry laboratory education has too often been completely overlooked in educational research.

The prominent role of GTAs is indisputable, even more so at large research universities where GTAs teach virtually all of the laboratory courses (Herrington & Nakhleh, 2003; Roehrig et al., 2003; Roundtable, and, National Research Council, 2000). Not surprisingly, already in 1994, Lazarowitz and Tamir suggested that GTAs are the most influential factor affecting laboratory instruction, and more recently Herrington and Nakhleh (2003) argued, “that the lack of progress in laboratory teaching is our failure to consider the laboratory instructor” (p. 1197). These assertions constitute a firm argument for more research-oriented studies in this area. Consideration of chemistry GTAs has traditionally revolved around their abilities to perform their responsibilities in compliance with a well-established curriculum or in tune with a given instructional innovation (Birk & Kurtz, 1996; Bond-Robinson & Bernard Rodriques, 2006; Burke et al., 2005; Nurrenbern et al., 1999; Roehrig et al., 2003). That is, an instrumentalist view of the role of GTAs has prevailed, and only rarely, have they been considered actual partners in instruction or has attention been paid to the impact that teaching experiences may have on their professional development. Seldom has “TAing” been actively seen as integral part of chemistry graduate education and often it seems to be reduced to a necessary evil to secure graduate researchers’ financial support (Sandi-Urena, Cooper, & Gatlin, 2011a).

There are some significant exceptions to this approach in the sciences in general. For instance, Seymour and collaborators (2005) have conducted ethnographic studies on science graduates and undergraduates involved in laboratory and small-group facilitation to investigate the benefits of teaching. In 2002, French and Russell posed an intriguing question that has
influenced our prior research: “Can teaching inquiry-based labs complement other activities through which GTAs learn to conduct research?” (p. 1036). By using a pre and post semester questionnaire, French and Russell (2002) provided evidence that the GTAs participating in an inquiry based introductory biology course perceived that facilitating the learning environment contributed to their research abilities. More recently, Feldon et al. (2011) compared written proposals of students holding teaching assistantships and research assistantships and found those who held a TA position showed improved abilities to generate testable hypothesis and design valid experiments. However, a specific focus on benefits available for the chemistry GTA is missing for these studies. Using qualitative methods, Roehrig and collaborators (2003) first approached the task of understanding new chemistry GTAs’ experiences when engaged in inquiry-based instruction. Their discipline-specific findings and insights led to a series of suggestions to address some of the obstacles faced by these GTAs through training and staff meetings. Similarly, other authors have provided descriptions of GTA training at different levels of detail and sometimes in the context of a teaching course linked to the GTA experience (Abraham et al., 1997; Bond-Robinson & Bernard Rodriques, 2006; Brooks et al., 1972; Garland, 1969; L. L. Jones & Liu, 1980; Marbach-Ad et al., 2012; Nurrenbern et al., 1999; Pentecost et al., 2012). Such is the case of Bond-Robinson and Bernard Rodriques (2006) who provided a detailed description of a GTA course based on their Laboratory Teaching Apprenticeship model. Understanding the factors that influence GTAs’ performance as instructors is pivotal in developing their effectiveness in accomplishing the laboratory instruction goals that chemistry educators value and national reports recommend (Singer et al., 2006). As part of a larger research program, we have conducted phenomenological studies to explore the lived experiences of two groups of GTAs engaged in instruction in two substantially different
General Chemistry programs: one inquiry-based (Sandi-Urena, Cooper, & Gatlin, 2011a), the other expository (Sandi-Urena & Gatlin, 2012). The students’ experiences in these two environments have been studied as well (Sandi-Urena, Cooper, Gatlin, & Bhattacharyya, 2011b). This prior work shed light on the essence of the GTA experience in each program and the nature of gains and benefits available to the GTAs. Moreover, from these studies, the construction of a self-image as instructor and its impact on the learning environment emerged as an influential factor in GTAs’ experience. The research described here derives from this prior work, and its purpose is to investigate how graduate students in two independent and very different learning environments constructed their GTA self-image and what factors were associated with this process.

Method

Study design and context. We chose an embedded multiple case design to gain understanding of the processes associated with GTAs’ construction of their self-image as instructors and the factors influencing these processes. Case study is a qualitative tradition that has gained increased use since the 1980s (Merriam, 2009). Our selection of case study was guided by the stance that case studies are the “preferred strategy when “how” and “why” questions are being posed, when the investigator has little control over event, and when the focus is on a contemporary phenomenon within some real-life context” (Yin, 1984). In an embedded multiple case study, researchers conduct independent case studies and make comparisons within each case and across the cases.

The cases in this study are the experiences of GTAs in two diverse General Chemistry Laboratory programs at two research-intensive US universities in the Southeast. By defining the cases in this manner, the units of analysis are the GTAs within each case. In our view, the
multiple-case approach is justified given the significant differences in the instructional context of each program. Based on common criteria to classify laboratory experiences (Domin, 1999), the first program can be described as traditional, deductive, and verification based, hereafter referred as the *expository* program. In the expository program, students worked in groups to complete weekly experiments and individually completed weekly reports (For a detailed description see Sandi-Urena & Gatlin, 2012). Using the same classification scheme (Domin, 1999), the second program would be classified as *inquiry*. In this program, students worked cooperatively on multi-week projects, and each project was followed by either a laboratory report or group presentation (For a detailed description see Sandi-Urena, Cooper, & Gatlin, 2011a).

**Data collection.** Primary data collection for both cases used a semi-structured interview protocol divided into three main parts. GTAs were given the opportunity to describe their prior experience as a general chemistry student, their perceptions of their current students’ experiences, and finally, their experience teaching in the laboratory. Interviews were conducted with eleven GTAs with teaching experience ranging from one to four semesters in the expository program. Thirteen GTAs participated from the inquiry program after their first semester teaching in the program. Table 3.1 provides characteristics of the GTA participants. All interviews were conducted either by one, or by both, of the co-authors. Interviews lasted approximately one hour, were audio-recorded and later transcribed and cataloged with pseudonyms.

Interviews with the laboratory coordinators focused on the coordinators’ goals for laboratory instruction, GTA training and typical GTA duties. These interviews helped clarify references that GTAs made to features of their training.

In addition to these interviews, laboratory manuals, course syllabi, GTA training materials and interviewer memos were collected for each case (Table 3.1). These materials were
used to supplement information that was not clear during the original interviews (e.g. a reference to a specific lab project).

Table 3.1

<table>
<thead>
<tr>
<th>Participants Demographics, a</th>
<th>Expository Program, N = 11 b</th>
<th>Inquiry Program, N = 13 b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Domestic</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Prior teaching experience</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

Note: a) These participants’ ages ranged form 20s to early 30s. b) These data sources were used: interviews (GTAs and lab coordinators), interview memos, laboratory manual, course syllabus.

**Data analysis.** Data analysis followed the explanation-building strategy described by Yin (1984; 2009). This strategy involves comparing findings of an initial case to theoretical propositions, revising the propositions, if needed, and checking the evidence of the case against the revised propositions. The revised propositions can then be checked with the facts of multiple cases, repeating the steps as necessary. The use of multiple cases also allows for cross-case analysis – comparing and contrasting evidence across the individual cases. Figure 3.1 presents the sequence we followed during data analysis. These steps are described in the following paragraphs.

Figure 3.1 Data analysis scheme
In accord with case study methodology, we developed a set of propositions to guide our research. In the process, we considered propositions related to advisors’ influence, personal interests, departmental culture, and other similarly relevant domains. However, we decided to keep only those propositions that fell directly within the impact range of the lab experience. These propositions were based both on our own prior studies and on literature:

Proposition 1: GTAs teaching performance is associated with the way they see themselves as instructors, that is their GTA self-image (Sandi-Urena & Gatlin, 2012; Sandi-Urena, Cooper, & Gatlin, 2011a).

Proposition 2: In the absence of any other factor, GTAs will base the construction of their GTA self-image on their perception and interpretation of prior experiences (Roehrig et al., 2003).

Proposition 3: Training and staff meetings influence GTAs’ construction of their self-image (Bond-Robinson & Bernard Rodriques, 2006; Herrington & Nakhleh, 2003; Roehrig et al., 2003).

Testing against these propositions involved multiple steps (Figure 3.1). First, we generated a narrative of each GTA’s experience. A sample narrative is provided in Appendix C. Next, we selectively coded each interview, based on our propositions, looking for instances in the interviews that related to GTAs’ self-image, prior experiences, and training. Analysis of the narratives and coding results were checked against the propositions using a pattern-matching strategy (Yin, 2009). This involves identifying what evidence would look like if the proposition were true versus if the proposition were false. For example, evidence may suggest ‘mentors’ implement mentoring strategies or suggest ‘mentors’ implement strategies consistent with a different self-image. At this stage, the initial propositions can be expanded in depth and number.
to account for any emerging evidence. All propositions were checked again against the case evidence before moving on to the analysis of the second case, the inquiry based program. For the second case, we replicated the analysis procedures used for the first case except the selective coding included items related to the revised propositions. After the completion of the second case, we carried out a cross-case analysis by contrasting and comparing the individual case findings. The cross-case analysis helped us refine the model presented in the findings. A discussion of findings from each case and the cross-case analysis follow.

**Findings and Discussion**

The model presented in Figure 3.2 condenses findings from the cross-case analysis and addresses our revised propositions.

![Diagram of Factors associated with GTA self-image development](image)

Figure 3.2 Factors associated with GTA self-image development

In this model, there is a recursive interaction between the learning environment and the GTA self-image. Although at first, the learning environment is shaped by the way that the graduate students perceive themselves as instructors (GTA self-image) the learning environment
may influence this perception by either reinforcing it or by creating a conflict that may lead to re-evaluation of that self-image. This potential conflict may occur at different levels, e.g. cognitive, affective, or epistemological. The model suggests that there is an interaction between the learning environment and GTA self-image that spans from a static confirmation of GTAs’ initial stance to a dynamic and continuous informing of each other. Two components of the model are consistent with and support Propositions 2 and 3, which were initially drawn from literature: GTAs’ prior experiences as students and their current training and staff meetings. Emerging evidence allowed us to put forth a mechanism through which the initial propositions may exert influence on GTAs’ self-image and practice. Our model postulates that their impact derives from their influence on GTAs’ beliefs about the nature of knowledge (Proposition 4) and GTA’s beliefs about the nature of the academic laboratory (Proposition 5).

We have chosen to first present this model and subsequently detail aspects related to its components along with quotes that support its construction. In the following paragraphs, we substantiate our final propositions by case. Although differences across the cases will be apparent, it is important to emphasize that the model captures features that are independent of the valence each factor may take for the individual cases. It is also important to note that we are not making claims related to GTAs’ effectiveness in their perceived roles. Rather, we focused on how they viewed themselves as GTAs and components associated with those views.

**Proposition 1: GTAs’ teaching performance is associated with the way they see themselves as instructors, that is, their GTA self-image.** GTAs in the expository program viewed themselves as providers of knowledge and managers of time and safety (Sandi-Urena & Gatlin, 2012). The interactions they described with their students were a reflection of this perception of themselves. For example, Avery in relation to her self-image as a provider
discussed giving explanations to the students: “I went into the class and I taught my students, I could explain everything to them, it was much easier for me.” Similarly, Dylan describes providing an abundance of information to the students:

\[
I \text{ try to be really, really thorough about saying everything. And that helps, I think. They really kind of need, like, before the lab almost like 30 to an hour of really describing what they’re going to do before they do it.}
\]

Avery, and Dylan’s actions of explaining everything and telling students what they were going to do before they did it, even though it was not a strategy promoted in GTA training, was consistent with their self-image as providers. Elaine even classified her role as the “inter|preter of the laboratory manual”.

GTAs from the inquiry-based program viewed themselves as mentors and facilitators (Sandi-Urena, Cooper, & Gatlin, 2011a), and these views were reflected in their reported teaching. Reflecting her image as a mentor and facilitator, Ursa chose to guide students through problem-solving behaviors:

\[
...you \text{ don’t tell them the answer but kind of make them think, then you know they are actually problem solving during the lab, all the time pretty much. And also they need to think about it, so they need to reflect upon their answers because I told them, you know...}
\]

Similarly, Larry described the mentoring process that occurred when his students faced difficulties in the laboratory: “You know, making sure that when someone is stressing out...[I, say:] ‘Sit down, stop, what are you stressed out about?’ If you are stressed out you don’t learn anything.”
Guiding students through problems and modeling problem solving behaviors were staples of these GTAs’ practices, and these practices were associated with their views of mentoring and facilitating learning.

Through cross-case analysis and the previous studies (Sandi-Urena & Gatlin, 2012; Sandi-Urena, Cooper, & Gatlin, 2011a), we see that GTAs in these programs viewed themselves differently. However, the relevance is that in both cases the way GTAs viewed themselves was related to their reported practice.

**Proposition 2: In the absence of any other factors, GTAs will base the construction of their GTA self-image on their perception and interpretation of prior experiences.** GTAs in the expository program frequently compared their current experience with that of their prior lab instructors and used them as models of appropriate pedagogy. Perhaps the clearest example Avery’s comment:

*I tried my level best for my students, to do it the same way [as my professors]. My professors helped us in everything that we did. If we had a doubt, we went up to them, and they were there to tell us.*

GTAs in the inquiry-based program reported on the notable differences between what they were being asked to do and the actions of their previous laboratory instructors. They were also aware that their previous laboratory experiences differed from the ones they provided for their students. In line with the other GTAs from this case, Naomi described the differences in the following way:

*...the students are more active...they have to think a lot, that is something that I didn’t have during the experiments [as a student], I didn’t have to understand everything [...] as I told you, I could have answered the questions about the lab at the beginning without*
having to do the experiment but in this case they have to actually go through the experiment to actually be able to answer the questions.

All of the GTAs in the inquiry-based program experienced expository type laboratories as students, and they were unable to rely on their prior lab instructors as an acceptable model for their teaching performance. Rather, they were likely to include prior mentors, such as research advisors, as models for behavior: “…you basically are trying to mimic, I’d say when I sit down with my professor and say ‘how can we solve this problem’.” (Nate)

We envision this proposition as a manifestation of what Lortie (2002) described in teacher education as the notion of “apprenticeship of observation”. For many, this term condenses the idea that as product of having experienced instruction as students, individuals are prone to teach the way that they were taught. This default option is intuitive and imitative and it generates the false sense of expertise that many discipline-based science educators will promptly agree abounds in our departments. In this study, GTAs called upon different exemplars to base their image and practices, and although these images were not always based on how they were taught they were grounded in their prior experiences.

**Proposition 3: Training and staff meetings influence GTAs’ construction of their self-image.** GTAs in the expository lab viewed their training, particularly completing the experiments before their students, as serving function for their managerial and providing roles:

*Like when you do that practice lab, you know what to expect from the student’s point of view. So if something does happen, you know, they get something that is only supposed to take 11ml to titrate and it’s taking 22 mL...If I had that experience or some other TA had that experience, “well did you clean out your burette?” Oh yeah, you know, 20/20 hindsight (Jaylen)*
You [GTAs] do the experiment so you will understand or realize...when your student [is] doing the experiment, what kind of difficulty they will meet. Or what kind of result they will have. (Hayden)

Through these quotes, GTAs imply they would know what obstacles may arise and could attempt to prevent them, or at least have an answer ready to provide to the students. Interestingly, this was not the purpose of the training activities as described by the laboratory coordinator. The coordinator expected GTAs to use their knowledge of the projects to help students think through their problems. Yet, that design was not enacted as training and staff meetings were interpreted by GTAs as ways to gain knowledge that could later be transferred to the students.

GTAs in the inquiry case discussed their training and staff meetings in a manner consistent with their mentoring image. The inquiry GTAs were not required to perform the labs before they facilitated them for the students; however specific project procedural aspects were addressed during weekly meetings. The main difference was in how GTAs viewed and used that information. They used the information as a guide and starting point to consider how they could get students to think: “Every time I go...before the lab, I thought about it for a few minutes, you know, what kind of questions I could ask to make them think” (Ursa). Time spent planning carried over into the laboratory as GTAs sought to guide their students through the thought processes.

The nature of the training was different across the cases and the specifics of the training programs have been previously reported (Sandi-Urena & Gatlin, 2012; Sandi-Urena, Cooper, & Gatlin, 2011a). The importance here is that across the cases there was an association between the perceived nature of the training activities and the way the GTAs view themselves as instructors.
Similar associations have been noted with college science faculty (Hutchins & Friedrichsen, 2012) and pre-service science teachers (Pilitsis & Duncan, 2012).

**Proposition 4: GTAs’ beliefs about the nature of knowledge are associated with their construction of their self-image.** Emerging evidence from the expository case, led us to propose beliefs about the nature of knowledge were associated with GTAs’ self-image. GTAs in this case exhibited naive views of knowledge insofar as related to instruction (Sandi-Urena & Gatlin, 2012). For example, Avery, whose earlier quote addressed “explaining everything” to her students, described the need to accumulate knowledge:

> And there are numerous questions they can ask. Some students ask such weird questions, they come from different things. So, you need to accumulate all the knowledge and then come for the class, so it is a huge thing. I think it was really good. It was a good process.

Conceptions of accumulating knowledge to later transfer to students were central features to these GTAs’ experience. These beliefs in the certainty of knowledge and dualistic and authoritarian ways of knowing corresponded with their self-image as providers and managers. Training and teaching events were interpreted as reinforcement of their prior beliefs.

Evidence for GTAs in the inquiry-based program was consistent with more “sophisticated” views of knowledge (Baxter Magolda, 2004). GTAs focused on students’ understanding, and they viewed students as having an active role in meaning making. For example, Ben stated:

> ...they [students] have more ideas, maybe someone can come with something they didn’t think about, they can go with that kind of things, working in groups, understanding that research or science is not like a cookbook that, you know, oh this is expected to happen
but we did it in the lab and it didn’t happen, so why didn’t it happen, that kind of reasoning should help them, I think.

Likewise, Frank stated:

*You know, cooperative lab is, it’s very good, you know, like knowledge is not put in one person’s head, ok. We all have different experiences based on where we have been before...*

Inquiry GTAs often experienced epistemic conflicts and reflected on their prior beliefs (Sandi-Urena, Cooper, & Gatlin, 2011a), which together serve as precursors for the adoption of more sophisticated beliefs (Bendixen, 2002). They perceived leading an environment that recognized “different perspectives” and the construction of knowledge as a challenging task that often conflicted with their prior experiences. One GTA described it as being “dropped into boiling water.” This difficult process of confronting preconceived beliefs promoted reflection that may have contributed to their adoption of mentoring and facilitating self-images (Sandi-Urena, Cooper, & Gatlin, 2011a).

GTAs from each case held different views of knowledge in relation to laboratory instruction. However, these differences were associated with their self-image and described practices thus underscoring the importance of attending to GTAs beliefs about the nature of knowledge. Interestingly, students in both programs worked in groups, yet, GTAs perceived this “teamwork” as serving different functions. The expository GTAs viewed teamwork as a way to conserve resources whereas the inquiry GTAs viewed teamwork as a way to promote understanding of concepts and problem-solving skills.

**Proposition 5:** GTAs’ beliefs about the nature of the academic laboratory are associated with their construction of their self-image. GTAs from the expository program
viewed the laboratory as a place for students to apply learned concepts and verify known theories. Elaine explained that although each lab session involves different concepts or equipment the nature of all labs is the same:

*I hope they take away, basically, how to get through a lab class. And I don’t mean that in a... in a performing sense so much as... You know, I try to tell them all the labs are the same. You start out with a theory, you try to test it, and that at the end you... you let ‘em know if... if your data matches the theory. Sure, you have to learn different concepts, you have to learn different equipment, but, you know, between that and safety and protocol, it’s... it’s... every lab class is the same.*

Elaine’s comment was aligned with other expository GTAs who saw the purpose of the general chemistry laboratory as preparing students for future laboratory classes through technical competence. For example, when asked if students could learn to think through problems in the lab, Dylan was “not sure they knew enough” or “had enough tools.” When prompted on the tools, he responded, “How to be in a lab, what to do, how to measure, or...do whatever, you know.” Later he reaffirmed that “working in a lab, insofar as, you know, how to use certain basic tools” as the primary goal for laboratory instruction. GTAs placed less emphasis on conceptual development or meaningful learning. They viewed the lab as a place for students to “see” concepts already learned and to develop technical skills.

