EXPLORATIONS OF CHEMISTRY GRADUATE STUDENTS' PROFESSIONAL TEACHING ASSISTANT ROLE-IDENTITIES: CONNECTING THE SEEN TO THE UNSEEN

By

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I dedicate this work to my husband, Brent Frick. I would have abandoned this adventure long ago - you convinced me to keep moving forward. Thank you for saying, "it takes as long as it takes."

ACKNOWLEDGEMENTS

It has taken a significant number of people to complete this research project. Thankfully I am part of a scholarly community that supports the growth of knowledge. In the Mathematics and Science Education (MSE) Doctor of Philosophy program, I was expected to become members of a scholarly community, even if our goal is not to go into academia. I believe that the MSE program faculty interactions with students continuously promotes the growth of a scholarly identity. As a researcher, Dr. Amy Phelps pushed me past boundaries and cared enough to make me feel uncomfortable - congratulations. I think that makes you smile because you know I might have learned something. I am very grateful that you were raised by two math teachers. This research could not have been completed without your guidance and your willingness to go along with whatever direction I wanted to pursue, up to and including teaching a bunch of scientists how to teach. Dr. Greg VanPatten and Dr. Angela Barlow, I appreciate your leadership and support in the implementation of the professional development for chemistry graduate teaching assistants. Without leaders that were willing to embrace change, I could not have completed this research. I would like to thank all my fellow graduate students in MSE, past and present, for the support and friendship you have given me over the years; particularly those that contributed to making sure I followed my curiosity to a completed dissertation: Heather Barker, Josh Reid, Kristen Heartland, Candace Terry, Lucy Watson, and Jan Cathey, thank you for supporting my research, Skype writing, and being my sounding boards – I will miss you all the most.

ABSTRACT

Middle Tennessee State University has a diverse and impactful group of graduate students in its chemistry department. Many of these students worked as instructors for introductory laboratory classes. This dissertation focused on their developing role-identity as the graduate teaching assistants (GTAs). In the Spring semester of 2017, some of the GTAs in the chemistry department participated in a six-workshop professional development, implemented for this study. The workshops were designed to enhance knowledge and practices related to chemistry education. I used phenomenological research practices to gather qualitative evidence about the beliefs and practices of GTAs as science teachers. I used three previously developed and validated analytical tools to collect information related to the GTA's strengths (Clifton StrengthsFinder Assesment), teaching practices (Reformed Teaching Observation Protocol), and beliefs about teaching (Teacher Beliefs Interview). I used notes and recordings of the professional development activities to summarize the workshops. I used the evidence to compile the stories of ten graduate students. In general, graduate students found that the workshops instilled a sense of community among the GTAs and most attendees appreciated the experience. The professional development reassured graduate teaching assistants of their identity and authority in the classroom; although, they were not all impacted equally. The master's GTAs differed in their thoughts related to the epistemological development of students when compared to more sophisticated ideas of doctoral students that participated in the majority of workshops.

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CHAPTER ONE: INTRODUCTION

As a student, my research interest has involved the teaching and learning of chemistry education skills and practice, first as an undergraduate preparing to be a high-school teacher at a state university in the northern midwest United States and again while attaining my master's and doctoral degree in chemistry at a state university in the southern United States. As chemistry students, we are trained to explore and utilize the interactions occurring between and within elements. I enjoy the ability to interpret the world through the lens of atomic particles. To me, there is something beautiful about the atomic perspective through which we can visualize what takes place inside a raindrop, from the perspective of billions of tiny water molecules. Knowing that hydrogen and oxygen form intramolecular polar covalent bonds, and each molecule of water interacts with other molecules of water forming intermolecular hydrogen bonds, making the solid ice less dense than the liquid, which is unusual for chemicals. The more precisely I envisioned the interactions between elements, and even the interatomic relationships such as electron affinity, the better I became at predicting the results of what would happen if those elements were combined to form molecules and compounds.

The experience was so enlightening that I wanted to share my joyful understanding with others - and I have for many years, as a tutor and teacher. I found that I am fascinated by the intensity with which some students dislike chemistry and the interactions with mentors that can change their beliefs. As an educator, I have had many opportunities to interact with teachers and students and all levels of education. I wanted to share some of this knowledge with my GTA peers and volunteered to help design a professional development for the chemistry graduate students to facilitate their understanding of science teaching.