GTAs in the inquiry program viewed the laboratory as a setting to develop problem solving and scientific skills: “Well, problem solving skills is the best way [...] for such a collection of students, so that is what science is about, being critical, ask[ing] questions to solve a problem” (Frida). They recognized variation and ambiguity in experimental methods and viewed lab experiences as having multiple pathways and outcomes:
I don’t know what it is but it is the general fear that they [students] have to be accurate.

That chemistry is an exact science, and it’s not. And…once my students realized that chemistry is not an exact science and nothing in chemistry is exact that it can always be varied … (Naomi).

Finally, the inquiry GTAs were concerned more with the processes of learning and experimentation than they were with final answers or products: “Reassuring that we are not really worried about right or wrong answers because I reassured them so many times…Not the product but the process…”(Ursa).

Apparently, the behavior of GTAs was tied to the nature of the tasks they were facilitating. Parsons (2008) observed a similar effect although in elementary literacy teachers. In this case, evidence indicated that teachers implementing challenging, open tasks adapted their instruction in more thoughtful ways than teachers limited to closed tasks such as worksheets. In our two cases, GTAs’ beliefs of the nature of the laboratory were associated with their self-image and the tasks they were facilitating.

Conclusions

In summary, the five propositions supported by this multi-case study provided evidence that GTAs’ construction of their self-image is associated with several factors: prior experiences, training, beliefs about the nature of knowledge and laboratory work, and teaching experiences. Across the two cases, we observed vastly different GTA self-images. However, we do not believe GTAs entered their respective programs with such diverse views. Rather, the differences may be attributed to the presence, or lack thereof, of conceptual, epistemological and affective conflicts and to the ways GTAs framed their training and teaching experience.
Bendixen (2002) proposed epistemic doubt—the process of doubting one’s beliefs about knowledge and knowing (Hofer & Pintrich, 1997)—as a precursor to development of more sophisticated beliefs about knowledge. Epistemic doubt may be triggered by, but not limited to, exposure to differences, independence, and beliefs not matching with experiences and is often experienced and evident as frustration, confusion and feelings of not knowing (Bendixen, 2002). We postulate that the intense differences between the inquiry GTAs’ prior experiences and what they were being asked to do likely resulted in greater instances of epistemic doubt. Likewise, GTAs’ experiences in the expository program may have reaffirmed and strengthened their prior beliefs of knowledge, teaching and learning thus leading towards counter-productive epistemologies (Hammer & Elby, 2002).

Another reason GTAs exhibited such different views is likely a result of how they framed what they were being asked to do. Framing is the ongoing process of interpreting, “what is it that’s going on here” (Goffman, 1974), and a frame is “a set of expectations an individual has about the situation in which she finds herself that affect what she notices and how she thinks about it” (Hammer, Elby, Scherr, & Redish, 2005). These expectations are based on organized prior experiences and are activated when one recognizes “new situations as being similar to previous, familiar, situations” (Berland & Hammer, 2011). GTAs in the expository program recognized what they were being asked to do as similar to their prior laboratory experiences. However, GTAs in the inquiry program recognized differences between their teaching experiences and their laboratories as students. They began to frame their teaching experience from the reference of mentors and advisors. Because of the need to adopt new frames, they likely experienced more epistemological and affective conflicts related to their teaching and had greater opportunity for development.
Limitations

This study used a strictly purposeful sampling approach to choose the two cases investigated. A relevant aspect of the selection was that these cases were exemplars of quite different instructional approaches and, as such, they might shed light about principles applicable to a broad spectrum of lab settings. Nevertheless, findings must be interpreted in the context of small, purposeful samples, and assumptions about transferability must be judged carefully. We ascribe to the stance that treats findings from case studies as propositions for future use and testing rather than as definite generalizable claims (Patton, 2002). We invite readers to consider extrapolations of our findings to similar conditions and to test their applicability. As part of our own research program we intend to extend our approach to include additional laboratory programs.

The design of this study honed in on the graduate students’ lived experience as GTAs. Consequently, the only data collection point occurred after one semester of participating in instruction. We realized that this retrospective approach might have limited our understanding of the factors that influence development of GTA self-image; therefore, in a follow-up study, we gathered information from new cohorts of GTAs before the teaching appointment started and after the completion of the semester. Through the ongoing analysis of these data we aim at elucidating changes experienced by individual GTAs in the factors that we postulate influence their self-image development. It is worth reiterating here that we limited consideration of propositions to those that fell directly within the impact range of the lab experience. That is, we excluded, for instance, those linked to interactions with research advisors and departmental culture and norms. In our view, such highly specific idiosyncratic aspects may render findings less transferable.
Implications for Laboratory Instruction

In this report, we argue that GTAs’ self-image is associated with their instructional decision-making and thereby the nature of their students’ laboratory experience and learning. We contend that regardless of how crystallized it may appear to be, this self-image is susceptible to transformation. The model that we present describes factors that may catalyze this transformation in order to accomplish specific goals of laboratory instruction (Bruck et al., 2012; Singer et al., 2006) and to support graduate student professional development (Loshbaugh, Laursen, & Thiry, n.d.; Roundtable et al., 2000). Instruction is a complex process, and we do not intend to provide a prescriptive model to conduct GTA training. However, we believe this model may prompt laboratory coordinators to reconsider GTA participation in instruction in a new and different light, and to look at training and support from a new angle. In this model, the fidelity of implementation of the learning environment is influenced by the GTA self-image, which in turn is shaped by GTAs’ beliefs about the nature of knowledge and their beliefs about the nature of laboratory instruction. Instead of focusing exclusively on what and how to teach, GTA training and support programs may target these two factors in a way that is conducive to a self-image in accord with the specific instructional objectives. For example, how GTAs’ incoming beliefs may hinder or facilitate what they are asked to do could become a focal point of training programs (Goertzen, Scherr, & Elby, 2010b; Smith & Southerland, 2007). To this end, a laboratory coordinator may, for instance, survey graduate students’ beliefs about the purpose of academic laboratories. If their responses strongly point at technical competence and verification of lecture concepts as fundamental, training can be designed to address potential conflicts with the goals of the designed laboratory. Evidently, this is more relevant when implementing reform-based instruction (Luft et al., 2004; Roehrig et al., 2003; Seymour, 2005; Smith & Southerland, 2007;
S. A. Southerland, Sowell, Blanchard, & Granger, 2011). Laboratory coordinators may succeed in guiding GTAs’ behavior by telling them how to teach and by closely monitoring them. However, as Goertzen and collaborators (2010b) exemplified, “helping TAs learn to ask questions will not necessarily help them share [...] motives for questioning”. One may think of this as adding a new dimension to GTA training, why to teach, that may assist laboratory coordinators to find ways to help GTAs engage more fruitfully in facilitating laboratory instruction.

In addition, GTA training programs rarely consider the impact that teaching has on GTAs. This model calls specific attention to the recursive interaction of GTAs’ self-image and their experiences in the laboratory environment. If indeed “the lack of progress in laboratory teaching is our failure to consider the laboratory instructor” (Herrington & Nakhleh, 2003), this holistic picture of GTA self-image development may be a step forward in shifting attention to the most influential factor affecting laboratory instruction, the GTA (Lazarowitz & Tamir, 1994). We hope the present research contributes in placing this aspect at the forefront of general chemistry laboratory instructional design.
Chapter Four

Case study of two graduate teaching assistants’ self-images before and after teaching in a cooperative problem-based chemistry laboratory

Introduction

Graduate teaching assistants (GTAs) play a prominent role in tertiary chemistry education. At large research institutions in the US, GTAs are involved in most undergraduate laboratory courses. In a survey sponsored by the American Chemical Society (2002), 93% of respondents held a GTA position at some point during their graduate studies and 60% taught exclusively in laboratory settings. In 2012, a presidential task force of The American Chemical Society recommended that departments continue the practice of funding first year graduate students through teaching assistantships (American Chemical Society, 2012). Therefore, the prevalence of GTAs in tertiary chemistry laboratory instruction is likely to continue.

With continued emphasis on laboratory reform (Hofstein & Kind, 2012; Seymour, 2005), the role of the teaching assistant has arguably become more important. Already in 1988(b), Pickering argued laboratory reform was held back by a lack of consideration for GTAs. As goals for laboratory education have shifted towards aspects of scientific inquiry, GTAs roles have become more demanding (Seymour 2005). For example, Seymour (2005) found that GTAs working in inquiry programs had to troubleshoot curriculum design elements and consult with coordinators about what was or was not working. The GTAs were also important to the fidelity of implementation of each of the reforms. Seymour (2005) postulated that as GTAs gained familiarity with the reforms there would not be as many design issues to consult upon thus some
aspects of the GTAs roles may shift. However, even as reforms take shape over time, involvement in inquiry-based instruction would seem to require more of GTAs than is required by involvement in expository programs. Inquiry-based GTAs are asked to take on new and different roles such as leading discussions (Obenland, Kincaid, and Hutchinson, 2014), facilitating writing-to-learn strategies (Burke et al., 2005), mentoring and coaching students (Cooper, 2011), or leading novel research (Szteinberg and Weaver, 2012).

It is understandable that as GTAs roles have shifted, the nature of training and preparation for GTAs should have as well. However, Roehrig et al. (2003) noted that little consideration was given to preparing GTAs for this type of instruction. Although it has been over ten years since the observation by Roehrig et al. (2003), laboratory reforms are still being undertaken without careful consideration the role of the GTA. For example, Obenland et al. (2014), reported a redesign of their laboratory program in which the main reform was the addition of “weekly, separately scheduled times for teaching assistant-moderated student discussion of concepts, analysis of data, and reflection on the laboratory” (p. A). Structurally, the teaching assistants’ role in that program was changed. Further, the success of the program rested on the GTAs ability to moderate discussions. Unfortunately, the authors did not mention anything about how they prepared teaching assistants their new roles. It seems highly unlikely that the authors would make major reforms without preparing their teaching assistants in some fashion, but for whatever reason it was not viewed as a relevant part of the redesign to include in the publication. By omitting a discussion on the GTAs, it makes it appear as if they are inconsequential to the laboratory design.

Indeed, even when considered and described, preparing GTAs for inquiry-based assignments has not been an easy task. In chemistry and other science disciplines, GTAs are
often not adequately prepared for their roles as facilitators in inquiry-based laboratories (Brennan, 2011; Goertzen, Scherr, & Elby, 2009; Luft et al., 2004; Nurrenbern et al., 1999; Volkmann & Zgagacz, 2004). Luft et al. (2004) argued that in some cases, this is due to the lack of any formal training or support program. In other cases, GTAs have undermined reform efforts by increasing direct instruction and other traditional teacher-centered practices (Brennan, 2011; Goertzen et al., 2009; Nurrenbern et al., 1999; Volkmann & Zgagacz, 2004). It is possible that GTAs deviate from the designed curriculum in order to make up for what they perceive to be shortcomings of inquiry programs. For example, GTAs may believe general chemistry students are not capable of designing procedures, and thus they provide procedures for the students.

Unfortunately, years since GTAs’ experiences were called into attention, research has made little progress in considering the role and experiences of GTAs in chemistry laboratory settings (Sandi-Urena, Cooper, & Gatlin, 2011a). Groscuh (2012) argued that the lack of research on GTAs’ experiences has lead to training programs based on “good practices” while theory remains in the background, if at all. Although she was speaking about teaching assistants across disciplines, the same could be said specifically for chemistry.

In fact, literature on chemistry GTAs tends to view them as instruments of instruction. They are “trained” to do something onto students more or less the same way pH meters in the General Chemistry lab are calibrated to produce reliable readings. This instrumentalist approach to GTAs views them in terms of the undergraduates they teach. This view is often present even in the research studies focused on GTAs. For example, when describing their research objectives Bond-Robinson and Bernard Rodriques (2006) stated,

the final component is to assess the underlying goal of GTAs gaining understanding, which is the undergraduates’ learning—Do the UGs [undergraduates] of these GTAs
actually learn to understand chemistry at a deeper level as a result of GTAs’ gain in pedagogical chemical knowledge?

This objective highlights a characteristic shared by much literature regarding GTAs in chemistry. GTAs’ gains and benefits were viewed and analyzed from the perspective of how the benefits would help the undergraduates they teach. To be fair, the authors were focused on pedagogical knowledge, and it is understandable that gains in such knowledge should also impact the students. However, it highlights that research involving graduate students is usually focused on undergraduates’ learning of chemistry.

Rarely is research undertaken to ask how teaching experiences might benefit graduate students in their development as scientists. While it is important to consider undergraduate students’ learning of chemistry, it is just as important to consider what graduate students learn or gain from their teaching experiences that would help them in their careers as chemists. In other words, research should be undertaken to determine what impact teaching laboratory courses has on graduate students’ development as scientists. Research that focuses on what GTAs learn or gain from their teaching experiences should ultimately lead to better undergraduate laboratory experiences. In addition, it has the potential to be transformative in relation to graduate education in the chemical sciences since over 90% of chemistry graduate students teach at some point in their graduate studies (American Chemical Society, 2012). Although teaching assistantships remain largely viewed as time away from research, further research could provide clarity to the purpose and function of teaching assistantships in chemistry graduate education.

There are some exceptions to the instrumentalist view of GTAs in related fields. In 2002, French and Russell posed an intriguing question in biology education that has influenced this work, “Do Graduate Teaching Assistants Benefit from Teaching Inquiry-Based Laboratories?”
Based on self-report data, they concluded that teaching in inquiry-based laboratories impacts graduate students’ research abilities. More recently, Feldon et al. (2011) reported that teaching experiences of STEM graduate students improved their methodological skills as assessed in written research proposals. These studies shared a common focus with this dissertation; GTAs are recognized active learners during their teaching experiences, and interest rested in learning gains related to the graduate students becoming scientists not teachers.

We agreed with Pickering’s (1988b) assertion that failure to consider GTAs has held laboratory reform back. In addition, we contended that failure to consider GTAs’ experiences has held graduate education in the chemical sciences back. Along those lines, we undertook a research program studying GTAs’ experiences in diverse laboratory formats (Sandi-Urena & Gatlin, 2012; Sandi-Urena, Cooper, & Gatlin, 2011a). Our premise was that to determine the gains and benefits available to GTAs we must first understand what they experience. To this end, we documented that teaching experiences in an inquiry-based environment can support GTAs’ metacognitive engagement and epistemological reflection (Sandi-Urena, Cooper, & Gatlin, 2011a). On the other hand, in an expository laboratory environment, we found GTAs’ experiences to be counterproductive to the consideration of more complex conceptions of the nature of chemistry (Sandi-Urena & Gatlin, 2012). Metacognitive engagement and epistemological reflection have been linked to scientific development (Hunter et al., 2007), and each is viewed as a relevant component of quality graduate education (Baxter Magolda, 1996, Baxter Magolda 1998). Therefore, the previous research findings underscored the importance of focusing on GTAs’ experiences and questioning the impact these experiences have for the GTAs.

Recently, we focused on chemistry graduate students’ construction of GTA self-images in General Chemistry laboratory teaching (Sandi-Urena & Gatlin, 2013). The GTA Self-image
refers to how a graduate student views himself or herself as teaching assistants within the laboratory setting. In general, self-images are thought to influence behavior and are shaped by experiences within the relevant context (Shavelson, Hubner, & Stanton, 1976). Our initial conjecture was that graduate students who develop a GTA self-image that is not consistent with the requirements and objectives of their laboratory programs face obstacles in facilitating learning. In our view, this may explain why some GTAs in reformed environments default to implement traditional teacher-centered strategies. Unfortunately, this creates a vicious cycle since they do not get to experience the context that could help them snap out of their counterproductive self-image. By the same token, a self-image aligned with the laboratory program design may maximize fidelity of implementation of the lab approach by individual GTAs. These considerations sparked our interest in the factors that may influence GTA self-image development. In our previous study (Sandi-Urena & Gatlin, 2013), we proposed that the GTA self-images of two cohorts exposed to different laboratory formats were associated with: (a) prior experiences, (b) training, (c) beliefs about the nature of knowledge and the nature of academic laboratory work, and (d) involvement in the laboratory setting (Figure 3.2, p 41). This work allowed us to propose a model that condenses the factors that influence GTA self-image construction in General Chemistry GTAs. Although these factors were common in both cases, findings suggested different patterns for how each GTA cohort viewed themselves as teaching assistants at the end of their first semester appointment. That is, despite the commonalities in the process of self-image construction, the outcomes—the self-images—were dependent on group membership. Supported by our model, we postulated that differences in GTAs’ self-image were related to involvement in different laboratory environments (expository and cooperative problem-based). Nonetheless, since data were not collected before the GTAs entered their
respective programs, the transformative nature of their GTA experience was not substantiated and thus the differences in their self-images could have been pre-existing. Therefore, the present study was initiated to respond to the corollary of the prior work.

The initial goal of this study was to compare the incoming beliefs about learning in the lab and the nature of knowledge held by an incoming cohort of chemistry graduate students with their GTA self-images at the end of their first appointment in a problem-based laboratory program. As is common in qualitative inquiry, immersion in data collection and analysis led towards different, emerging research goals (Bodner, 2004). In this work, an evident occurrence of an extreme case (Patton, 2002), a GTA that exhibited very little change, led to the exploration of its similarities and differences with a representative case. The representative case was a GTA that adopted a self-image in alignment with the laboratory program. Therefore, this work sought to illustrate two divergent GTA self-image constructions in response to the same cooperative, problem-based laboratory program.

**GTA Self-Image Model**

In this section, factors of the GTA self-image model (Figure 3.2, p 41) are described. The GTA Self-image model was derived from empirical data, and it served as the analytical framework for this study. Further information about the origin of the model can be found in Chapter 3.

**GTA self-image.** We define GTA self-image as the way graduate students view themselves in their role as teaching assistants within the laboratory setting. In teacher education, images, have been considered “a means of representing how individual teachers view themselves in their teaching context and how this influences the way they teach” (Johnston, 1992). Teachers’ images are often shaped by prior experiences as students and
influence their teaching practices (Calderhead & Robson, 1991; Southerland & Gess Newsome, 1999). It should be noted though that teachers’ prior experiences as students typically include coursework in pedagogy and student teaching practice. Chemistry GTAs usually have not participated in such courses before they begin teaching in laboratory settings. They are not professional teachers, and they have not received formal training. Also, most chemistry graduate students have not made the choice to become a teaching assistant; it is a funding method for their graduate studies. Therefore, teacher education literature should not be considered to completely transfer to the GTA context.

**Beliefs about the nature of knowledge.** GTAs’ beliefs about knowledge, learning and instruction fall within this factor (Baxter Magolda, 1992; 2004). These beliefs are commonly referred to as *epistemological beliefs* (Baxter Magolda, 2004; Schommer-Aikins, 2004). For this component, we draw from Baxter Magolda’s (1992; 1996; 2004) epistemological reflection model since she tracked students throughout graduate school and their early careers.

GTAs’ beliefs about the nature of knowledge were associated with their self-image in previous work (Sandi-Urena & Gatlin, 2013). Further, epistemological development has been linked with identity formation (Baxter Magolda, 1998) and the journey of becoming a scientist (Hunter, Laursen, & Seymour, 2007). Consistent with Baxter Magolda’s (1992) methodology, our work explores GTAs’ beliefs about the role of instructors, students, and peers in the learning process to provide access to their beliefs about the nature of knowledge in chemistry.

**Beliefs about the nature of the laboratory.** This factor represents GTAs’ beliefs about what should happen in an academic laboratory and why it should happen. Their goals for laboratory instruction are included within this factor as well. Understandably, beliefs in this
factor may be related to GTAs’ general conceptions about the nature of knowledge and learning in chemistry. However, the unique context of laboratory instruction is not always included in discussions of teaching and learning because discussions are often based on lecture environments. Therefore, this factor can be viewed as domain specific epistemological (Muis, Bendixen, & Haerle, 2006). As such, it adds an extra component that may not otherwise be evident in a discussion of teaching and learning chemistry. Reid and Shah’s (2007) discussion of laboratory goals provide a suitable topography for discussion of GTAs’ beliefs about the purpose and nature of laboratory work. They proposed that laboratory goals could be presented under four categories: skills related to learning chemistry, practical skills, scientific skills, and general skills (Reid & Shah, 2007).

**Prior experiences.** In the GTA self-image model, this factor refers to the GTAs prior experiences in laboratory settings. Most entering graduate students have not taught before in any setting. Therefore, their prior experiences usually are based upon the laboratory classes they had as students. In the absence of training or support, new GTAs will attempt to teach as they were taught. Likewise, when new to laboratory teaching, GTAs will initially form a self-image in relation to their previous laboratory instructors. Prior experiences also influence GTAs’ beliefs about the nature of knowledge and the nature of laboratory work.

**GTA training and support.** This factor refers to any training and support GTAs received in preparation for their teaching assignment. GTA training and support are often designed to teach GTAs what and how to teach. Activities are designed to result in certain behaviors in the laboratory. The GTA self-image model highlights that the training and support will be interpreted through the GTAs beliefs and self-image. For this specific study, the GTA training and support that was provided is described in detail below.
Methods

In order to illustrate two GTAs’ construction of their self-images, we chose a multiple case-study design. Yin (2009) supports the use of case studies when researchers have little control over the behavior of the participants and when the context of the phenomenon is relevant to the study. Each of these considerations was important for the current study thus case study methods were deemed the most applicable. Furthermore, case study methods have a documented history of being useful in studies in chemistry and science education that investigated changes in aspects of teachers’ beliefs or conceptions (Brickhouse & Bodner, 1992; Cronin-Jones, 1991; Markic & Eilks, 2008; Smith & Southerland, 2007; Southerland & Gess Newsome, 1999; Volkmann & Zagacaz, 2004).

In this multiple case study, each GTA was a single case. Defining a case as one GTA allowed us to explore the self-image of each GTA and to compare and contrast across GTAs. We bound our study by both time and place (Creswell, 2012). Since this study was derived from previous work (Sandi-Urena, Cooper, & Gatlin, 2011a), we chose the same research setting for this study. We bond the case study to the first semester the graduate students were on campus. This allowed us to capture the graduate students initial views before they had been introduced to the laboratory program or received any training or support. Limiting the study to this time frame also restricted potential effects of graduate research experience on GTAs’ self-image since graduate students in this program began research during their second semester.

Setting. This study took place in the General Chemistry Laboratory program at a mid-size research-intensive university in the United States of America. The General Chemistry program serves approximately 1500 students per semester and employs over 20 chemistry GTAs to facilitate laboratory instruction. GTAs are trained and supervised by an instructional staff
member with ten years of experience in the program. Other than the laboratory coordinator, no faculty or staff members worked directly with the GTAs in regards to their teaching responsibilities. Each GTA was assigned to teach three laboratory sections with 20 to 24 students each. Each laboratory section was scheduled to meet once a week for three hours. Students earned one credit for the laboratory course and were enrolled consecutively with the General Chemical lecture course.

The laboratory format followed a cooperative, project-based instructional approach (Cooper, 2011) that has been in place since 1994. A description of the laboratory program was previously published (Cooper, 1994). Further, experiences of students and GTAs in the laboratory environment were studied and reported elsewhere (Sandi-Urena, Cooper, & Gatlin, 2011a; Sandi-Urena, Cooper, Gatlin, & Bhattacharyya, 2011b). The cooperative portion of the designed laboratory draws from cooperative learning literature (Johnson and Johnson, 1991). The design of the laboratory “exposes students to the process of scientific problem solving, emphasizes collaborative work, and requires the students to communicate their results both orally and in writing” (Cooper, 1994, p 307).

As stated before, graduate students at this institution started their GTA assignment during their first semester of graduate school. Two weeks before the semester began, all incoming graduate students attended a GTA orientation and training. GTAs performed several activities to become acquainted with the cooperative problem-based format and expectations of the laboratory program. Orientation activities are discussed below. After the initial orientation, GTAs attended weekly staff meetings led by the laboratory coordinator. Staff meetings took place in a shared office space. Whether they were teaching General Chemistry Laboratories or not, all first-year graduate students had access to the office. Many students routinely worked
from there on their GTA duties or coursework. Students were expected to have office space within their adviser’s laboratory starting in the second semester. However, experienced GTAs continued to attend the weekly staff meeting in the shared office. The weekly meetings presented a forum to discuss project specific tasks and broad strategies to successfully function within the laboratory format.

GTAs were expected to act as coaches, facilitators and mentors, by providing advice to students on the adequacy of their plans without telling students what and how to do it. In addition to duties related to the weekly in-class facilitation of the laboratory session, GTAs were also responsible for assessing students’ written and oral reports and assess weekly planning questions and procedures.

Students worked in groups of four throughout the semester. Students started each project from a problem-based scenario and a few guiding questions; procedures were not provided in the manual. Each group engaged in an array of problem-solving activities in order to meet the goals of the project. Students routinely analyzed the problems, set goals, planned strategies, designed and implemented experiments, and discussed and analyzed processes and outcomes. The laboratory design prompted students to actively engage in the process of doing science rather than reproduce the conclusions of science.

**GTA orientation.** Two weeks before the semester began new GTAs had a two-day orientation program for the general chemistry laboratories. During this orientation, GTAs met each other and the laboratory coordinator. Through the orientation, GTAs were exposed to the laboratory philosophy and the duties that would be expected of them. The orientation was led by the laboratory coordinator and assisted by one returning mentor GTA. Three activities, a modeling activity, a team reflection activity, and an expectation activity that took place during
the GTA orientation are discussed in detail below. In addition to these three activities, the new GTA orientation also covered laboratory safety, chemical hygiene, familiarization with the laboratory rooms and stockroom procedures, and other procedural aspects of the teaching assignment.

The first orientation activity, after general introductions, was a GTA modeling activity. In this activity, the returning GTA modeled the expected GTAs role. This activity took place in one of the laboratory rooms. When the new GTAs arrived the mentor GTA arranged them into groups and carried out many of the activities that would normally take place on the first day of a laboratory course. The new GTAs observed how the model GTA would act with students. They were also encouraged to consider what they would be doing on their first day. They were encouraged to jot down any ideas, comments, questions or recommendations that arose during the activity.

Embedded within the GTA modeling activity was an open-ended estimation problem. At one point, the model GTA assigned the new GTAs an open-ended estimation problem. The mentor GTA asked the new GTAs to work in groups to determine the number of tennis balls that would fit within the room. After a designated time, the groups of new GTAs wrote their answers on the board, and then a member of each group shared their process for solving the problem. After each group presented their answers, a discussion led by the mentor GTA and laboratory coordinator introduced the cooperative and problem-based nature of the laboratory program. The discussion drew parallels between GTAs’ initial confusion with their problem, working together, and their need to defend their methods with what would be expected of their students. Essentially, the problem-solving process that the GTAs engaged in was the same as what the students would face within the program, although with a different context and content.
This estimation problem served multiple purposes. First, it specifically modeled what they were going to ask their students to do. On their first day of teaching, each GTA would ask their students to complete a similar estimation problem. Second, it allowed the new GTAs to experience what it would be like for the students to go through the problem-solving process. It was hoped that by having this experience, GTAs would have both knowledge of the cooperative, problem-solving process and be able to relay expectations to the students. The non-chemistry nature of the activity was chosen to place the new GTAs into a situation that was similar to the confusion and frustration their future students would experience upon beginning their chemistry projects. Due to the GTAs’ background in chemistry, presenting them with one of the general chemistry laboratory projects may not have created the confusion or frustration that is involved in solving problems. Thus, using a chemistry project may not have served to introduce the cooperative and problem-solving components of the laboratory format.

The GTA modeling activity ended with a question and answer section. During this time, the mentor GTA and laboratory coordinator addressed many of the questions and comments that had been recorded by the new GTAs. Anonymously, the GTAs turned in sheets with their questions and comments. These written questions and comments covered a range of topics. Some were procedural and asked about the frequency of notebook checks, how to access the course management system or how to arrange student groups. Other comments were affective in nature. For example, GTAs stated they felt less nervous and more comfortable, and they stated that going through the modeling activity would help them anticipate and plan what they should do within their classes.

The next activity was a team reflection designed to get GTAs to think about their beliefs about laboratory teaching. Each group was presented with a list of 15 prompts related to
laboratory instruction. The prompts included short sentences or fragments such as “ask students questions or wait for students to find the TA and ask questions”; “group work promotes thinking or group work means less work for each member”; and “lecturing in the lab, is it good”. Each group was asked to choose three prompts and discuss them. Then, they told the rest of the GTAs one of the prompts they chose and described what they discussed. A record of the GTAs’ discussion was not collected as part of this research.

The discussion from the team reflection led to the last activity that focused on expectations of GTAs. Each group was asked to create a list of expectations that differentiated their upcoming roles as GTAs from the role of GTAs in a traditional laboratory format. Each group was asked to present and discuss the expectation they believed to be most relevant. Finally, they were told that their list of expectations would be compiled, possibly augmented, and returned to them to be signed as recognition that they understood their role and expectations as a teaching assistant.

Participants. This work focused on two first-year chemistry graduate teaching assistants whom will be referred to as Shea and Lyle. Purposeful sampling (Patton, 2002) was used to choose two participants that illustrated variation in regards to their GTA self-image after the end of one semester teaching within the cooperative problem-based labs. Shea was chosen as typical-case (Patton, 2002). Her post-teaching self-image fit the pattern found in prior studies (Sandi-Urena and Gatlin 2012, Sandi-Urena and Gatlin 2013). The second case, Lyle, was chosen as an extreme or unique case (Patton, 2002). Lyle was considered an extreme case because his GTA self-image did not change over the course of the semester. Further, his post-teaching self-image was divergent from Shea and other GTAs involved in the prior research that taught within the same context (Sandi-Urena and Gatlin, 2013). According to Patton (2002), “the logic of extreme
group sampling is that extreme cases may be information-rich cases precisely because by being unusual, they can illuminate both the unusual and the typical” (p. 234). Taken together, the typical and extreme cases of Shea and Lyle were chosen to illustrate the complexities of GTA self-image construction. Further background characteristic for both Shea and Lyle are presented in the Findings and Discussion section.

Each case was chosen from a pool of five first-year graduate students that participated in all aspects of data collection. More information on participant selection is provided in the data analysis section. Seven other graduate students initially volunteered to participate. However, they were excluded from consideration, because they were either moved to teaching organic labs, not assigned to teach due to a low score on an English speaking test, or not available for a post-teaching interview. Only the two GTAs chosen for this case study will be discussed further.

**Data collection.** Consistent with case study methodology (Yin, 2009), we gathered multiple sources of data to help clarify each case. Pre- and post-semester interviews served as the primary source of information to explore GTAs’ self-image and beliefs about the nature of knowledge and nature of the laboratory, as well as to inquire about their prior educational experiences. The interviews also shed light on the GTAs’ teaching experience during the semester. Surveys served as a source of secondary information on GTAs’ beliefs, and they provided access to information about GTAs’ prior laboratory experiences. These surveys also served to triangulate portions of the interviews (Patton, 2002; Yin, 2009). Checking for congruence between the interviews and surveys provided an extra layer of validation to the primary data source, the interviews. For example, GTAs’ description of the laboratory experience in the interview was triangulated with their responses on the survey that regarded prior lab experience. Finally, we collected additional data that served a supporting role during
analysis. Access to the laboratory manual, course syllabus, and communication with the laboratory coordinator allowed us to understand the context of the projects that GTAs discussed during the interviews. The GTA orientation schedule was discussed with the laboratory coordinator, and some artifacts, such as discussion prompts, from the GTA orientation, were collected to provide insight into the orientation. The design of interviews and surveys are discussed below.

Data collection was separated into two main time points, pre-teaching and post-teaching (Figure 4.1). Interviews were used during both time points, and a survey was administered during the pre-teaching phase. Pre-teaching data was collected over a two-day period, two weeks before the start of the semester. This time frame allowed us to interview GTAs before they were introduced to the laboratory program. In the morning, on the first day of data collection, GTAs completed the pre-teaching survey. The survey was administered after GTAs completed an entrance exam required by the department. The entrance exam was not part of this research; the department used it to gage if students were ready to take certain graduate level courses. Pre-teaching interviews began during the afternoon of day one, and continued during day two. Post-teaching interviews were conducted over a two-day period. These interviews took place during the second week of the GTAs’ second semester.

Figure 4.1: Relative timeline of data collection and GTA orientation and teaching
**Interviews.** Pre-teaching interviews followed a semi-structured protocol and focused on four topics: (1) GTAs’ experience as general chemistry laboratory students, (2) prior teaching experiences, if any, (3) expectations of the upcoming teaching experience, and (4) what and how students should learn in a general chemistry laboratory. Post-teaching interviews focused on three topics: (1) GTA perspective of students’ experiences, (2) GTAs’ teaching experience, and (3) what and how students should learn in a general chemistry laboratory. The interview guides were based on the interview guides used in previous work (Sandi-Urena and Gatlin 2012, Sandi-Urena and Gatlin 2013). The post-teaching interviews followed the same guide used in the previous studies. The pre-teaching interview guide was modified from the previous studies. Prompts that referred to GTAs’ experiences were changed to refer to GTAs’ expectations about the upcoming teaching experiences. Both pre- and post-interview guides are included in the Appendix D and Appendix E respectively.

Although topics were structured in a general interview guide, a conversational strategy was used during the interview process (Patton, 2002). Each GTA was asked questions from each semi-structure topic, but the conversational nature allowed GTAs the freedom to openly explore their expectations or experiences. Thus, the order topics were covered depended upon the nature of the each GTA’s conversation. This combination of the semi-structure interview guide and a conversational structure provided an effective means to access data on GTAs’ self-images.

One of the researchers conducted all interviews. The interviews lasted approximately one hour each, and they were digitally recorded and transcribed verbatim.

**Surveys.** The pre-teaching survey consisted of 55 items arranged in two parts (Appendix F). Part I contained twenty-nine items that probed the GTAs’ views of teaching and learning in the chemistry laboratory. For example, one item read, “laboratory students learn best when given
well-detailed procedures.” Each item was rated on a five-point Likert scale ranging from Strongly Agree to Strongly Disagree. Part II contained twenty-six items designed to gather descriptive information about the GTAs’ prior experiences as chemistry laboratory students. Items one through eleven in Part II required a yes or no response. For example, one item read, “the experimental procedures were known before the lab session (from the manual or given by the instructor).” Items twelve through twenty-six were rated on a five-point Likert scale ranging from Strongly Agree to Strongly Disagree. These items covered a range of topics about the goals and benefits of their laboratory experience. For example, one item read, “I developed critical thinking skills.” Both parts of the survey were administered in one session.

**Data analysis.** Data analysis was performed in four stages: (1) selection of cases (2) analysis of the pre-teaching self-image for each case, (3) analysis of the post-teaching self-image for each case and comparison with the pre-teaching self-image, and (4) a cross-case analysis.

The first stage of data analysis resulted in the selection of the cases. Interviews and surveys were used during this stage. This stage amounted to preliminary data analysis, and it began before post-teaching interviews were conducted. Memos and notes were recorded after each pre-teaching interview. Before the post-teaching interviews, the notes were read, and the pre-teaching interviews were listened to again. The survey responses were reviewed. This preliminary analysis provided an initial sense of each GTAs self-image. During the post-teaching interview memos and notes were recorded. After the post-teaching interviews, each recording was listened to again.

Interestingly, it was during this stage that the focus of this research shifted. In the initial plan, all five GTAs’ cases would have been considered in this research and a brief overview of the changes that each GTAs self-image underwent were to be analyzed and discussed. However,
during this preliminary analysis one GTA, Lyle appeared to have not adopted a self-image in alignment with the laboratory program. Due to the emergence of this extreme case, the research focus shifted towards providing and in-depth illustration of the similarities and differences in the self-image construction of two GTAs. Lyle was chosen as the extreme case since the preliminary analysis suggested his case would illustrate the GTA self-image construction of a GTA who had not adopted a self-image compatible with the design of the program. Shea was chosen as a typical case since the preliminary analysis suggested her GTA self-image changed in accordance with the laboratory program and resembled the self-images exhibited by GTAs in the same context in the prior study (Sandi-Urena and Gatlin 2013). Further, as discussed below, her pre-teaching beliefs appeared to be the most representative of how new teaching assistants have been described in previously literature (Nyquist and Spraque, 1998).

The second stage of data analysis focused on each of the two chosen GTAs’ pre-teaching self-image. The survey results were treated qualitatively. A short narrative was written based on the GTAs’ responses and appended to the interview transcript for analysis. The qualitative analysis followed an interview analysis scheme posed by Seidman (1991). First, each transcript was read and read again to gain a sense of each GTA’s story. During the second reading, passages were marked and labeled when the passage spoke to a factor relevant for this study. Next, the marked passages were read while asking, “what do these statements say about the GTA’s self-image, beliefs about knowledge and beliefs about laboratory work,” respectively. This process led to a set of assertions that described each GTA’s pre-teaching self-image and beliefs about the nature of laboratory work and the nature of knowledge.

Stage three of data analysis focused on each of the two GTAs post-teaching self-image. The initial steps in this stage mirrored those from stage two: reading the transcripts, labeling and
coding passages. Once the interview was coded, the data was compared to the original pre-teaching assertions. If the post-teaching data supported the pre-teaching assertion, it was concluded that there was no evidence of change. However, if the post-teaching data did not support the initial propositions, the recursive process of generating assertions and rechecking them against the data was continued. The process led to a set of assertions that described each GTAs’ post-teaching self-image and beliefs about the nature of knowledge and the nature of laboratory work. Comparison of the pre-teaching and post-teaching assertions led to the description of changes in each GTA’s self-image.

The fourth and final stage of analysis involved conducting a cross-case analysis (Patton, 2002; Yin, 2009). Cross-case analysis involves comparing and contrasting findings from both cases. The guiding questions during this stage of the study were how do Shea’s and Lyle’s cases compare to each other and taken together, what do these cases illustrate about GTA self-image construction. This involved comparing the case findings for each GTA looking for similarities and differences in their self-image constructions to provide further insight into GTA self-image construction. Findings from both cases, which are presented below, were analyzed in reference to the other. Changes or lack thereof, in each GTA’s self-image and associated factors, were explored in reference to the GTA self-image model that served as the framework for this work.

**Role of the Researchers**

Two researchers were involved in aspects of data collection and analysis. Within the research setting for this study, the researchers were outside researchers with an insider perspective. At the time of the study, a separate university employed both researchers involved in the study. Neither researcher was directly involved with implementation or oversight of the laboratory program or participants under study. However, both researchers had previous
Participants knew that each researcher had prior experience within the program. They also knew that a report of their expectations for teaching and training would be shared with the laboratory coordinator, and they knew their responses would be used within this research. Participants were informed that their names would not be attached to specific comments or data in the report to the coordinator or future research manuscripts.

**Findings and Discussion**

**Shea’s and Lyle’s pre-teaching background.** Shea was a first-year chemistry graduate student. She entered graduate school directly after completing her Bachelor’s degree in chemistry from a US university, she had no prior teaching experience, and her undergraduate general chemistry laboratory followed a traditional weekly, expository format. “Expository” is how Domin (1999) classified laboratory programs where the procedures are given, the outcomes are predetermined and the students’ approach is deductive. This format is often referred to as “cookbook” as you can perform the experiments in order without questioning the design. Shea’s background characteristics are provided next to Lyle’s background characteristics in Table 4.1.

Lyle was a first-year graduate student with prior experiences as a teaching assistant in laboratory settings. Lyle completed a Bachelor’s degree in Chemistry. He entered graduate school directly after his undergraduate studies. Lyle had prior experience as a teaching assistant in laboratory courses including General Chemistry and a discussion setting. The General Chemistry program at his undergraduate institution followed the traditional approach of using weekly experiments and providing students with detailed procedures.
Neither Shea nor Lyle had prior professional teaching experience. Likewise, neither of them had taken courses in education. This was important for their selection as cases, as most chemistry GTAs do not have a background in education prior to beginning their graduate studies. Therefore, the cases in this chapter include a teaching assistant completely new to laboratory teaching, Shea, and a teaching assistant entering a new program with a vastly different format from his prior experiences, Lyle.