Chemistry as a subject is a scientific, societal construct of the knowledge and skills obtained during the learners' formal academic training that creates the foundation of understanding the physical matter in the entire known universe. Everything you hear, eat, breathe, stand-on, touch, and ultimately your physical self is constructed and can be represented chemically. The knowledge gained in more than two centuries of study in the natural sciences continues to grow daily. What is learned in formal education barely scratches the surface of the knowledge yet to be found, and we continue to develop theory and instrumentation that helps model our universe. The content knowledge gained is fascinating to professional chemists, and yet, the subject's allure is not enough to attract many undergraduates. The reality is STEM (Science, Technology, Engineering, and Mathematics) programs often do not to retain individuals long enough to finish a degree in STEM fields. Retention and graduation rates for undergraduate students in STEM fields have been of concern for universities for decades (Strenta, Elliot, Adair, Matier, & Scott, 1994; Carnevale, Smith, & Strohl, 2010; Atkinson & Mayo, 2010). Strenta et al. (1994) reported many students rationale for leaving was that they felt they did not fit into the competitive environment. Mentors, in the form of graduate students, have the potential to impact the retention/graduation rates of undergraduate students.GTAs account for 4.37% of universities' workforce, according to the Bureau of Labor statistics for 2017.

Gardner and Jones (2011) noted that GTAs also have the potential to impact the undergraduate students' understanding of science. GTAs have interactions with undergraduates while teaching laboratory classes for introductory courses, making GTAs an essential component of the undergraduate science experience (Travers, 1989). The course requirements for many chemistry graduate students include preparation in multiple sub-disciplines including biochemistry (studying the complex molecules and the processes related to living organisms) analytical chemistry (determining and designing the correct instrumentation and sampling procedures to obtain chemical composition) and organic chemistry (developing ways to create molecules found in nature, synthetically). Even though master's or doctoral programs in chemistry require extensive training in chemistry content and research methodologies, there is often no professional training in educational issues, although many campuses do offer optional instructions (Shannon, Twale, & Moore, 1998). GTAs are expected to teach without any formal preparation, in many instances with very little pedagogical knowledge or training. After researching science graduate students at 27 universities, Golde and Dore (2001) found that GTAs may have an overblown confidence in their teaching abilities that could be addressed with the same attention and guidance as given to GTAs in practicing research.

Professional Teaching Model

Graduate teaching assistants have become an integral part of the undergraduate STEM experience (Travers, 1989). So, improving undergraduate STEM education requires helping GTAs to engage students in the practices of chemistry in laboratory settings as their teacher. Luft, Kurdziel, Roehrig, and Turner (2004) emphasized the need to develop an understanding of science teacher development when requiring GTAs to attend training. The research on teacher development to engage students in learning science has resulted in a detailed model of the knowledge necessary for science teachers as professionals summarized in Figure 1. This flowchart was created at a summit which collaboratively examined pedagogical content knowledge (PCK) development in science education by multiple experts. (Gess-Newsome,2015). The flowchart in Figure 1 details the numerous factors necessary to be an expert science teacher. In a keynote address at the summit to reexamine PCK in science education, Shulman (2015) explained how the understanding of teachers as professionals had evolved over the past six decades to include successful instructional techniques that required mastery of skills and knowledge about teaching discrete scientific topics. GTAs could use guidance regarding the instructional strategies, habits of mind, and student understandings regarding the vital chemistry topics covered in the laboratories they are teaching. Shulman urged researchers to focus on understanding signature professional pedagogies, habits of cognition, beliefs, and practice forming the identity of science educators.

Classroom Context

GTAs have identities outside of being science educators and have little time or interest in building skills and knowledge associated with teaching. They are working to develop expertise in their sub-discipline of chemistry as a researcher and being asked to study chemistry in a broader context as a student. Departments often share the responsibilities necessary to be a successful science teacher and design the lessons and experiments for the GTAs to implement.