Table 4.1

Background characteristics for each case

<table>
<thead>
<tr>
<th>Context</th>
<th>Shea</th>
<th>Lyle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest Degree</td>
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<td>B.S. in Chemistry</td>
</tr>
<tr>
<td>Degree granting institution</td>
<td>Master’s Colleges and Universities (larger programs)</td>
<td>Master’s Colleges and Universities (larger programs)</td>
</tr>
<tr>
<td>classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior Laboratory Experience</td>
<td>Expository, Cookbook</td>
<td>Expository, Cookbook</td>
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<tr>
<td>as Gen. Chem. Students</td>
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<td></td>
</tr>
<tr>
<td>Prior Teaching Assistant</td>
<td>None</td>
<td>4 Semesters</td>
</tr>
<tr>
<td>Experience</td>
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<td></td>
</tr>
<tr>
<td>Prior Teaching Experience</td>
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<td>None</td>
</tr>
<tr>
<td>Prior Education Courses</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

Shea and Lyle’s responses to part II of the pre-survey (Table 4.2, see page 78), suggest the design of their prior general chemistry laboratories shared many common features. In fact, they only responded to three items on different sides of the disagree to agree Likert scale. Shea’s laboratory course had a final written exam (item 6), included aspects of data manipulation (item 13) and emphasized correctly learning techniques (item 22). Lyle reported that his laboratory did
not include those aspects. Both of their laboratory courses followed traditional setups where students completed weekly experiments and were provided with detailed procedures. They were responsible for completing individual laboratory reports each week. Interestingly, neither Shea nor Lyle reported that their laboratory helped them understand the process of scientific research (item 23) or made them more excited about learning Chemistry (item 24).

The similarities in the structure of Shea’s and Lyle’s prior general chemistry labs were a relevant factor in selecting them as cases. Most teaching assistants entering an inquiry-based teaching assignment have not experienced that format as a student in the laboratory (Sandi-Urena and Gatlin 2012; Seymour, 2005). Therefore, Shea and Lyle’s background in expository laboratory formats is most likely transferable to many GTAs in other contexts.

Shea was concerned and nervous about her upcoming GTA duties. She stated, “I have like zero experience…I’m kind of nervous about it, but I feel like the labs are an easier setting than if I was TAing a lecture-type course.” Her concerns focused on aspects that Nyquist and Spraque (1998) refer to as self and survival concerns. These types of concerns focus more so on the teacher than on students or students’ learning. Shea was concerned primarily with how she would perform in the laboratory. For example, she discussed in the pre-teaching interview that she hoped to be able to answer students’ questions. She had some reservations about how students would perceive her, especially if she had difficulty responding to the questions. Fuller (1969) referred to these concerns as related to beginning teachers responding to the prompt “how adequate am I?” and revolving around abilities to “understand subject matter, to know the answers, to say, ‘I don’t know’… among other things.”
Table 4.2

Pre-Survey Part II: Prior Laboratory Experiences

<table>
<thead>
<tr>
<th>Number*</th>
<th>Item</th>
<th>Shea</th>
<th>Lyle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>My laboratory section was only for chemistry and/or biochemistry</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>majors.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>The laboratory objectives for the experiments were known beforehand</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>(from the lab manual or given by the instructor).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>The experimental procedures were known before the lab session (from</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>the manual or given by the instructor)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>The experiments were completed in one lab session</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>There was a practical end-of-course laboratory exam</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>There was a theory/written end-of-course laboratory exam</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>Work was done individually or in pairs</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>The reports were written individually</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>The reports were weekly and due the week after the experiment was</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>performed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>The instructor/teaching assistant lectured at the beginning of the</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>lab session</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>The procedure was discussed at the beginning of the lab session</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>12</td>
<td>Experiments were focused on verifying well-established knowledge,</td>
<td>Agree</td>
<td>Agree</td>
</tr>
<tr>
<td></td>
<td>for example determining the molecular weight (molar mass) of a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>compound, or some thermodynamic constant.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Data manipulation (calculations) and interpretation were discussed</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td></td>
<td>previous to the experiment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Discussion with other students during the experiments was common</td>
<td>Agree</td>
<td>Neutral</td>
</tr>
<tr>
<td>15</td>
<td>There were quizzes to assess students’ preparation and/or</td>
<td>Agree</td>
<td>Strongly</td>
</tr>
<tr>
<td></td>
<td>understanding of the experiment</td>
<td></td>
<td>Agree</td>
</tr>
<tr>
<td>16</td>
<td>Students were encouraged to develop or modify their experimental</td>
<td>Disagree</td>
<td>Disagree</td>
</tr>
<tr>
<td></td>
<td>procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Achieving the established goal counted for an important portion of</td>
<td>Agree</td>
<td>Agree</td>
</tr>
<tr>
<td></td>
<td>the experiment grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Accuracy in achieving the established goal was a measure of success</td>
<td>Agree</td>
<td>Strongly</td>
</tr>
<tr>
<td></td>
<td>in the lab experience</td>
<td></td>
<td>Agree</td>
</tr>
<tr>
<td>19</td>
<td>There were activities aimed at enhancing communication skills</td>
<td>Disagree</td>
<td>Strongly</td>
</tr>
<tr>
<td></td>
<td>(posters, presentations, talks, group discussions, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>The instructor was expected to give clear straight answers to student</td>
<td>Neutral</td>
<td>Agree</td>
</tr>
<tr>
<td></td>
<td>questions (even if s/he failed to do so)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>When asked a question, the instructor was expected to make students</td>
<td>Agree</td>
<td>Neutral</td>
</tr>
<tr>
<td></td>
<td>think through the problem to find the answer (even if s/he failed to</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>do so)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Emphasis was placed on correctly learning the laboratory techniques</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>23</td>
<td>The laboratory teaching methodology helped me understand the</td>
<td>Agree</td>
<td>Strongly</td>
</tr>
<tr>
<td></td>
<td>process of scientific research</td>
<td></td>
<td>Agree</td>
</tr>
<tr>
<td>24</td>
<td>The laboratory format made me more excited about majoring in</td>
<td>Disagree</td>
<td>Strongly</td>
</tr>
<tr>
<td></td>
<td>chemistry</td>
<td></td>
<td>Agree</td>
</tr>
<tr>
<td>25</td>
<td>I developed critical thinking skills in the lab</td>
<td>Disagree</td>
<td>Neutral</td>
</tr>
<tr>
<td>26</td>
<td>I developed problem-solving skills</td>
<td>Agree</td>
<td>Agree</td>
</tr>
</tbody>
</table>

*Note: Items that Shea and Lyle responded on different sides of the agree to disagree scale are bold.
Lyle did not describe being nervous about his upcoming teaching experiences. Lyle was very confident that he would be able to fill the role of a teaching assistant adequately. He did not receive training in his prior teaching assistantships. He figured he would not need much assistance with being a GTA within this new program. He mentioned that in his prior positions, for which he received no prior training and little support, he attempted to teach the way he was taught: “I mean, I just based whatever I did on whatever I saw the people that I had for those classes do previously.” He figured that GTAs new to teaching within this program would also base their teaching on their prior teachers: “I would assume that the other students would do that here.” Lyle had not considered that there might be ongoing meetings, need for support, or formal teaching training.

Based on part I of the pre-survey (Table 4.3), Shea and Lyle held different beliefs on the value of social interactions and group work and the nature of knowledge. Based upon their responses to items 6, 17 and 26, Shea valued group work more so than Lyle. Further, Lyle’s responses to items that related to the nature of knowledge suggest that he held an absolute view of knowledge (items 23, 24, 25). For Lyle, knowledge was either right or wrong, and he believed students should find the correct answers in the laboratory.

These survey results did not drive the selection of the cases. However, they did validate the selection of Lyle as the most absolute minded incoming GTA. Further, the responses represent prior experiences and incoming beliefs. In reference to the GTA self-image model, understanding these incoming beliefs is useful for providing explanations for the similarities and differences found in the changes or lack thereof in Shea’s and Lyle’s self-images.
<table>
<thead>
<tr>
<th>Number*</th>
<th>Item</th>
<th>Shea</th>
<th>Lyle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I consider teaching laboratories relevant for my professional development</td>
<td>Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>2</td>
<td>Learning and practicing of lab techniques (like titrations and filtration)</td>
<td>Very Important</td>
<td>Very Important</td>
</tr>
<tr>
<td>3</td>
<td>Enhancement of problem solving skills</td>
<td>Very Important</td>
<td>Very Important</td>
</tr>
<tr>
<td>4</td>
<td>Development of skills to design and implement lab procedures</td>
<td>Moderately Important</td>
<td>Moderately Important</td>
</tr>
<tr>
<td>5</td>
<td>Strengthening of communication skills</td>
<td>Very Important</td>
<td>Very Important</td>
</tr>
<tr>
<td>6</td>
<td>Development of group-work skills</td>
<td>Very Important</td>
<td>Unimportant</td>
</tr>
<tr>
<td>7</td>
<td>Verification of fundamental chemical concepts</td>
<td>Very Important</td>
<td>Very Important</td>
</tr>
<tr>
<td>8</td>
<td>Learning safety in the chemistry environment</td>
<td>Very Important</td>
<td>Unimportant</td>
</tr>
<tr>
<td>9</td>
<td>Reinforcing the concepts learnt in lecture Laboratory students learn best when…(prompt for items 10-17)</td>
<td>Very Important</td>
<td>Very Important</td>
</tr>
<tr>
<td>10</td>
<td>…well-detailed procedures are given to them</td>
<td>Disagree</td>
<td>Agree</td>
</tr>
<tr>
<td>11</td>
<td>…instructors find an effective way to transfer what they know to students</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>12</td>
<td>…they know the expected outcome of the experiments</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>13</td>
<td>…they have to devise and implement the experimental procedure</td>
<td>Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>14</td>
<td>…the instructor gives examples of calculations before the experiment</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>15</td>
<td>…they are allowed to create their own knowledge as they progress through an experiment</td>
<td>Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>16</td>
<td>…they are first demonstrated the experiment/procedure by the instructor (either with the actual instruments or with diagrams or animations) before performing it</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>17</td>
<td>…they discuss amongst themselves and try to find their own solution to their questions or problems</td>
<td>Strongly Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>18</td>
<td>A General Chemistry Laboratory course is necessary only for majors that require higher-level chemistry courses (biochemistry, analytical, organic, etc.)</td>
<td>Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>19</td>
<td>It is unrealistic to expect students to figure out things in lab unless they have already covered the topics in lecture.</td>
<td>Strongly Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>20</td>
<td>Effective teaching occurs when instructors help students to carefully and accurately follow procedural instructions</td>
<td>Agree</td>
<td>Neutral</td>
</tr>
<tr>
<td>21</td>
<td>It is the role of lab instruction to acquaint students with scientific experimental/research practices</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>22</td>
<td>Knowledge is already existing, it is verified through experiments but cannot be created by students during lab activities</td>
<td>Disagree</td>
<td>Agree</td>
</tr>
<tr>
<td>23</td>
<td>Knowledge is either right or wrong</td>
<td>Strongly Agree</td>
<td>Agree</td>
</tr>
<tr>
<td>24</td>
<td>Accuracy of results is a good indicator of student’s understanding of the lab</td>
<td>Disagree</td>
<td>Disagree</td>
</tr>
<tr>
<td>25</td>
<td>It is important that a student or group get the expected results; otherwise, they may get the wrong impression about scientific processes.</td>
<td>Disagree</td>
<td>Agree</td>
</tr>
<tr>
<td>26</td>
<td>Group work promotes laziness in students who like to rely on others doing the work for them</td>
<td>Disagree</td>
<td>Agree</td>
</tr>
</tbody>
</table>

*Note: Items that Shea and Lyle responded on different sides of the agree to disagree scale are bolded.*
Shea’s pre-teaching GTA self-image. As detailed in the methods section, we made assertions about Shea’s pre-teaching GTA self-image and beliefs about the nature of knowledge and the nature of the laboratory based upon the evidence found in her pre-teaching narrative. Since Shea is new to teaching, her pre-teaching self-image is attributed to the qualities she associates with being a teaching assistant. Our assertions are placed in italics within the text and listed in Table 4.4. The post-teaching assertions presented in Table 4.4 are discussed in a later section. Each assertion is numbered to assist in future comparisons. For example 1.i (initial) is an assertion about Shea’s pre-teaching self-image while 1.f (final) is an assertion about Shea’s post-teaching self-image.

Table 4.4

Assertions about Shea’s pre- and post-teaching self-image and related factors

<table>
<thead>
<tr>
<th>Factor*</th>
<th>Pre-Teaching Assertions</th>
<th>Post-Teaching Assertions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-image</td>
<td>1.i Shea holds a self-image as manager and provider of knowledge.</td>
<td>1.f Shea holds a self-image as a guide and mentor.</td>
</tr>
<tr>
<td>Nature of Knowledge</td>
<td>2.i Shea believes students obtain knowledge from GTAs and by ‘doing.’</td>
<td>2.f Shea views students as providing active exchanges and sharing views.</td>
</tr>
<tr>
<td>Nature of Laboratory</td>
<td>3.i Shea envisions students as physically active.</td>
<td>3.f Shea values physical and mental activity.</td>
</tr>
<tr>
<td>Nature of Laboratory</td>
<td>4.i Shea believes the purpose of general chemistry laboratories is to prepare students for future laboratory courses.</td>
<td>4.f Shea believes the general chemistry laboratory prepares students for future problems.</td>
</tr>
<tr>
<td>Nature of Laboratory</td>
<td>5.i Shea values practical skills as the most important student outcome.</td>
<td>5.f Shea values practical skills, scientific skills, general skills, and content knowledge.</td>
</tr>
</tbody>
</table>

*Factors derived from the GTA self-image model (Sandi-Urena & Gatlin, 2013).

Shea holds a GTA self-image as a manager and provider of knowledge (1.i). Shea emphasized a few times that she should be “available” for students “to answer any questions they
may have.” Further, Shea felt each class would start with her introducing a lab concept while the students had their manual in front of them. Students could either get information from the manual, or they would get it from her as she wrote it on the board. Either way, she stressed, “hopefully I will be able to cover everything that they will have to do before they start. If it’s showing them where the equipment is or setting it up, what procedures to do.”

Shea assumed the students would have more questions if she did not cover everything in the beginning. She also thought providing everything would keep students from “fidgeting with not knowing what to do” and losing time. It would be her responsibility to set “the pace for the lab” and let students “know exactly what they need to do so that they aren’t lost or anything.”

Consistent with her image of herself as a manager and provider of knowledge, Shea planned to be the one who would make the decisions about what students should do. Students would follow instructions from her or the laboratory manual. Evidently, Shea’s views of herself as an instructor are related to how she views students, and are also reflective of the teaching assistants she had in prior experiences.

*Shea believes students obtain knowledge from teachers and by ‘doing’ (2.i) and Shea envisions students as physically active (3.i).* Shea summed up her thoughts on how students learn best in the laboratory by saying, “by doing, by having an objective and knowing the key things that they have to do to get to the objective, and doing it.” Students, in her view, will learn by doing what they know they have to do.

While research supports having clear goals for what students should accomplish in laboratory settings (Singer et al., 2006), Shea’s goals were limited primarily to practical skills. Her emphasis was on providing students with clear laboratory procedures. In essence, Shea equated learning in the laboratory with performing in the laboratory.
Focusing on the physical aspects of what students are doing is a common occurrence in laboratory instruction across school levels (Abrahams, 2011; Abrahams & Reiss, 2012; Calderhead & Robson, 1991; S. Southerland & Gess Newsome, 1999). Abrahams (2011) claimed that the majority of laboratory work is hands-on, but minds off. By this he meant that students could generally follow directions without the need to think critically about what they were doing. Likewise, Domin (2007) suggested that conceptual development within an expository laboratory program happens largely outside of the laboratory. Shea described her prior laboratory experience as a student similarly, and likewise, Shea described physical actions of students but did not discuss aspects of students’ thinking or conceptual development.

Shea believes the purpose of the General Chemistry Laboratory is to prepare students for future laboratory courses (4.i), and Shea values practical skills as the most important student outcome (5.i). Shea wanted students to learn “how to perform a lab” and to keep good notes and to always clean up after themselves because they are sharing a lab space with other people.” She added that “how to perform a lab” meant “setting up a hypothesis, making sure you have all your reagents and stuff prepared, making sure you’re all set so that you’re not going to make any random errors, and making sure you know how to conclude the lab.”

Shea felt this “awareness of a basic skill”—“how to perform a lab”—would help students prepare for their future careers in chemistry. However, she could not identify a purpose of the general chemistry lab for students not taking future courses in chemistry.

Shea believed the most important skills students should learn in general chemistry labs were those used in future laboratory courses. Shea placed heavy emphasis on practical skills since she believed those to be useful for future laboratory courses. Along with the general skill of
following directions and technical competence, she felt it was important for students to know how to write reports.

Notably absent from Shea’s pre-teaching narrative were discussions of goals for conceptual understanding, higher-order thinking skills, or conceptions of the nature of science. The closest she came to providing goals related to scientific processes was when talking about writing reports. However, even then what she most wanted students to gain was knowledge of the sections included in a report, which is the practical aspect of writing reports. Her views were more in alignment with training practicing chemists, or technicians, than with using the laboratory to educate the citizenry in science.

**Shea’s Post-teaching GTA self-image**. Shea’s post-teaching self-image was analyzed in light of the pre-teaching assertions (Table 4.4). The post-teaching assertions are compatible with the evidence found in the post-teaching narrative. They are listed in Table 4.4 and are typed in italics within this section. Also, comparing the assertions in Table 4.4 provides an overview of the documented changes for Shea’s case. Each pre-teaching assertion was changed at least somewhat in light of the evidence in Shea’s post-teaching interview. Had there been no changes, the assertions would have remained the same.

**Shea holds a self-image as a guide and mentor for her students (1.f)**. Shea tried her best to guide students in the laboratory. Shea described prompting students to think “what am I doing wrong” when they were faced with confusion. She noticed that when students’ plans did not work they would “forget to try new things”. In those times, she prompted them to think “what are you missing,” and she would suggest they reread their manual again and report back to her what they planned to do next.
Shea’s GTA self-image was evident when she was asked hypothetically if GTAs were necessary for the laboratory:

I guess they [students] would have just done [something] and it would have been over. They wouldn’t have been told you know ‘well, what’s the next step.’ You know, they wouldn’t have been given those ideas or like, or like reinforcement, or you know [had a GTA] saying ‘you did this, this is really great that you tried to do this’ and stuff like that. It wouldn’t have been the same experience [for students]. […] And, you know, if they [students] get really frustrated you’re there to say ‘well, that’s, that’s fine that you’re frustrated, it’s fine that you’re data doesn’t show you, you know, what you think it should. The fact is that you know you’re doing; you’re going in the right direction.’…Yeah, so like, the TA is definitely needed.

Shea’s description of the GTA in this scenario was that of a mentor, one who guides her students through the complexities of solving a problem and was attentive to the affective components of learning in the laboratory. As she put it: “as a TA you can make sure that you’re pointing them in the right direction, make sure they’re understanding that they are solving a problem.” This quote highlights how much had changed since Shea’s pre-interview when she wanted to provide everything for the students so that they would not encounter the feeling of “not knowing what to do”.

Interestingly, in the quote above Shea also alluded to students’ frustration and motivation. While immersed in the learning environment, Shea recognized the impact of these affective components, and she developed strategies to help her students make progress with their projects even when they faced confusion and frustration. Likewise, interactions within the learning
environment caused her to question her initial self-image as provider of knowledge. For example, she stated:

It was good to learn how to deal with students and to know that everything you say they aren’t immediately absorbing it you know. I guess [it] was a shock for me. I am just thinking they’re going to, you know, if I say it once I’ll never say it again but that wasn’t the case.

This realization was shocking for Shea because what she experienced in the lab was different from her pre-teaching epistemic assumption that knowledge could be transferred and absorbed and therefore all she would need to do is tell students what to do. Shea’s realization that knowledge is not transferable was a precursor to developing more sophisticated mentoring skills. In other words, Shea’s self-image was responsive to challenges to her beliefs about the nature of knowledge and laboratory work.

There was nothing in her post-teaching interview to suggest a shift towards a mentoring self-image was immediate or the direct result of GTA training. On the contrary, the examples she provided about mentoring and being challenged by laboratory interactions covered the span of the semester. He construction of this new, mentoring self-image resulted from the interplay of both the initial training she received and the weekly interactions with students. In the lab, she gained feedback that telling the students what to do did not work. She questioned her views within that nature of knowledge dimension and ultimately began to adopt a mentoring self-image.

*Shea views students as providing active exchanges and sharing views (2.f).* She acknowledged the potential of group work during her post-teaching interview: “Advantages [of this lab format] were definitely working with groups. I liked [that].” She went on to say, “I feel like if the groups were working well together they would bounce off ideas from each other and
answer them.” In these instances, Shea no longer discussed students in terms of recipients of knowledge or “doers” of what they were told. Rather, Shea viewed students as capable of being in control of their projects and their learning.

As a mentor, Shea sought ways to help students work together. Shea described occasions where one student would not be contributing, or one student would attempt to answer all post lab questions. In those cases, she attempted to prompt him or her to work with the group members or involve the other members’ opinions. However, she felt most groups “got into a method of who did what.” Further, she enjoyed watching her students’ interactions, especially when they began to “disagree on the methods to use.” During those times, she felt her role was to remind students that multiple approaches might work to solve a problem and that it was their responsibility to decide which path to choose. Shea’s focus for interacting with the groups was to help them build upon each other’s ideas.

Post-teaching, there was a big departure with how Shea discussed the role of students in the pre-teaching interview. Before, students were there to help each other do things, to do them faster and better. Now, in the examples above, peers are viewed as providing active exchanges and participating with each other in the construction of knowledge. These post-teaching views of students’ roles in the learning process are representative of a shift towards transitional knowing (Baxter Magolda 1992; 2004). Again, there is evidence of interplay between the different factors of the self-image model. Shea’s prior experiences suggested students could help each other perform the experiments quicker and more accurately. They were there to share resources and time. As Shea interacted with students and the new laboratory environment, she shifted her views towards paying attention to what students were thinking and contributing to the mental aspects of laboratory work. The laboratory experience influenced this aspect as it was designed for this type
of student interaction. For example, in a quote above, Shea mentioned students “disagreeing on methods to use.” That type of disagreement and therefore the necessity to engage in mentoring strategies would likely not have been there if the projects provided explicit procedures.

*Shea values physical and mental activity (3.f).* During the post-teaching interview, Shea discussed the “process” students had to go through multiple times. The process involved students being confused, not knowing exactly what to do, and having to think through problem situations. When students were confused, they would have to rely on each other, outside resources, or her help to overcome their confusion. She noted that students became more comfortable with the process as the semester progressed. Although students would still meet confusion with each new project, they were more adept to plan their projects. Shea’s description of students being better prepared and learning how to go about the process as the semester progressed represented an understanding component within the students’ experience (Sandi-Urena, Cooper, Gatlin, & Bhattacharyya, 2011b). While Shea’s recognition of students’ development in the laboratory was in part a reflection of what she observed during the semester, it is important also to note that Shea valued these experiences:

> I feel like the experiences that they [my students] had is definitely I don’t know the word, more well rounded [than mine as a student]…[In my experience], I just remember you know doing what’s on the page and stuff. So I would hope that [through] this process they got a better understanding of you know real world scenario type things.

Students were in control of the process; Shea’s role was to mentor or guide them through the process. She placed the students as thinkers, in control of their projects and learning.

Shea had shifted from a procedural view of laboratory work to a process view of laboratory work. Before teaching, Shea valued the learning of techniques and procedures more
so than other goals. She talked in terms of students following procedures and directions. Before the semester, Shea only discussed what students were physically doing. She felt students would follow procedures, set up equipment and complete other technical aspects of a lab. This is what she had done as a student. Teaching caused Shea to reflect upon her prior experiences, and she recognized what was expected of her students was different than what was expected of her as a student. Rather than focusing on purely procedural aspects of laboratory work, she began to value students’ physical and mental activity. The overall process of solving problems was more important that the specific procedures or techniques used within the process.

The shift in Shea’s views on students’ role in learning and knowing are related to the shift in her GTA self-image. In response to the new value she placed on students thought processes, it was no longer good enough to manage the laboratory. She had to pay attention to more than what they actions and their safety. She had to be engaged in the process of solving problems with her students.

*Shea believes the general chemistry laboratory prepares students for future problems (4.f) and she values practical skills, scientific skills, general skills, and content knowledge (5.f).* After teaching for one semester, Shea still believed the laboratory should prepare students for future laboratory courses. However, post-teaching she also believed the chemistry laboratory had value for students not taking future laboratory courses. Part of the value of the general chemistry laboratory was placed on the previously discussed “process” of completing the projects. She believed learning the “process” of working through problems could “transcend to other scenarios:”

Yeah, it’s just not being in the lab it’s learning how to approach a problem and solve a problem and working with other people and you know learning that if you don’t know
how to do something, you know, you’re just not going to stop and not ever do it, you’re going to have to figure it out, how to do it.

In this quote, which also highlights students’ mental and physical activity, Shea summed up the nature of the laboratory as a place to learn to solve problems. The problem-solving process included social aspects of working with others and cognitive aspects of working with chemistry content. In fact, Shea believed the nature of the laboratory made it useful to attain a number of goals. Interestingly she valued goals from all areas identified by Reid and Shah (2007): skills related to learning chemistry, practical skills, scientific skills and general skills.

These views represented a change in Shea’s beliefs about the nature of laboratory work. At the beginning of the semester, she could not identify a single goal for laboratory instruction for non-chemistry majors. She viewed the laboratory as a place to train chemists in basic techniques and safety. However, through the teaching experience, she came to view the laboratory less a place for learning procedures and more as a place to learn the process of doing science. This shift in her views about the nature of laboratory can be attributed to a combination of factors. First, her new views are more in alignment with the program she was teaching within. Also, those views were encouraged through GTA training and support. Finally, she received feedback and perhaps strengthened this new stance by interacting with the students. She evaluated their experience in light of her prior experience as a student and preferred the experience her students were having.

Lyle’s Pre-teaching Self-Image. As detailed in the methods section, we made assertions about Lyle’s GTA self-image and beliefs about the nature of knowledge and the nature of the laboratory based upon the evidence found in his pre-teaching interview. Our assertions are placed in italics within the text and summarized in Table 4.5. The post-teaching assertions
presented in Table 4.5 are discussed in a later section. Each assertion is numbered to assist in comparison. For example 1.i (initial) is an assertion about Lyle’s pre-teaching self-image while 1.f (final) is an assertion about Lyle’s post-teaching self-image.

Table 4.5

Assertions about Lyle’s pre- and post-teaching self-image and related factors.

<table>
<thead>
<tr>
<th>Factor*</th>
<th>Pre-Teaching Assertions</th>
<th>Post-Teaching Assertions</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTA Self-image</td>
<td>1.i</td>
<td>Lyle held a self-image as a content expert and questioner.</td>
</tr>
<tr>
<td>Nature of Knowledge</td>
<td>2.i</td>
<td>Lyle envisions students as physically active.</td>
</tr>
<tr>
<td></td>
<td>3.i</td>
<td>Lyle holds an absolute view of knowledge.</td>
</tr>
<tr>
<td>Nature of Laboratory</td>
<td>4.i</td>
<td>Lyle believes the laboratory is a place to prepare for future laboratory courses and to learn techniques and theory.</td>
</tr>
<tr>
<td></td>
<td>5.i</td>
<td>Lyle views laboratory learning as experiential.</td>
</tr>
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</table>

*Factors derived from the GTA self-image model (Sandi-Urena & Gatlin, 2013).

*Lyle holds a self-image as a content expert and questioner (1.i).* Lyle believed he would be successful in his upcoming role as a GTA because of his content knowledge. As he stated, "I know the material, I can just walk in and do my thing and not worry about it too much." Part of this confidence came from reflecting upon his prior teaching assistantships, for which he received little training or support. For example, he stated, "Well I really haven’t had much help or supervision or anything like that [in the past]. So whatever help [the coordinator] gives me is a plus." Lyle’s prior experience led to the view that he would not need guidance or assistance
from a laboratory coordinator. He believed his knowledge of chemistry and his prior teaching would be sufficient. For example, Lyle stated, "I really don’t expect all that much [support]. She can hand me the lab manual and tell me what to do, where the chemicals are, where the equipment is, and I’d be pretty well off." The self-image that Lyle presents resonates with the previous GTAs, who had experience in an expository laboratory experience (Sandi-Urena and Gatlin, 2012). Three dimensions conceptualized their experience: doing, knowing and telling. They did things so that they would know everything and could thus tell their students what to do. Likewise, Lyle feels he already knows enough and simply needs to be told what to do.

In relation to his prior experience as a teaching assistant, Lyle stated his role was to "basically make sure [students] aren’t going to do anything to hurt themselves, other than that, there’s answering questions if they ask you [questions] and grading lab reports." Clearly, he saw his role as being there to make sure everything ran smoothly, to make sure the students were doing what they were supposed to do and to answer their questions. Again, these views aligned with previous teaching assistants from the expository program, who viewed themselves as managers of time and safety (Sandi-Urena and Gatlin, 2013).

There is a general saying or idea that teachers teach the way they were taught. In the GTA self-image model (Sandi-Urena and Gatlin 2013), this would be best represented as the effects prior experiences have on a GTA’s self-image. In the absence of training or preparation, prior experiences likely hold greater sway on a GTA’s self-image and their actions in the classroom. In Lyle’s case, he not only had no formal training, but he had multiple semesters of experience as a teaching assistant. Therefore, his self-image is a reflection of not only what his prior teaching assistants or instructors did, but also what he experienced as a prior teaching assistant. That is to say, the nature of his prior experiences in an expository laboratory suggested
to Lyle that he would be fine in this laboratory; all he would need is his content knowledge.

**Lyle views students as physically active (2.i).** In the lab, students are doers:

The way I’ve always had it done is just get in there and work on stuff…I mean…I really don’t know of any other learning techniques for laboratory courses other than just getting in there and doing what you’re supposed to do. I know a lot of techniques for the lecture classes, but I only saw just the one way of doing the laboratory classes.

After this quote, Lyle did not expand on how students come to realize what they are supposed to do. However, it appears he is referring to doing what is provided, either by the laboratory manual or the instructor. That is how his laboratory as a student worked, and it is how he described the laboratories he facilitated. Therefore, for Lyle, students must perform the lab and learning will happen as a result of “seeing” and interacting with the physical objects.

Again, Lyle prescribes to the model of teaching as taught. He only “saw” one way of doing laboratory classes as a student and prior teaching assistant. He described students as taking a hands-on, minds-off approach, which is common in college and high school laboratories. Students are simply doing what they are told. Conceptual development or thinking in general is something that takes place outside of the laboratory. There was no discussion of students figuring things out in the lab. They were described as simply doing what they were told. In essence, the students were doers and followers. They would ultimately follow the instruction of an authority source, either the lab manual or the GTA. With this view of what students should do in the lab, it is easier to understand why Lyle would feel content knowledge would be all that is required of him. If he knows the chemistry and has been told what the students should do, he can tell them what to do. Then as was referenced earlier, he would make sure the students are safe and answer their questions.
Lyle holds an absolute view of knowledge (3.i). At the end of Lyle’s pre-teaching interview, he engaged in a discussion on the nature of science. In summary he felt scientific results are not debatable, and science is purely objective, which represents an objectivist worldview. Specifically, when referring to the nature of scientific results, Lyle stated:

Well that depends. Were the experiments done correctly? Were they done by people who are known for doing things well? Umm, provided that experiments are done correctly and all that. I mean experiments should be reproducible by anyone else with the same amount of knowledge on the subject, but other than that, if they’re reproducible by others then they shouldn’t be debatable…That’s how a lot of our laws like in thermodynamics or Newtonian physics, we’ve done them over and over again and we’ve never been able to prove them wrong. So that’s why we accept them.

In this quote, Lyle adhered to a falsification model of science that suggests an idea is scientific if there are some criteria that could prove it to be false. Interestingly though, the example he used, Newtonian physics, has been falsified many times over. In this instance, Lyle did not account for contextual features of scientific laws that allow scientists to use them within certain context; rather, he accepted the laws as truth.

When asked if scientists’ personal beliefs impact their research, he said:

“Not good ones….Not good researchers, they don’t let their personal beliefs get in the way of science….Yeah there should be no subjectivity behind what we’re doing. We can’t allow our beliefs and thoughts to get in the way of how actually things work.”

In this passage, Lyle again reflected an objectivist worldview where there is a true nature and scientists are to be impartial observers of that truth. Again, in this quote, Lyle did not entertain
contextual factors of scientific theories nor did he consider socio-cultural aspects that may have led to their creation. In relation to Baxter Magolda’s (2001) epistemological reflection model, Lyle’s views fall into the absolute knowing category. He treated learners as doers, recipients of knowledge from authority. Further, he firmly believed that knowledge is either right or wrong and results are not debatable as they represent absolute truths.

*Lyle believes the laboratory is a place to prepare for future laboratory courses, learn techniques and theory (4.i). Also, Lyle views laboratory learning as experiential (5.i).* When asked what students would miss if they did not have a General Chemistry lab course, Lyle stated, "I think they, [students], would have a lot more trouble than what they have in Organic lab." Part of trouble he perceived that students would have would result from students lack of "understanding how to do things." Lyle felt that “understanding how to do things” was the "main part of the lab [experience]" in general chemistry. Therefore, the purpose of general chemistry labs was to prepare students for the next lab. For example, he said,

First and foremost, understanding of the fundamentals [is important]. It’s not as important for freshman to get the experiment perfect or anywhere near that. Basically, seeing that they were doing each of the steps and actually trying. That’s a good first part.

He went on to say the difference between earning an A or a B may relate to whether students "got the correct results or at least somewhere close to that." Again, Lyle reiterates his view that knowledge is either right or wrong. Except this time, he is using it to justify laboratory work. His preferred grading scheme would be based on getting the correct result.

At another point, he reiterated his stance on the importance of techniques in the laboratory:
Well the whole point is to get a practical understanding of what they learn in lecture so I
would expect them to use the lab to better understand what they’ve learned from the
lecture part of the course. Learn how to actually do some of the actual techniques that
real chemists do.

Lyle's emphasis on learning techniques and theory were again evident when he discussed what
he as a teaching assistant may take away from the experience. "The more you teach the more you
understand about the subject…I mean, you understand more about the right way to do the
techniques, you understand more about how the theory works. You never really know about
something until you teach it is what I’ve always heard and that seems to be true." Again, Lyle is
referring to performance and right and wrong. The laboratory, even for him as a GTA is a place
to practice the right way. Lyle frames expertise in relation to the amount of practice without
considering the importance of the quality of that practice. Through practice, he feels he will
continue to perfect his skill.

Lyle touched on an experiential aspect of laboratory work a couple of times. First, in
relation to what students would miss without a lab, he said,

A lot of people need to see what magnesium looks like, umm what a beaker of oxygen
looks like to see that it actually looks just like a beaker full of air. That sort of thing. They
really need to see concrete objects, not just this abstract theoretical stuff we talk about in
lecture.

Later when asked if students might gain those aspects from virtual laboratories, Lyle stated,
yeah, but they can’t touch it, they can’t…well you can’t really smell oxygen, but say it
was ethyl acetate or something like that. They wouldn’t be able to get the smell. They’re
not going to realize that acetone is really the fingernail polish that they use…They’re not going to realize things like that just by seeing pictures on a screen.

Lyle summarized these thoughts by saying, “I don’t believe [students without a lab] would have as good of an understanding of that [lecture] material without the laboratory.” Lyle’s stance that laboratory work can help learning of lecture content is not objectionable. Learning can be improved through lab activities, experiments or projects. However, Lyle reduced laboratory work to a sensory level. He focused on sight, smell and touch. Again, the concreteness of laboratory work is centered on doing, not thinking. He does not explicitly connect doing with thinking.

**Lyle’s Post-teaching self-image.** Lyle’s post-teaching self-image was analyzed in light of the assertions from pre-teaching (Table 4.5). The revised assertions, which are compatible with the evidence found in the post-teaching narrative, are also included in Table 4.5. Post-teaching assertions are in italics within this section. As can be noted from the assertions in Table 4.5, four of the five pre-teaching assertions still fit for the post-teaching data collected for Lyle. Very little change was noted in Lyle’s post teaching self-image or associated factors.

**Lyle holds a self-image as a content expert and questioner (1.f).** At the end of the semester, Lyle had not adopted a self-image fully aligned with the laboratory program. In fact, Lyle stated, “The way I see labs and the way we see labs here are pretty different.” This quote was the clearest message that Lyle had not adopted a self-image as a mentor.

Although Lyle was asked to teach differently and take on a different role from how he taught in his previous teaching assistantships, he continued to follow many of the same strategies. For example, after mentioning that teaching in the lab is “not really that hard to do,” he said:

Basically I would go in and write all the information on the chalkboard so that they would have it and so that I wouldn’t have to keep repeating myself because I learned very
quickly that not everyone listened the first ten minutes of lab when I was telling them what they were doing.

Here, Lyle references telling students what they were to do each day. He provided what was expected, and he tried to avoid confusion by writing some things on the board even if it may have been counter to the program design. This strategy is very similar to how previous GTAs in expository programs described their opening minutes (Sandi-Urena and Gatlin, 2012). Like them, Lyle tried to avoid confusion by providing what was needed. However, unlike the expository program that he worked in before, confusion about solving problems should have been a natural part of the students’ experiences within his current program.

After the initial introduction for the day, Lyle found it best to stay on his feet in an attempt to keep the students on track:

Um...staying on your feet and walking around the entire time seemed best to keep them motivated and working the entire time. I found that was [...] definitely worth the energy, because I tried sitting around one day and just watching them and thirty minutes later I find myself back on my feet telling them to get back to work because they weren’t [working].

This discussion of staying on his feet was somewhat of a departure from how he saw his role at the beginning of the semester. In the prior labs, sitting back, watching and waiting for questions would have been acceptable. He attempted teaching his old way, but the laboratory structure did not support that style. Students did not have procedures and could not simply follow along. They needed support in planning their experiments. Therefore, as suggested by the GTA self-image model (Sandi-Urena and Gatlin, 2013), the laboratory format and experiences in the lab played a role in Lyle’s need to be more active and ask more questions of students. Of course, as
mentioned earlier, a way Lyle adapted to the format of the lab was to provide students with more information at the beginning, which was counterproductive to the laboratory design.

Questioning students and responding to questions was something that Lyle mentioned a few times during the post-interview. Comparisons of the two interviews suggest Lyle spent more time involved in questioning and answering students in this laboratory format than he did in his previous teaching assistantships. For Lyle, it was an enjoyable aspect of being a teaching assistant: “it was enjoyable to help them solve some of the problems that would come up. Not [giving] them the answers — the good old Socratic method—I like that a lot.”

The idea of not giving students direct answers or procedures was something discussed during weekly staff meetings. Lyle reported following the guideline of not giving answers. However, he may have also reduced the Socratic method to answering a question with a question rather than considering it a dialectical method of argumentation aimed at promoting critical thinking or furthering conceptual understanding. At times, Lyle’s questions may have come across as interrogative:

“I think a lot of the times when I would just ask questions they would be intimidated just because I was putting them on the spot, and I’ve been told that I have that problem sometimes. […] So I’m sure that some of them were just scared. Some of the times I think there’s not really anything you can do about it. You just have to keep trying to prod them to ask questions and to learn.”

The questions Lyle asked were usually thought of on the spot in relation to what students were doing at the time: “Just random questions about things that they had done or parts of the theory that I thought they should understand […].” He would ask these questions as he walked throughout the room, and also during the groups poster presentations: “[…] and I would just ask
them randomly when we would have like the poster presentations. Like, I would point to each of
the persons and ask them a question.” Lyle reported rarely thinking of questions before the
laboratory. When asked specifically if he planned questions before each lab, he stated: “before
lab, no, I try not to think about it much before going in because that just gets your expectations
way too high and its just setting yourself up for failure.”

Although he did not plan the questions ahead and had low expectations of his students, he
hoped that questioning the students would lead them to strive to do better and learn more. Yet, he
also felt some students could not be helped:

For some individuals you’re never going to make them care. You’re not going to…
anything you do is not going to help, but some…a lot of people, when they’re put on the
spot to understand something, and they don’t they’ll strive to understand it; do what they
can [to] answer you next time. I had a few that were like that.

As the picture of Lyle’s questioning and answering unfolded, it was clear that he was
more active in this laboratory. But, it also appeared that what Lyle really enjoyed about the
Socratic method was playing the role of Socrates, the master, the authoritative source of
knowledge in the room. He was not creating a cooperative environment, but rather presented oral
quizzes. He admitted his strategies intimidated students, but felt the fear that resulted from
putting them on the spot would motivate them for the next time. He was attempting to condition
the students through the on the spot oral quizzes.

Mentoring and coach strategies were absent from Lyle’s case. He did not discuss aspects
of modeling problem-solving behaviors or other aspects that would suggest he had adopted a
mentoring or guiding self-image. Rather he showed an antagonistic relationship with the students.
He felt they did not try and should be continually quizzed. He felt there was no hope that some
would do what was expected. There is no evidence that he attempted to relate to them as humans or learners or to understand their affective needs within a new and challenging laboratory course. In most regards, Lyle’s post interview could have been describing his experience teaching in the prior “cookbook” labs, albeit with more activity this time.