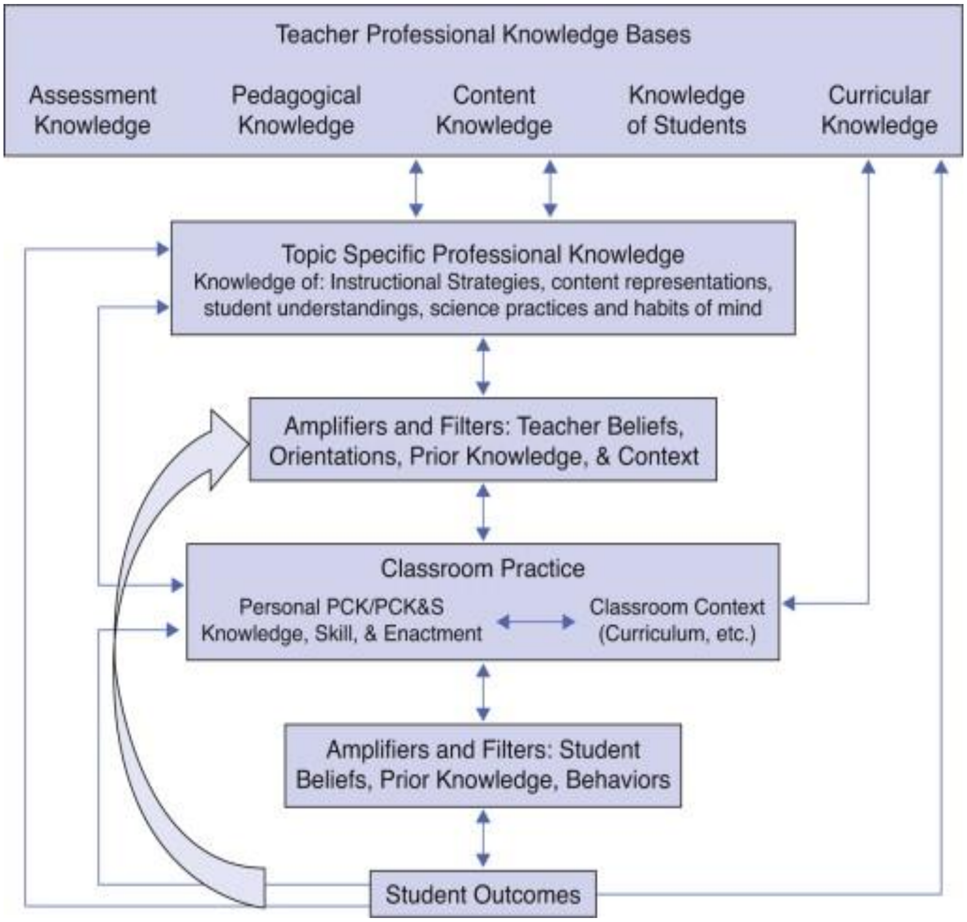


Figure 1. Flowchart of factors that impact science teacher professional knowledge bases. The diagram shows an equilibrium of teacher's PCK and pedagogy content knowledge and skills (PCK&S) tied to classroom context in the book "Re-examining Pedagogical Content Knowledge in Science Education"(Gess-Newsome, 2015. p 31).

Generally, the laboratory coordinators design both the curriculum and assessments, both of which are components of the professional science teacher knowledge foundation required of the teacher (Figure 1). Colbeck (2008) explored the multiple identities of GTAs revealing that research, teaching, and community service (which are the foundations of academic professors) were not integrated for the GTAs. Therefore their identities of researcher and teacher come into conflict. Colbeck recommended the aligning multiple roles in the preparation of doctoral students by creating contexts where they are asked to integrate their understandings of service, teaching, and research and encouraged opportunities for GTAs to explore epistemological understandings.

Sandi-Urena, Cooper, and Gatlin (2011) examined metacognitive and epistemological development of chemistry GTAs as they implemented laboratory experiments using a problem-based learning curriculum. Sandi-Urena et al. (2011) found that the student-centered teaching experience facilitated learning for GTAs as educators and as researchers, indicating an opportunity to integrate at least two of the identities Colbeck (2008) highlighted. The problem-based curriculum used in an undergraduate general chemistry lab required GTAs to work as facilitators. At the conclusion of their research, Sandi-Urena et al. proposed the following question, in relating the teaching of chemistry to the education of swimming, they asked: “Can someone who does not know how to swim be a swimming coach?” (p. 99). In the Sandi-Urena et al. (2011) study a dramatic change to classroom context through problem-based learning curriculum was possible because the materials and skills necessary were presented weekly in coordinated meetings; not all departments have preexisting student-centered instructional practices or coordinated weekly team meetings. Consequently, I looked outside the fields of science and education to obtain a different perspective on development.

The analogies Sandi-Urena et al. (2011) presented for coaching led me to consider business models for professional development. In business, companies will hire coaches of consultants as a way to develop their employees. The coaches do not necessarily have expertise in the product of services related to the company. Instead, their knowledge may be in leadership or team development. In the book *Destination Unstoppable,* Monte (2016) explained how she used the innate talents of players (identified using the CSFA) to develop teamwork and leadership. Monte was not a hockey player her education and experience were in engineering, but she did coach the team including the coach on how to win together by recognizing the strengths of each other. Monte (2016) is a Gallup-certified strengths coach. If GTAs could use their innate talents to assist in the integration of their identities, perhaps they could also develop their concept of science teaching. The ability to promote growth in an individual’s leadership ability may impact their promotion of knowledge understanding, and ultimately build a professional academic identity that integrated research, service, and teaching.