In reflection, it appeared that Lyle’s pre-teaching self-image was rigid. Although the laboratory structure promoted changes in Lyle’s behavior, he had not, after one semester changed his view of himself as a teaching assistant. He was not quick to accept the laboratory message of reform. In order for Lyle to adopt a mentoring self-image, he would have had to overcome both prior experiences as a student and prior teaching experiences that suggested a GTA should be a manager. By the end of the semester Lye still did not see the laboratory or himself in the way the laboratory was designed.

**Lyle envisions students as physically active (2.f).** There was insufficient evidence in the post-interview to suggest that Lyle had changed the way he viewed students. The laboratory was still viewed as a place for performance. Although he made concessions that students were becoming better at solving their projects, he longed for verification in the laboratory and more focus on techniques and lecture material. His discussion still focused around what his students were or were not doing physically, but rarely mentioned thinking or thought processes.

Lyle did not expect to learn from his students, and he held relatively low expectations of them. He felt students would give the minimum required effort, would not think for themselves and would ride on other students’ work. Lyle mentioned problems such as some students thinking that “one of their group members can do the majority of the lab, and they can just sit around and do nothing.” He went on to say he saw those students “in each of the three sections.”
Lyle did not mention successful strategies for dealing with these problems. At one point he mentioned that there is not much you can do:

That’s a good question. Not sure if I know how to answer it though. I’m really not sure…beyond what we do already that we can get them to learn the information better. Um, in some part they have to, I mean we can only do so much. At some point, they have to realize that they have to teach themselves some things.

Lyle’s reference to learning “information” is suggestive that he is still framing the experience in relation to his pre-teaching self-image and prior experiences where the focus was on acquiring information. When he says “information,” he was not referring to students learning how to solve problems in chemistry or consider knowledge claims in chemistry. He was referring learning to techniques and content.

In the pre-interview, Lyle stated that students should learn by getting in the lab and doing what they have to do. From his prior experience and his incoming self-image, he expected students to know what to do, and do it. However, the laboratory was not setup in that fashion. In this course, students were not given procedures to follow in their laboratory manual. Students had to plan their projects. Rather than recognizing the challenge they faced, Lyle characterized their behavior as lazy and helpless. After all, from his incoming perspective, he felt students should be able to enter the lab and do it, whatever it may be. After the semester, he was still viewing students as recipients of knowledge.

Lyle mentioned students’ difficulty with the initial projects:

[when students were] figuring out how to go about the lab for each of their projects, I had to poke and prod at a lot of them and get a lot of small hints as to what to look into before they could really get started.
He treated it as a problem though; he was concerned with how much time he had to “poke and prod.” He felt the students should be given more information. He did believe that students became better at working with the projects as the semester progressed: “They got better at doing it. They got more accepting on the later projects that they had to get in there and do it.” Lyle’s students were beginning to take charge of their work and complete their projects. He attributed part of this to his not giving in to students asking for specific answers and procedures:

I’m sure that there were some of them in there the first time that thought ‘Gee he’s going to have me do this for a few minutes and then give me the answer’ I’m sure that’s going to happen and in later projects they realized that’s not going to happen. So, it went a little more smoothly.

Lyle also felt that his students had “learned some problem-solving skills.” According to Lyle, students learned “how to take a problem they know nothing about [and] research it if only using Wikipedia to try and figure out a solution to the problem; whether it be right or wrong.”

Although many would consider the learning of problem-solving skills an achievement for laboratory instruction, Lyle was somewhat dismissive of what his students had gained. He remained concerned that they were not reinforcing content from lecture enough in the labs. Part of the minimization of problem-solving gains was due to Lyle’s perspective that the laboratory is for performance. In the incoming interview, he felt the difference between an earning an A or B should be related to how close students were to the correct value. Understandably, the fact that his students’ projects did not have specific procedures or correct answers caused some concern. By the end of the semester, he had not fully adopted problem solving as the main goal for laboratory instruction. As such, Lyle was not very celebratory that his students were developing problem-solving skills.
Lyle holds an absolute view of knowledge (3.f). There was not enough evidence to suggest Lyle’s beliefs about the nature of knowledge shifted during the course of the semester. On the contrary, evidence suggested his beliefs were persistent. He continued to view himself as the authority; he viewed students as receivers of information. He focused on how well or not they performed. His oral quizzes mentioned previously were used to see if students held the correct knowledge. Further, he did not expect to learn or gain much from the experience since he was dealing with students less knowledgeable than he. He still treated experts as ones that know a lot of information or facts. All of these aspects pointed towards a lack of change. He continued to work form an absolute way of knowing (Baxter Magolda, 2001).

Although there was not enough evidence to suggest that Lyle’s view of knowledge changed, there was evidence that suggested that moments in the teaching experience challenged his epistemological beliefs. For example, Lyle recalled instances of seeing how non-scientists “see science.” He stated, “I guess you get to learn how to communicate science with people who are not as understanding of it as you are. You learn how to talk to people…you learn how to convey the information that you already know.” Although he was discussing students multiple perspectives, he still viewed them from a standpoint of right or wrong, and focused on communicating the correct knowledge. Lyle further discussed an instance of being surprised by some of his students’ work, specifically when they were doing something that he, as the content expert, would not have done:

I had a couple of students that were doing something that I thought was completely off the wall, but I can’t remember exactly what it was, but in the end they got what they were supposed to. I looked at it, and it was right.

This was a memorable moment for Lyle because it conflicted with his pre-teaching tendency of
absolutes, of having one way to go about the procedure. It challenged his authority. He had a preferred way to do the lab, and he thought students would do best by following his way.

Lyle did reflect upon his status as authority in the laboratory and the lack of questioning by students: “[some of] my students were quick to just accept things that I said rather than asking how it’s true or what [it] does. Sometimes they wouldn’t ask what things meant even though they needed to…” These interactions promoted Lyle to reflect upon doing science. He stated, “it showed me that…just how…I’m not sure how to word it. Hmm, I think when you’re doing science you need to be inquisitive about what you’re doing to understand it and a lot of people aren’t.” This quote was relevant for a couple of reasons. First, it demonstrates Lyles approach to students. He felt they either were inquisitive, or they were not. He did not take the time to mentor or attempt to model this approach for his students. He also stopped short of saying that he may have become more inquisitive after the experience. Finally, Lyle did not openly question if his approach to the classroom might be a contributing factor into how students treated knowledge. Nonetheless, these interactions in the problem-based environment caused Lyle to reflect at least upon his views, which is seen as a necessary precursor to developing more sophisticated views of knowledge and knowing (Bendexien, 2002). For example, due to both the cooperative nature of the projects, and the freedom students were given to design aspects of their projects, Lyle was confronted with the views and thoughts of his students. He stated, “you get to see how other people think rather than just your peers who are graduate students.

Lyle differentiated goals for majors and non-majors of chemistry (4.f) and Lyle views laboratory learning as experiential (5.f). Even though Lyle did not change his self-image during the course of the semester, his beliefs about the nature of laboratory work shifted. At the end of the semester, he valued different goals for chemistry and non-chemistry majors. He still believed
chemistry majors should focus more on techniques and confirming laws, but he thought students in other majors could benefit more from the problem-based approach.

The shifts in Lyle’s beliefs about the nature of laboratory work are most significant because of where they originated: in the laboratory environment, through interactions with students. Lyle stated, his current teaching experience “definitely has influenced me to at least incorporating more of this problem-solving to my ideal lab.” His new vision would be “two third[s] of what I had in my mind when I had my lab and then maybe a third of what they do here.” Lyle’s statement reflects that teaching experiences in the laboratory can shape the way GTAs come to view the nature of laboratory work, and ultimately themselves within the laboratory environment. It is unlikely that Lyle would have come to this conclusion from training and support alone. Rather, interactions in the laboratory suggested to him that the problem-solving approach could be valuable.

One of the reasons he preferred two-thirds his old way was because he felt he had a better experience as a student than his students did: “I think my experience was better. I learned a lot more about Chemistry as far as applications of the theory and whatnot. He went on to say, I may have gotten less of this problem solving thing that we’re so apt on but…I would say that for non-chemistry majors, especially people that are really far from chemistry spectrum of different disciplines then this class is probably better for them in the end. But for people that are going to be closer to Chemistry […] I would say that the Chemistry experience that I had was better because you do learn more of the techniques to use later on. And […] it reinforces the theory that you learn in lecture.

Lyle still valued techniques and theory acquisition as the most important goals for a laboratory
program. However, he began to consider aspects of problem-solving to be a beneficial goal for laboratory instruction.

As far as goals for the chemistry laboratory, Lyle stated:

Well, first I think lab should always try to expand on what they’ve learned in lecture. They should take whatever they’ve learned like chemistry equations, pH or whatever like that, and the lab should give them a visual appreciation of what that means.

In this quote, Lyle addresses his view that laboratory work should be subservient to lecture. It should reinforce concepts learned in lecture. He also addresses the “visual appreciation.” This comes from his view of the laboratory as an experiential learning experience, and it is very similar to the views he presented at the beginning of the semester. Along the same lines, he discussed his prior experience as a student:

I found in labs where I’ve actually seen um, what I learned about in lecture, I remember those topics better. I remember…those are the things I remember from Organic. […] I can remember the lab from a few years ago but the rest of the stuff was pretty much gone, so that reinforcement shows me that in later years I would remember those topics better. Again, Lyle appreciates laboratory work for allowing students to “see” the concepts for lecture.

Although, he still believes techniques and theory should be the cornerstone of the laboratory program, he stated: “[…] there should be some problem solving involved, maybe not as much as they have here, but definitely learning to identify chemical compounds lends itself well to the whole problem solving experience.”

Embedded within this discussion of Lyle’s current goals for laboratory work, we see examples of many aspects of the GTA self-image model (Sandi-Urena and Gatlin, 2013). Part of his ideal laboratory is based upon his prior experience. He believed the laboratory experience he
had as a student was valuable and worth repeating. This could be indicative of why there were so few changes in Lyle’s case. He had yet to find the relevance of the programs goals and philosophy. It appears as if he was not change-ready. It should be noted that most of Lyle’s views, both pre-teaching and post-teaching were in alignment with the views of other teaching assistants that had experience in an expository program (Sandi-Urena and Gatlin 2012). Therefore, the prior teaching experience most likely solidified Lyle’s views about the nature of laboratory work and his self-image making any resulting changes upon entering a new program even harder.

Of course, as much as Lyle would have liked to be facilitating his old lab format, he was not. Therefore, some of the structural features of the lab and his resulting experience caused him to reflect upon his prior experiences. He referred specifically to his prior views about the nature of laboratory work and how the current teaching experience caused him to shift his views. It was not an instant change. Nor did the change result from training or preparation alone. Rather the changes, valuing problem solving for non-majors, were the result of continuous engagement with students in the laboratory setting and explicit reflection upon the beliefs he held.

**Cross-case analysis of Shea and Lyle**

Analyzing across Shea’s and Lyle’s cases illustrate different but important aspects of GTAs’ self-image constructions. First, both cases illustrate that “GTAs’ construction of their self-image is shaped through the interaction of several factors: prior experiences, training, beliefs about the nature of knowledge and about the nature of academic laboratory work, and involvement in the laboratory setting” (Sandi-Urena & Gatlin, 2013). More importantly, these cases illustrate that the extent to which GTA self-image construction occurs and the speed of change varies amongst graduate students. In one semester, Shea had adopted a GTA self-image
in alignment with the laboratory program while Lyle had not adopted a self-image as a coach or mentor. This deviation serves as a reminder that GTAs are not blank slates. The experiences and beliefs they bring into the teaching assistantship will have an impact on both what they do and what they take away.

Prior experiences were important in both Shea’s and Lyle’s self-images. Before entering this program, Lyle had more experience with all factors of the GTA self-image model. For Lyle, these prior experiences led to a more crystallized view of his image before entering the program. Although he did not receive formal training or preparation for his previous teaching assistantships, the lack of training was significant in shaping his views that preparation would be unnecessary for this program as well. Further, his pre-teaching self-image was consistent with the self-images of a prior group of teaching assistants involved in cookbook laboratories (Sandi-Urena and Gatlin 2012). That is to say, the feedback he received from interactions in the cookbook laboratory helped form the way he saw himself as a teaching assistant. On the other hand, Shea was new to teaching. She drew upon prior experiences as a student and based her views more on what she saw others do. She entered the program with a less than certain view of herself as a teaching assistant. She had not spent as much time considering what being a GTA meant for her. She planned to model her actions on what she had observed from her prior teaching assistants. From a change perspective, Shea’s pre-teaching self-image had yet to be supported or refuted by teaching experience.

The cross-case analysis also suggested Shea’s and Lyle’s openness to reform may have impacted what they took away from their experience. Science educators have proposed discontentment with current teaching practices as a starting point for openness to reform and practical change (Feldman, 2000; Southerland et al., 2011), and it is postulated here to have
played a role in the outcome of Shea’s and Lyle’s cases. Shea was unhappy with her laboratory experience as a student. Further, her survey suggested she was more receptive of group work in the laboratory setting, which was a major component of the program she was being asked to facilitate. Therefore, she may have been initially more open to the message of reform. On the other hand, Lyle believed strongly in the experience he had as a student and likewise may have been less open to the message of reform. For example, he continually referred positively back to his experience as a student. He wished his own students within this program could have had more of what he had. It may have been this desire to give them what he felt they were missing that led to his questioning strategies that were designed to test them on factual information and things he thought they should know.

Together, the two cases illustrate a larger message. Laboratory instruction can provide transformative learning opportunities for the GTAs who are asked to facilitate the courses. Baxter-Magolda’s (1996) longitudinal study on epistemological development suggested that one way graduate education promotes students’ epistemological development is through creating experiences that students have not encountered. Baxter Magolda (1998) also stated, “engaging students in exploring multiple perspectives and conveying that students must construct their own perspectives by using the evidence of their discipline” influences epistemological, intrapersonal, and interpersonal development (Baxter Magolda, 2008). In essence, this is what Shea and Lyle were asked to promote with their students. Shea and Lyle were engaged in new and unfamiliar situations, and the multiple perspectives of their teaching assistant peers and their students consistently confronted their perspectives. Shea and Lyle discussed being surprised by their students’ perspectives and discussed finding interest in seeing how others think. These aspects of
their experiences were epistemological and were likely a precursor for Shea’s and Lyle’s development (Bendixen, 2002; Kinchin & Hatzipanagos, 2009).

**Limitations**

We used a purposeful sampling approach to choose participants for this study. The setting for the study was chosen because of familiarity with the laboratory context through prior research that suggested a possible impact on GTAs’ self-image (Sandi-Urena & Gatlin, 2013; Sandi-Urena, Cooper, & Gatlin, 2011a). Further, only two cases were included in this case study. Therefore, findings should be judged within the context of small purposeful samples. Rather than viewing specifics of Shea’s and Lyle’s cases as generalizable to all GTAs in all contexts, we support the stance that case-study findings generalize to propositions for future study (Patton, 2002; Yin, 2009). In that sense, these cases contribute support to the usefulness of a model of GTA self-image construction (Sandi-Urena & Gatlin, 2013) and the importance of considering GTAs’ self-image in laboratory curriculum design. Further, readers are encouraged to consider the context of Shea’s and Lyle’s cases in order to gage the transferability of these case findings into other settings.

Validity for this research came primarily from the lens of the researcher and the lens of the readers of the study rather than the lens of the participant (Creswell and Miller, 2000). Here, a lens refers to the viewpoint from which validity is considered. The following strategies that employed the researcher lens were used enhance the validity of this work. Pre-surveys served to triangulate the information GTAs provided during the interviews and assisted in the selection of relevant cases. The interview guide was taken from previous work with GTAs (Sandi-Urena and Gatlin 2012, 2013). The interviews took place before GTAs were introduced to the laboratory format as to capture their beliefs. During the analysis stage, data was compared to the initial
assertions in a search for disconfirming evidence. Finally, within this report, thick, rich
description was provided for each case to provider further validity from the lens of reader.
Readers are encouraged to judge the relevance and importance of this work in relation their
context (Bodner, 2004).

Strategies that employ the lens of the participants such as member checking and
prolonged engagement in the field (Creswell and Miller, 2000) were not used for the follow
reasons. First, prior work has documented problems associated with using member checks after
participants have had new experiences or their perspectives have changed (Sandelowski, 1993;
Goldblatt et al., 2011). Goldblatt et al. (2011) challenged the use of member checks when
dealing with elapsed time stating,

The participants might interact with the transcript from a different perspective from
then at the time of the interview leading to a change in perspectives… How can such
member-check validate research findings and interpretations? (p. 392).

Both Shea and Lyle continued in their graduate studies and held further teaching assistant
positions between the time of the interview and the analysis of their interviews. Therefore, as
argued by Goldblatt (2011), asking them to comment on their prior self-image as a member-
checking strategy would not have provided validity to the research. Returning to Shea and Lyle,
on the other hand, could have provided more insight to their continued construction of their self-
images. However, that longitudinal aspect was not the focus of this research. Therefore, Shea and
Lyle were not interviewed again or asked to member-check their cases.

Second, prolonged engagement in the field, another strategy often used to enhance
validity form the lens of the participants (Creswell and Miller, 2000), would have altered the
context under study and therefore, not increased validity in this work. Within the GTA self-
image model, training and support are considered to influence the GTAs self-image. It would have been difficult to maintain engagement in the field without influencing the support provided for the teaching assistants. Simply causing GTAs to reflect upon who they were in that environment could have led to changes in a GTA’s self-image that would otherwise not have been present. Therefore, in wishing to keep the laboratory in its natural state, there was minimal contact between researchers and research participants.

Conclusions and Implications

From the illustration of these two cases, we see both the potential and the pitfalls of having GTAs teach. On the one hand, the laboratory has the potential to be a transformative learning environment for the GTAs. On the other, GTAs may undermine the curricular design and educational experiences of the undergraduates they teach.

The findings from this work fit with prior research in that GTAs have difficulties facilitating laboratory reforms and inquiry-based laboratories (Brennan, 2011; Goertzen, Scherr, & Elby, 2010b; Roehrig et al., 2003; Schussler et al., 2008; Seymour, 2005). These difficulties are usually thought of as GTAs not knowing what or how to teach. However, Shea’s and Lyle’s cases illustrate that their beliefs about who they are in the environment, their GTA self-image, and their beliefs about why they are teaching laboratory courses, the nature of laboratory work and the nature of knowledge are just as important. Undoubtedly, understanding what and how to teach is important, but training and support that ignores GTAs’ beliefs about why they are teaching will not be as productive. Therefore, it is not enough to teach GTAs what and how to teach. GTAs must spend considerable time developing their understanding of why laboratories are taught and who they should be as a GTA. Goertzen et al. (2010b) called for GTA support to
be responsive to each GTA. Focusing on GTAs’ self-image construction would be a substantial first step to meet that call.

This work demonstrates that GTA training and support, in whatever form provided, will be framed by the beliefs GTAs hold. Accordingly, consideration of GTAs’ self-image development should be a prominent concern for laboratory coordinators. Current and future training and support models may be evaluated in terms of how they challenge GTAs’ beliefs of teaching and learning and how they may support or hinder GTAs’ development of more complex ways of knowing.

Shea’s and Lyle’s cases illustrated that changes in beliefs are linked to the conflicts that arise during teaching. The conflicts are a natural occurrence of being immersed within the problem-based laboratory environment, but training and support could be designed to promote healthy conflicts or discontentment. Training and support should provide opportunities for GTAs to express and reflect upon their beliefs and self-image. The focus of this type of support is on helping GTAs develop more productive ways of viewing themselves as teaching assistants. These strategies would move away from the view of GTAs as instruments of instruction and towards a view of GTAs as learners within the laboratory setting.

One strategy for accomplishing this is by using reflective prompts either before or during weekly meetings. These prompts could come after reading an article on laboratory instruction or as stand-alone activities. For example, a paper by Hodson (1992) on assessment in laboratory instruction presents a unique perspective that could prompt reflection and discussion in a weekly staff meeting. He argues that assessments should follow from the question “is this good science?” Even if the GTAs have not read the article, prompts inspired from the paper could still facilitate discussion and reflection. For example, the following list could be provided to GTAs: “What is
good science?” How does students’ work in the laboratory reflect good science? How do I, as a GTA, promote good science?” Statements such as these could be used throughout the semester. Obviously, other prompts would be beneficial. However, the nature of those prompts should be determined by the interplay of course goals and the current group of GTAs. For example, if GTAs are overly concerned with techniques, an analogy found in Hodson’s (1992) article may be a productive prompt to generate discussion and reflection. He argues focusing attention on basic technical skills is analogous to “language arts concentrating attention on the skills of using a word processor, rather than on what is written (and why) and how it is expressed” (Hodson, 1992, p. 140). Prompts such as these directly challenge certain aspects of GTAs’ beliefs about the nature of laboratory work or the way they see themselves. Using them, or prompts like them may contribute to GTAs rethinking of their self-images in the laboratory setting.

Finally, in 2011, in reference to a group of GTAs within the same laboratory context under study, we stated that “it is not the explicit objective of the lab format to accelerate GTAs’ epistemological transformation, but it is evident that the context challenges them and requires such reflection” (Sandi-Urena, Cooper, & Gatlin, 2011, p. 99). Shea’s and Lyle’s cases provided further evidence that the laboratory prompts reflection upon epistemological beliefs. At this point, it may be better to say that GTAs’ epistemological transformation should be an explicit goal of laboratory instruction. Conceptualizing teaching experiences as such would go a long way towards answering questions about what purpose teaching assistantships serve for the graduate students in their graduate studies.
Chapter Five:

Conclusions

Graduate teaching assistants (GTAs) have been described in a number of ways ranging from a “forgotten army” (Cottrell Scholars Collaborative, 2014) to “donkey’s in the department” (Ramos, 2002). It is hoped that this dissertation will be a catalyst towards shifting the view of GTAs to simply yet importantly as *learners* within the laboratory environment. Too often, consideration of GTAs has been based upon what they can provide for the department or how they can provide it better. Viewing GTAs as *learners* shifts focus towards what teaching assistantships offer graduate students. Conceptualizing teaching assistantships in this way could help them become an integral component of graduate education rather than “time away from research.”

Chemistry departments, laboratory coordinators, and the GTAs should have expectations and goals about what GTAs should and will take away from their teaching experience. It is often assumed that GTAs will make gains in general teaching skills. However, as laid out in the Introduction, relatively few chemistry GTAs plan to pursue careers in academia. Even those who plan to pursue teaching or academia will likely need more preparation than currently gained through laboratory teaching assistantships. Therefore, chemistry departments and the chemistry education community are urged to question how teaching assistantships may contribute towards the scientific aspirations of their learners, the GTAs. This dissertation is a step towards fulfilling those goals.
Two broad questions guided the work of this dissertation: (1) what do GTAs experience in academic laboratories, and (2) what impact and benefit do teaching assistantships have on chemistry graduate students. Findings from this work contributed towards these broad objectives and advanced the underdeveloped research field regarding teaching assistants in chemistry education. The discussion that follows addresses the contributions of this research, limitations of the research, and implications for GTA training and support, laboratory instruction and chemistry graduate education.

**GTAs’ Experiences in Academic Laboratories**

The premise behind this work was that understanding GTAs’ experiences should be the first step in considering the benefits and impact of teaching assistantships. To this end, the study presented in Chapter Two used a phenomenological approach. This theoretical framework had been implemented in prior research on students’ (Sandi-Urena, Cooper, Gatlin, & Bhattacharyya, 2011b) and GTAs’ laboratory experiences (Sandi-Urena, Cooper, & Gatlin, 2011a). As such, the work presented in Chapter Two, joins the previous studies in seeking to understand the meaning of laboratory experiences as lived by the participants.

The phenomenological approach used in this work is very different from other research approaches that seek to analyze learning in the laboratory. The focus on participants’ experiences is especially different from the approaches that seek to determine meaningful learning from faculty and laboratory coordinator perspectives (Bruck, Towns, Bretz, 2012; Bretz, Fay, Bruck, Towns, 2013). In 2007, Casey called attention to the potential of phenomenological studies on laboratory learning. Outside of this work it has not been used within the laboratory setting. Much earlier, Hodson (1990) suggested that a focus on students’ actual experiences in the laboratory could contribute to the long-running debate about the pedagogical value of laboratory
instruction. Therefore, it is within this spirit that the group of phenomenological studies was conducted. These types of studies provide insight into the meaning that the participants give to their experience. In addition to the information gained through the research presented in Chapter Two, the study serves as an exemplar of phenomenological research within chemistry education. It is hoped that it and the related studies will inspire others to spend more time considering and investigating the lived experiences of chemistry learners, which should ultimately provide a better starting point for future curricular design.

Using the phenomenological framework, Chapter Two described the experiences of eleven GTAs involved in an expository laboratory program in three dimensions: Doing, Knowing, and Transferring. GTAs’ perceived role emerged as the interconnecting factor among the dimensions. GTAs viewed themselves as providers of procedural and conceptual knowledge and managers of grading, time and safety. They viewed students as consumers of knowledge responsible for performing experiments. As proposed in the Introduction, knowing what these GTAs experienced in the academic laboratory allowed for a discussion of the benefits available to this group of GTAs, which are discussed in the next section.

**Impact and Benefit of Laboratory Teaching Experiences**

GTAs involved in an expository laboratory program stood to gain general chemistry content knowledge, teaching skills related to communication, and satisfaction helping students. These gains are consistent with what others have reported for teaching assistants (Seymour, 2005). Just as relevant as the gains available to the GTAs were potential gains that were not evident in the study. There was an absence of intellectual discomfort, which has long been associated with the process of intellectual development (Perry, 1970) and epistemological development (Baxter Magolda, 1992; 1996). However, the GTAs’ experiences presented in
Chapter Two was in contrast to a previous study that involved GTAs working in a problem-based laboratory environment (Sandi-Urena, Cooper, & Gatlin, 2011a). Findings from the prior study suggested “appropriate teaching experiences may contribute towards preparing graduate students for their journey in becoming scientists and to embark on successful research” (Sandi-Urena, Cooper, & Gatlin, 2011a). Unfortunately, no such claim could be made for the graduate students described in Chapter Two.

In fact, the GTAs teaching experiences in the expository laboratory appeared counterproductive to the development of more sophisticated epistemologies and views of the nature of science. A series of papers in physics education discussed that counterproductive epistemologies are implicit within many instructional methods and materials (Hammer, 1994; Redish, Saul, & Steinberg, 1998; Scherr and Hammer, 1998). For example, Hammer (1994) referred to verification labs as leading towards counterproductive epistemologies whereas methods that expect students to “generate and critique their own ideas” (p. 181) may lead towards productive epistemologies. A similar effect seems relevant for the GTAs involved in this work. The GTAs described in Chapter Two engaged in teaching filled with messages such as doing is knowing, teaching is telling and chemistry is verification. While it cannot be stated that laboratory teaching caused such beliefs, it is maintained that the GTAs’ experience did not sufficiently challenge these counterproductive epistemological beliefs.

In relation to physics students, Scherr and Hammer (2009) asked:

“Are students treating knowledge as provided by experts, or do they see themselves as having a role in its construction? Do students take the completion of assignments as the end in itself, or do they focus on ideas?” (p. 172)

Similar questions can and should be asked of GTAs and undergraduate students in chemistry.
laboratories. Unfortunately, the GTAs discussed within Chapter Two saw themselves as ‘experts’ and viewed performance of the procedures as the end goal. As a result, the messages about science and learning they were sending to the students may have also been counterproductive.

These findings underscore the need for chemistry educators to consider the experiences of their GTAs. Although it is believed teaching assistantships can be an integral component of the graduate education experience, it did not appear to be of strategic value at this specific program for these teaching assistants. If graduate programs plan to use teaching assistantships to promote scientific development for their graduate students, it is not enough to assume that any teaching experience will lead to fruitful gains.

The impact of teaching assistantships was also addressed through the work on GTAs’ self-images. The work presented in Chapter Three resulted in a model of GTA self-image. It showed that GTAs’ self-images were associated with their prior experiences as students, training and support, beliefs about the nature of knowledge and the nature of laboratory work, and their experiences in the laboratory environment. This GTA self-image model is relevant for laboratory coordinators as well as other science education researchers. Consistent with the case study methods from which it was derived, the factors associated with GTAs self-images should be viewed as propositions for further research or program evaluation. For example, laboratory coordinators have some control over events that take place in training and support meetings, and they are usually involved in the selection or creation of the learning materials used within the laboratory environment. Therefore, they could critique materials and training methods to determine what messages they send to the teaching assistants about chemistry content, about doing chemistry, and about learning chemistry. This type of critical reflection by a laboratory
coordinator may help reveal why GTAs seem themselves as they do. GTAs should also be involved in the process of looking for the underlying messages of their teaching and the learning materials. Ultimately, engaging in these forms of reflection will bring GTAs’ beliefs to light and could provide the base of their continued growth as scientists.

It is unfortunate that so little attention has been paid to the beliefs of GTAs. In 1979, Fenstermacher argued that beliefs could be the most important construct in educational research. Similarly, Kagan (1992) referred to teachers’ beliefs as the “heart of teaching,” and Pajares (1992) agreed on the importance of the construct in research and practice. The underlying message from each of the papers was that understanding teachers’ beliefs would provide far greater insight into their teaching practices. The inclusion of a recent review of research by Bryan (2012) in the Second International Handbook of Science Education certainly suggests the construct of teacher beliefs has gained and sustained usefulness in science education. It is hoped that the work presented within this dissertation contributes to bringing these constructs to light in regards to chemistry GTAs.

It should be noted that focusing on GTAs’ self-images and beliefs is not a one-size fits all approach nor is it a solution to all issues associated with GTAs involved in laboratory instruction. But, with the noted difficulties GTAs have implementing inquiry-based instruction (Roehrig, Luft, Kurdziel, and Turner, 2003; Seymour, 2005), it is reasonable to expect that attempting to understand the why behind GTAs teaching could have a substantial impact on laboratory instruction. Again, though, this impact may not be immediate, and changes in beliefs and practices may not be noted within the first semester, as was the case for Lyle in Chapter Four. Further, the path between beliefs and practice is not always a direct one. Based on similar literature in teacher education, it should not be assumed there would be complete alignment
between beliefs and practices (Bryan, 2012; Lederman, 1999; Lederman & Zeidler, 1987; Southerland, Gess-Newsome, & Johnston, 2003). This was especially true for novice teachers. Novice teachers often have a hard time translating their beliefs into practice. Likewise, new GTAs will need help and guidance to understand how their beliefs are influencing their actions in the laboratory. Therefore, coordinators should think of GTAs’ learning trajectory as something that will continue throughout and beyond initial laboratory teaching experiences. The GTAs are more than tools for instruction. In the long run, a department continually focused on GTAs’ self-images and beliefs is one better prepared for the development of all their learners.

Self-image findings are also relevant from the standpoint of graduate education. Development of a teaching self-image is related to and perhaps contributes towards graduate students’ identity formation (Baxter Magolda, 2008) and acculturation into a scientific community (Bhattacharyya and Bodner, 2014), which are central components of graduate education. As highlighted in the Introduction, nearly all chemistry graduate students hold a teaching assistantship at some point. However, approximately two-thirds of chemistry graduate students do not continue with careers in academia (American Chemical Society, 2002; Golde & Dore, 2001). Further, it is commonly accepted that the main goals of doctoral programs are related to the preparation of researchers (American Chemical Society, 2012). Therefore, graduate programs and their students could benefit if experiences in academic laboratories supported a GTA self-image and underlying epistemological stance that is also productive in the research context (Kinchin & Hatzipanagos, 2009).

Limitations

Qualitative inquiry focuses on generating “rich, detailed descriptions of people and places” (Bodner, 2004, p. 619). The purpose of such work is not to generalize to a population.
Rather, the intent is to draw meaning from the participants’ stories that may transfer into other similar context. Ultimately, it is the readers’ responsibility to “interpret for themselves the meaning and significance of the research” (Bodner, 2004, p. 620.). Authors are responsible for providing sufficient background information so that readers may gage the transferability of the findings into their context. Therefore, readers are encouraged to consider how the findings from this work transfer into their context. For example, GTAs’ experiences in the expository program may not be transferable to contexts that use other instructional styles. Likewise, GTAs may bring different background experiences than the two GTAs in Chapter Four. Since there are more than two laboratory instructional styles (Domin, 1999), findings for this work may be most transferable to GTAs in expository and problem-based laboratory settings. Nonetheless, it is expected that the self-image model would be useful to consider GTAs’ self-image construction in multiple laboratory formats.

The time frame of this work also poses a limitation. By restricting the study of GTAs self-image development in Chapter 4 to one semester, the findings do not illustrate self-image development in continuous semesters or years of teaching. It is assumed that GTA self-image development would not stop, and the model derived in Chapter Three would be useful for exploring GTAs continued development. In fact, the model was derived from GTAs who had multiple semester of teaching experience, at least in one of the laboratory settings.

During this work, GTAs’ teaching practices were not observed. Observations were not part of the research for different reasons for the phenomenological study and the case studies. First, observations are not informative in phenomenological studies. Phenomenology seeks to determine the meaning of lived experiences through the information that presents itself within the consciousness of the participant (van Manen, 1990). It is a first-person account.
Observations, however, are made based upon the preconceived notions the researcher brings to the environment. Within phenomenology, researchers are called to bracket preconceived notions and focus solely on what presents itself to the participant. As such, observations would have carried little meaning and were thus not part of the research methods.

In the case-study approach presented in Chapter 4, observations would have presented a different challenge. They would have altered the natural ecology of the laboratory environment. GTAs may have acted differently upon being observed. They may have aligned their practices to the expectations of observers. Further, beliefs and practices are not always in total alignment (Bryan, 2012; Goertzen et al., 2010a). Therefore observing GTAs overt behaviors would have provided little relevant information on their beliefs and changes or lack thereof. More problematic, consistent observation could have increased GTA’s reflection upon who they were in that environment. Therefore, to avoid altering the laboratory environment and generating a source of continual prompting, observations were not included within these studies.

**Implications**

Graduate students serve multiple roles in a chemistry department. They are students, researchers and teaching assistants, often at the same time. As such, research that focuses on their experience stands to impact both the context in which they teach and the context in which they study. Therefore, findings from this work provide implications for laboratory coordinators who oversee their teaching responsibilities, laboratory curriculum designers, and chemistry department chairs and graduate coordinators who oversee the quality of the graduate program. As such, implications are provided below for GTA training and support, laboratory reform, and graduate education.
Implications for GTA training and support. Concerned educators have created GTA training and support programs to inform chemistry graduate students about how to teach (Gardner & Jones, 2011; Marbach-Ad et al. 2012; Pentecost et al. 2014). These often involve crash courses or lessons on pedagogy. Despite being informative, these attempts may not operate at the level of beliefs of new graduate students. This work suggested that GTA training is likely to have a greater impact if it becomes more responsive to GTAs’ incoming beliefs. Therefore, bringing GTAs’ beliefs to light and providing ample time for GTAs to reflect upon them should be an explicit goal of training and support.

At a base level, coordinators should consider how GTAs’ self-images are likely to support or hinder what they were being asked to do. Chances are good that GTAs will enter a program with teacher-centered beliefs that contradict many inquiry-based laboratory environments. Depending upon the goals and philosophy of the program for which they are expected to teach, training and support could be designed to promote healthy conflicts between GTAs’ self-images and the laboratory program’s goals. Teacher education literature suggests that discontentment with prior beliefs is a precursor to belief change (Feldman, 2000; Kagan, 1992; Southerland et al., 2003; 2011). Likewise, Shea’s and Lyle’s cases in Chapter 4 support this stance. Therefore, attending to GTAs’ beliefs and areas for which they may be discontent could be a productive strategy to push for lasting change in their self-image or conceptualization of laboratory work. It should be noted that this support would have to involve more than telling GTAs why they should teach in a certain way. It may seem easier, from a coordinator’s perspective to simply tell GTAs what to do and how to teach, and they might do it as told. However, as Goetrezn et al. (2010a) pointed out “helping TAs learn to ask questions will not necessarily help them share [...] motives for questioning.” In other words, focusing training
specifically on GTAs’ teaching practices or behavior is not likely going to help GTAs develop more productive views of laboratory work or their role, which could ultimately guide their behaviors. Therefore changing GTAs’ beliefs on laboratory instruction and their role as teaching assistants should be a primary goal of training and support.

The potential implications of this work are exemplified by changes one of the programs made to GTA training and support after being informed of these research findings. The outcomes of these changes were not evaluated as part of this dissertation. One of the institutions began implementing strategies focused on bringing GTAs’ self-images and beliefs to light. During weekly GTA staff meetings, GTAs were asked to consider how their roles would change as the laboratory format changed; GTAs were asked to consider which student goals they felt most and least comfortable with helping students achieve, and GTAs were prompted to consider in short writings how academic laboratory work related to chemistry research. These questions or prompts were usually discussed by the GTAs first in small groups before the groups rejoined to report back to the other groups what they discussed.

These strategies were implemented with the intent of bringing GTAs’ beliefs to light and providing an environment of reflection with their peers. Although the outcomes were not evaluated as part of this work, they have backing in terms of promoting the critical reflection that is documented as a necessary component of teachers’ belief change (Bryan, 2012; Pajares, 1992). Guskey (1986) even suggested that lasting change in beliefs results only after teachers notice a change in student learning outcomes. From that perspective, it is important for coordinators to provide continued support and discussion about what is happening in the laboratory and its relationship to GTAs’ beliefs. To do so, coordinators may consider using student feedback
through surveys or interviews during staff meetings to drive discussion on what students may be learning from the laboratory program.

Although published chemistry GTA training programs usually do not take GTAs self-image or beliefs into account, laboratory coordinators interested in doing so may be able to draw from teacher education literature. However, as pointed out throughout this work, readers should consider upfront that there is a major difference between teachers and GTAs. Specifically, GTAs have not made a professional choice to become or to be a teacher. In-service teachers are professionals who likely hold an identity as a teacher. Chemistry GTAs will most likely become a professional outside of teaching, and are in the process of forming identities as scientist. The GTA self-image that they form is related to identity development, but it is not the same as saying a graduate student has an identity as a teacher. Research has not addressed how this difference of choice affects GTAs’ orientations to teaching or their practices. Further, reported professional development for teachers usually involves in-service teachers who already have an identity as a professional teacher. Because of these factors some teacher education literature may not translate well for support and training of GTAs. In light of these differences there are some ideas on teachers’ beliefs that resonate with this dissertation and appear appropriate for working with GTAs.

One particular professional development model that laboratory coordinators may be able to adapt comes from Rushton et al. (2010). They provide a 10-day program designed to focus on chemistry teachers’ conceptions of inquiry. Each day was focused around a central question such as: “what is science”, “what is inquiry”, “how can we model our thinking for our students,” and “how do students learn” (p. 44-45). It is worth reviewing the entire program as many aspects could be incorporated into GTA training.
From the standpoint of this dissertation one thing is noticeably absent from the training program (Rushton et al., 2010). There were no explicit questions or days devoted to “what is the role of the GTA” or “who am I as a GTA in this inquiry process.” Although it could be argued that this self-examination is implicit within professional development, there is no reason it should not be made explicit. This seems incredibly important for GTAs who usually have not made the professional choice to be a teacher, have not taken education courses, and have no formal teaching experience. Actually, questioning the role of the GTA and how they see themselves in that role — their GTA self-image — would seem to be the most relevant questions for training programs. As such, they should be an explicit and reoccurring component within any GTA training program.

**Implications for laboratory reform.** While this work has focused specifically on graduate teaching assistants, it holds implications for laboratory reform. Calls for laboratory reform are not new (Singer et al., 2006), but they have been almost exclusively made in regards to students. One exception was Hodson’s (1992) proposal to change assessment practices in secondary science laboratories for the benefit of the students and teachers. In Hodson’s (1992) view,

“We can choose a teacher-proof, soulless mechanical approach that promotes bad science and dull, unimaginative teaching, or we can choose an approach that reflects good scientific practice and good pedagogy, and promotes the professional development of teachers towards genuine connoisseurship” (p. 142).

This dissertation supports Hodson’s (1992) stance and extends it to the tertiary level; laboratory reform is in the best interest of the GTAs who facilitate the laboratory curriculum.

Universities that employ their own graduate students to facilitate laboratory courses
should consider GTAs during all aspects of instructional design. Potential learning gains for GTAs and their expected teaching ability should be considered during instructional design. It should not be overlooked that entering graduate students are usually not teachers. This circumstance is often addressed by offering some form of support after the laboratory curriculum has been designed. However, it should also be taken into account from the beginning of laboratory design. The laboratory curriculum will need to survive with teachers who are not teachers. That is no doubt a challenging task, which further highlights the need to consider GTAs during all aspects of curriculum design.

**Implications for graduate education in chemistry.** The Introduction of this dissertation began by noting that practices in chemistry graduate education have been questioned and challenged. Specifically, the Introduction highlighted a recommendation to think more strategically about teaching assistantships and how they may be used for the professional development of graduate students (American Chemical Society, 2012). Findings from this work on GTAs’ experiences present avenues for the chemistry education community to use teaching assistantships more strategically within graduate education programs.

For far too long, teaching assistantships have been viewed as time away from research. However, this work joins a small but growing body of evidence that suggests GTAs stand to gain skills relevant to research and scientific development through their teaching experiences (Feldon et al., 2011; French & Russell, 2002; Sandi-Urena, Cooper, & Gatlin, 2011a). It is important to note that this would not require more to be added to a graduate program. Rather, since almost all graduate students are already being asked to teach, graduate programs could make use of the time their graduate students engaged in teaching to address goals of graduate education, namely epistemological development and acculturation of scientific norms. This work suggests that
teaching experiences can play a role in graduate students’ epistemological development and their construction of a self-image. Therefore, chemistry departments should strive to promote this development through the use of teaching assistantships.

It is hoped that this work will promote rethinking of the GTA position. It is past time to view teaching as an integral part of the graduate education experience, a part that shares the same overall goal as chemistry graduate education: “To teach graduates how to enter a new field, how to pose worthwhile problems, how to be productive in generating valuable new knowledge, and how to evaluate critically their findings and those of others” (American Chemical Society, 2012, p. 7). Conceptualizing teaching assistantships as preparation for scientific development would be a start to realizing the call from the American Chemical Society (2012) to use teaching assistantships more strategically within chemistry graduate education. Further, it would result in teaching experiences that contribute towards graduate students’ journeys towards becoming scientists.
References


Appendix A
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142
December 28, 2009

Guillermo Santiago Sandi-Urena, PhD
Dept. of Chemistry

RE: Exempt Certification for IRB#: 108639I
Title: Graduate Teaching Assistants' Perspectives of Undergraduate Chemistry Laboratory Instruction

Dear Dr. Sandi-Urena:

On December 22, 2009, the Institutional Review Board (IRB) determined that your research meets USF requirements and Federal Exemption criteria 2. It is your responsibility to ensure that this research is conducted in a manner reported in your application and consistent with the ethical principles outlined in the Belmont Report and with USF IRB policies and procedures.

Please note that changes to this protocol may disqualify it from exempt status. It is your responsibility to notify the IRB prior to implementing any changes.

The Division of Research Integrity and Compliance will hold your exemption application for a period of five years from the date of this letter or for three years after a Final Progress Report is received. If you wish to continue this protocol beyond those periods, you will need to submit an Exemption Certification Request form at least 30 days before this exempt certification ends. If a Final Progress Report has not been received, the IRB will send you a reminder notice prior to the end of the five year period; therefore, it is important that you keep your contact information current with the IRB Office. Should you complete this study prior to the end of the five-year period, you must submit a Final IRB Progress Report for review.

Please reference the above IRB protocol number in all correspondence regarding this protocol with the IRB or the Division of Research Integrity and Compliance. In addition, you can find the Institutional Review Board (IRB) Quick Reference Guide providing guidelines and resources to assist you in meeting your responsibilities in the conduction of human participant research on our website. Please read this guide carefully. It is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-2036.
Sincerely,

Krista Kutash, Ph.D., Chairperson
USF Institutional Review Board

Cc: Various Menzel, CCRP, USF IRB Professional Staff
    Todd A. Gatlin
Appendix C:

Sample Case Narrative: Avery, a GTA from the expository program

GTA narratives were created based upon analysis of the GTA’s interview transcript. Each researcher analyzed the interview separately before working together to create the narrative. Avery’s narrative is presented below as an example of the outcomes of this process.

Avery’s experience is defined by her perceived role and responsibilities. They place her at the center of the instructional environment as a provider of answers, “knowledge”, procedures, information, instructions, and grades.

The construction of the learning environment and self-image as GTA are informed by her experience as an undergraduate student (she tries to emulate her own teachers) and by her interpretation of the purpose of the weekly new-GTA training sessions.

She takes to herself to know everything, understand everything, and do everything with the purpose of being able to explain everything, demonstrate and show everything, answer all the questions appropriately and correctly, and help the students in every possible way so that they can “do” things “correctly”. She explicitly sees these as her duties and responsibilities as a GTA and draws those ideas from the model to which she was exposed as an undergraduate student. It is also reinforced by her interpretation of the purpose of the GTA training which to her functions as a way to prevent GTAs from ‘not knowing’, ‘not being able to show, explain, answer, demonstrate’, and to prevent things from not working ‘correctly’ during the lab.

The entire experience revolves around her and the knowledge she needs to pass on to her students: procedural and basic (factual) knowledge. She rarely mentions processing skills such as ‘figuring out’, ‘thinking through’, ‘problem solving’, ‘discussing’, ‘sorting information’, etc. Her references to students working in groups are strictly attached to practical convenience (like distributing work to make things ‘easier’ or because a single person cannot ‘do’ the entire thing) but there are no attributions of this work-in-group to meaningful social interactions like sharing ideas, clarifying concepts, self- or others-explaining, etc. There is very little reference to changes in the laboratory environment (including affective aspects) over the course of the semester; the laboratory is “static” and can be described with a single “shot” or “picture”.

Avery’s expectations from the students are simple: do what they have to do and learn from doing. Apparently, she does not even expect them to prepare or read the instructions from the manual—she writes them on the board for them to follow. She does not show expectations of them thinking through, discussing, or understanding their work.
Writing, techniques and ‘basic knowledge’ are the gains she sees for her students, though writing seems to take precedence over kind or extent of understanding. Avery views her students as passive recipients of knowledge whereas she is the “provider”. She makes no mention of students ‘frustration’ or any other kind of conflict. She describes them as ‘confused’ but apparently attributes that to their not listening to her or not reading. From her discourse it is inferred that students may show up unprepared and still be able to “do” the lab in part because she compensates for their lack of engagement.

Her understanding of the lab is in accordance with her views of knowledge and learning. Several of her references to knowledge resemble the views of an absolute thinker: knowledge is transferable and accumulative; knowing is expressed by recalling; knowledge is correct or not. She associates learning with “being told what to do” and with “doing”.

Avery’s teaching experience does not challenge in any ways her views about learning and knowledge, quite contrary it contributes to consolidating her beliefs. Her experience in this instructional environment does not provide any evidence of promoting reflection about her own learning, thinking or practice of teaching. Her reported gains are limited to reviewing concepts to which she refers as ‘basic knowledge’. Her practice may be described as “superficial teaching” approach.

Avery seems to be genuinely interested in giving her students the best experience possible (she does her ‘level best’) and comes across as very diligent, self-motivated, reliable and responsible. She displays a sound sense of responsibility that seems to go beyond just doing the minimum possible work.
Appendix D:

Pre-Teaching Interview protocol

1. Introductory aspects

We consider very important for the general chemistry program to understand TAs’ approach to teaching and their teaching background as well as their own experience as students in undergraduate labs. The best way to accomplish this goal is to listen to the TAs and give them the chance to tell us about their opinions. We want to learn from you, to be educated by you. This is not part of your evaluation as a TA; we are simply listening. The conversations will be audio taped just as a means for us to go back and review what was said. This interview is confidential; you will not be identified. During the conversation, I may take notes that most probably will be reminders to myself of something I want to inquire about later, or something especially interesting you said. I will not jot down things about you, you are not under observation. Please feel free to spend as much time as you need or want on any given topic. You do not have to reply to a question if for any reason you do not feel comfortable. We may stop the conversation at any time you wish or need to. Do not feel like I am being too insistent if I ask some follow up questions to your comments. It is our interest to clearly understand what you mean; we are trying to get to a deeper level of understanding. Once again, this interview is confidential and does not have any effect on your teaching assignments. There are no correct answers; we just want to listen to your comments. We very much appreciate your taking the time for this conversation. We will start with some general background information and then we will move on to aspects related to your thoughts about teaching in the lab environment.

2. Background

a) What was your undergraduate major in?

b) What triggered your interest in chemistry?

c) Would you say that your undergraduate lab experience was a motivating factor in your decision to pursue a graduate degree?

d) Did you do undergraduate research? Have you done graduate research before?

e) Have you decided on a concentration area?
3. General Chemistry Lab experience as a student.

   a) DESCRIBE EXPERIENCE AS GEN CHEM STUDENT. How would you describe your overall experience as a student in the general chemistry lab?

   b) DESCRIBE GEN CHEM LAB TAKEN AS UNDERGRAD. Would you please briefly describe your General Chemistry Lab? Would you describe a typical lab session? Promters: Was it taught by a Faculty or a TA? Was it a GTA or an UTA? How often did the lab meet? How was it structured, what kind of activities were performed? Were the procedures and goals given to the students? Was group used regularly, how large were the groups? Was cooperation encouraged?

   c) WHAT WAS LEARNED. What would you say you learned or gained from your General Chemistry Lab? Would you say that your lab experience somehow showed you what “real” chemistry labs are like? Did you engage in inquiry or discovery? Do you think that the experiences you had in that general chemistry lab course had any impact on the way you think of chemistry problems?

4. Previous experience as a laboratory Teaching Assistant. [Only if applicable]

   a) PREVIOUS EXPERIENCE. Have you taught laboratory before? If not, move to Number 5. What courses and how many semesters or terms.

   b) DESCRIBE LABS TAUGHT. Would you please describe the labs you taught? Would you describe a typical lab session? Promters: How often did the lab meet? How was it structured, what kind of activities were performed? Were the procedures and goals given to the students? Was group-work used regularly, how large were the groups? Was cooperation encouraged?

   c) What were your role and responsibilities as a TA?

   d) Did you receive any training before starting as a TA? Was there any follow up training or any assessment and observation? Were there TA meetings held? What was done during those meetings? Could you please describe a TA meeting?

5. Expectations in relation to upcoming experience as a laboratory Teaching Assistant.

   a) HOW DO YOU FEEL ABOUT TEACHING GEN CHEM LABS?

   b) WHAT DO YOU THINK SHOULD BE YOUR DUTIES AND RESPONSIBILITIES AS A TA? May need to clarify that this does not refer to the perfect, ideal TA but to him/herself.

   c) WHAT KIND OF EXPERIENCE DO YOU THINK GEN CHEM STUDENTS SHOULD HAVE? Follow up with what kind of gains do you think they should take away from being in the lab? What kind of experience do you want to create for them?

   d) Is there anything you’d expect to gain from being a TA?

   e) Would you please describe your expectations from your students?
6. Conceptions about how students learn
   
a) What do you think should be the main objectives of General Chemistry Lab?
b) What do you think students should learn from the General Chemistry Lab?
c) How do you think students would learn best in the General Chemistry Lab?

7. Wrap up
Thank you again for your valuable collaboration. Once more, this interview is confidential, it is not part of your evaluation, and it will not affect your teaching assignments.
Appendix E:

Post-Teaching Interview protocol

1. Introductory aspects [read to interviewee]

We consider of outmost importance for the general chemistry program to understand TAs’ approach to teaching and their teaching background as well as their own experience as students in undergraduate labs. The best way to accomplish this goal is to listen to the TAs and give them the chance to tell us about their opinions. We want to learn from you, to be educated by you. This is not part of your evaluation as a TA; we are simply listening. The conversations will be audio taped just as a means for us to go back and review what was said. This interview is confidential; you will not be identified by name and only the transcriber will listen to this tape. The transcriber is bound to confidentiality, as well. During the conversation, I may take notes, which most probably will be reminders to myself of something I want to inquire about later, or something especially interesting you said. I will not jot down things about you; you are not under observation.

Please feel free to spend as much time as you need or want on any given topic. You do not have to reply to a question if for any reason you do not feel comfortable. We may stop the conversation at any time you wish or need to.

Do not feel like I am being too insistent if I ask some follow up questions to your comments. It is our interest to clearly understand what you mean; we are trying to get to a deeper level of understanding.

Once again, this interview is absolutely confidential and does not have any effect on your evaluation as a TA or your teaching assignments.

There are no correct answers; we just want to listen to your comments.

We very much appreciate your taking the time for this conversation.

We will start with some general background information and then we will move on to aspects related to your thoughts about teaching in the lab environment.

2. Current experience as a laboratory Teaching Assistant. [Use prompts and follow-ups as necessary]

f) DESCRIBE STUDENTS’ EXPERIENCE.

How would you describe your students’ lab experience? What do you think your students have learnt from the lab experience?
g) COMPARE STUDENTS’ LAB EXPERIENCE AND OWN EXPERIENCE AS STUDENT.
If you compare the kind of experience your students were exposed to with your own experience as a student, what would you say?

h) DESCRIBE OWN EXPERIENCE AS TA. How would you describe your own experience as a TA in this teaching environment? What are your duties? What do you think TAs in general gain from their experience teaching these labs? Does TA’ing have any impact on grad students’ professional development?

3. Conceptions about how students learn

d) What do you think should be the main objectives of General Chemistry Lab?
e) What do you think students should learn from the General Chemistry Lab?
f) How do you think students would learn best in the General Chemistry Lab?
g) Do you think your opinions have been influenced in any way by your current TA experience?

4. Wrap up

Thank you again for your valuable collaboration. Once more, this interview is confidential, it is not part of your evaluation, and it will not affect your teaching assignments.
Appendix F:

GTA Survey

Following you will find a series of statements or items. Please read them carefully and select the letter option that best describes your agreement. Mark all of your responses on the scantron sheet. Enter your last name, all other spaces may be left blank.

There are no right and wrong answers to this survey; we are interested in knowing your “first thought”. Do not over-elaborate on the meaning of the statements. If you do not understand/know the meaning of a word, please ask for clarification.

Your responses are confidential; your supervisor will not have access to this information.

PLEASE, DO NOT WRITE ON THIS BOOKLET.
PART I

1. I consider teaching laboratories relevant for my professional development
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

   Please, mark the letter that corresponds with your agreement about the importance of each individual item (items 2-8) in the General Chemistry lab:

2. Learning and practicing of lab techniques (like titrations and filtration)
   (A) Unimportant     (B) Moderately Important     (C) Very Important

3. Enhancement of problem solving skills
   (A) Unimportant     (B) Moderately Important     (C) Very Important

4. Development of skills to design and implement lab procedures
   (A) Unimportant     (B) Moderately Important     (C) Very Important

5. Strengthening of communication skills
   (A) Unimportant     (B) Moderately Important     (C) Very Important

6. Development of group-work skills
   (A) Unimportant     (B) Moderately Important     (C) Very Important

7. Verification of fundamental chemical concepts
   (A) Unimportant     (B) Moderately Important     (C) Very Important

8. Learning safety in the chemistry environment
   (A) Unimportant     (B) Moderately Important     (C) Very Important

9. Reinforcing the concepts learnt in lecture
   (A) Unimportant     (B) Moderately Important     (C) Very Important

   Please, mark the letter that corresponds with your agreement with each item (items 12-19) regarding students’ learning. Each item starts with the prompt: “Laboratory students learn best when…”

**Laboratory students learn best when…**
10. …well-detailed procedures are given to them
    (A) strongly disagree  (B) disagree  (C) neutral  (D) agree  (E) strongly agree

11. …instructors find an effective way to transfer what they know to students
    (A) strongly disagree  (B) disagree  (C) neutral  (D) agree  (E) strongly agree

**Laboratory students learn best when…**
12. …they know the expected outcome of the experiments
    (A) strongly disagree  (B) disagree  (C) neutral  (D) agree  (E) strongly agree
13. …they have to devise and implement the experimental procedure
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

14. …the instructor gives examples of calculations before the experiment
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

15. …they are allowed to create their own knowledge as they progress through an experiment
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

16. …they are first demonstrated the experiment/procedure by the instructor (either with the actual
    instruments or with diagrams or animations) before performing it
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

17. …they discuss amongst themselves and try to find their own solution to their questions or
    problems
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

Please, mark the letter that corresponds with your agreement with each individual item (items 18-29):

18. A General Chemistry Laboratory course is necessary only for majors that require higher-level
    chemistry courses (biochemistry, analytical, organic, etc)
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

19. It is unrealistic to expect students to figure out things in lab unless they have already covered the
    topics in lecture.
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

20. Effective teaching occurs when instructors help students to carefully and accurately follow
    procedural instructions
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

21. It is the role of lab instruction to acquaint students with scientific experimental/research practices
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

22. Knowledge is already existing, it is verified through experiments but cannot be created by
    students during lab activities
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

23. Knowledge is either right or wrong
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

24. Accuracy of results is a good indicator of student’s understanding of the lab
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree

25. It is important that a student or group get the expected results; otherwise, they may get the wrong
    impression about scientific processes.
   (A) strongly disagree (B) disagree (C) neutral (D) agree (E) strongly agree
26. Group work promotes laziness in students who like to rely on others doing the work for them
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

27. The way I was taught in the General Chemistry Laboratory worked for me; I think it should work for my students
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

28. A practical exam requiring students to demonstrate proficiency in laboratory techniques (such as filtration, transferring of liquids, and titration) would be appropriate at the end of the semester.
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

29. I am interested in developing my teaching skills
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

Following you will find a series of statements or items. Please read them carefully and select the letter option that best describes your agreement. Mark your responses on the scantron sheet unless otherwise indicated. Enter your last name, all other spaces may be left blank.

There are no right and wrong answers to this survey; we are interested in knowing your “first thought”. Do not over-elaborate on the meaning of the statements. If you do not understand/know the meaning of a word, please ask for clarification.

Your responses are confidential; your supervisor will not have access to this information.
PART II
PRIOR GENERAL CHEMISTRY LABORATORY EXPERIENCE AS A STUDENT

Please base your responses on your own experience as a General Chemistry Laboratory student.

1. My laboratory section was only for chemistry and/or biochemistry majors.
   (A) Yes  (B) No

2. The laboratory objectives for the experiments were known beforehand (from the lab manual or given by the instructor).
   (A) Yes  (B) No

3. The experimental procedures were known before the lab session (from the manual or given by the instructor).
   (A) Yes  (B) No

4. The experiments were completed in one lab session.
   (A) Yes  (B) No

5. There was a practical end-of-course laboratory exam.
   (A) Yes  (B) No

6. There was a theory/written end-of-course laboratory exam.
   (A) Yes  (B) No

7. Work was done individually or in pairs.
   (A) Yes  (B) No

8. The reports were written individually.
   (A) Yes  (B) No  (C) Does not apply

9. The reports were weekly and due the week after the experiment was performed.
   (A) Yes  (B) No  (C) Does not apply

10. The instructor/teaching assistant lectured at the beginning of the lab session.
    (A) Yes  (B) No

11. The procedure was discussed at the beginning of the lab session.
    (A) Yes  (B) No

12. Experiments were focused on verifying well-established knowledge, for example determining the molecular weight (molar mass) of a compound, or some thermodynamic constant.
    (A) strongly disagree  (B) disagree  (C) neutral  (D) agree  (E) strongly agree

13. Data manipulation (calculations) and interpretation were discussed previous to the experiment.
    (A) strongly disagree  (B) disagree  (C) neutral  (D) agree  (E) strongly agree

14. Discussion with other students during the experiments was common.
    (A) strongly disagree  (B) disagree  (C) neutral  (D) agree  (E) strongly agree
15. There were quizzes to assess students’ preparation and/or understanding of the experiment
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

16. Students were encouraged to develop or modify their experimental procedures
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

17. Achieving the established goal counted for an important portion of the experiment grade
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

18. Accuracy in achieving the established goal was a measure of success in the lab experience
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

19. There were activities aimed at enhancing communication skills (posters, presentations, talks, group discussions, etc)
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

20. The instructor was expected to give clear straight answers to student questions (even if s/he failed to do so)
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

21. When asked a question, the instructor was expected to make students think through the problem to find the answer (even if s/he failed to do so)
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

22. Emphasis was placed on correctly learning the laboratory techniques
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

23. The laboratory teaching methodology helped me understand the process of scientific research
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

24. The laboratory format made me more excited about majoring in chemistry
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

25. I developed critical thinking skills in the lab
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree

26. I developed problem-solving skills
   (A) strongly disagree   (B) disagree   (C) neutral   (D) agree   (E) strongly agree