Strengths Development Model

Gallup, an analytics and leadership development company, has been working on strengths development courses for decades by refining strategies that allow people to use individual talents effectively in business and academic industries (Rath & Clifton, 2004; Liesveld, Miller, & Robinson, 2005). Clifton, an educational psychologist who examined teacher and student dynamics (Dodge & Clifton, 1956) studied the patterns of thoughts, feelings, and behaviors of successful individuals. Clifton and Nelson (2010) explained the strengths-based approach as developing people to use their natural talents to succeed. Gallup scientists have identified thirty-four themes of talents in successful individuals (Rath & Conchie, 2008). They claim that effective leaders, teachers, and mentors (regardless of discipline) understand which talents they access to be successful. Leaders combine those talents with knowledge and skills to attain positive results (Liesveld et al., 2005). As explained by Rath and Conchie (2008), leaders who can identify and utilize their strengths, while understanding their weaknesses, to improve engagement, particularly when part of a leadership team. Since GTAs should be leaders in their laboratory learning environment, identifying and understanding the top five talent themes for each GTA may help them to be successful as they mentor and engage undergraduate students in learning chemistry.

Professional Development

Marshall, Smart, and Alston (2016) examined test-scores of science teachers from a variety of school districts that participated in a three-year professional development designed to improve the quantity and quality of guided inquiry-based instructional techniques. The teachers who participated in the professional development had student test scores that consistently exceeded expected growth projections. Addy and Blanchard (2010) found that GTAs needed more opportunities that challenged their instructional practices and beliefs after participating in a reform-oriented teacher certification program.

The researchers “recommend that future studies be conducted to determine the extent of change that occurs throughout the professional development” for both teacher beliefs and practices (Addy & Blanchard, 2010, p. 1068). Similarly, while implementing an intervention to develop GTA knowledge of instructional methods, Lampley (2015) found that GTAs reported intent and behaviors did not align. Lampley requested further examination into the development of GTA PCK. The following phenomenological investigation of chemistry GTAs’ professional development helped to inform the process that occurred as GTAs encountered research from chemistry education in this study.

Constructing Change. In many universities, GTAs are responsible for a great deal of the instruction of undergraduate introductory courses, but instructional training is seldom available and rarely mandatory (Golde & Dore, 2001). Research conducted by Herrington and Nakhleh (2003) found that effective laboratory instruction required the GTA to act as a guide for undergraduate students. There is ample evidence that professional development opportunities for GTAs can be successful. Park (2011) reviewed the implementation of GTAs in North America and produced a multipoint guide highlighting the strengths and weaknesses of programs already in existence. He found that providing professional development opportunities for GTAs created stability for the graduate programs (Park, 2011). The variety of professional development opportunities varied considerably, as did the success of the programs implemented. In chemistry, Marbach-Ad et al. (2012) found that a six-section preparatory class for GTAs significantly improved their average score on student evaluations. The positive effects of professional development can be dramatic, and many GTAs are eager to adopt research-based pedagogy techniques (Bauer, Libby, Scharberg, & Reider, 2013). Although they indicated GTAs were keen to take research-based student-centered pedagogical methods in laboratories, lack of experience and preparation led to struggles for some of the GTAs in the implementation of these activities.

Addy and Blanchard (2010) described the epistemological understanding and development of GTAs resulting from the implementation of reform-based techniques: GTAs in this study felt they had little control over the curriculum and no flexibility in the instruction. Addy and Blanchard (2010) found the GTAs beliefs were more student-centered their practices were not. Sandi-Urena et al. (2011) examined GTAs during their first year as laboratory instructors in a problem-based learning environment. They found that GTAs acted as mentors to their students while gaining valuable scientific training, metacognitive and epistemological growth resulting from experiences within the learning environments even though the GTAs did not feel adequately prepared (Sandi-Urena et al., 2011). GTAs struggle with the formation of a teaching identity and researcher identity while continuing their role as a student (Gardner & Jones, 2011).

Theoretical Framework - Symbolic Interactionism

Symbolic interactionism (SI) works as a qualitative lens with which to view the participants as individuals who accept a mental role in enacting behaviors related to their perceived identity. As suggested by Bodner (2007), research in chemistry education should follow the design prescribed by a theoretical framework. The framework allows other researchers to construct an understanding of a study and assimilate the findings into their conceptual knowledge. The wholistic investigative nature of this study required a structure that would support theoretical structures of chemistry pedagogy and epistemology. The SI framework was developed in sociology, originating from George Herbert Mead's book *Mind, Self, and Society* (1934).

The philosophical underpinnings of the SI framework allow for the investigation of knowledge that is socially constructed to be actively applied in practice, effectively bridging the gap between cognition and behavior. Transformative paradigms such as pragmatism and social constructivism help to define a reality that evolves based on individual needs and interaction with others. Pragmatists are concerned with "what works" to answer a specific research question. In this philosophical paradigm, the focus of researchers is on the outcome and application of the study (Cresswell, 2013; Patton, 1990). Social constructivism, on the other hand, pays particular attention to context and setting of the learning environment (Bandura, 1986; Cresswell, 2013). SI framework allows researchers in chemistry education to define sociological boundaries related to their participants, such as the role and identity that refine our understanding of the pedagogical and epistemological reality presented in the classroom environment. Observations of behaviors and social interactions enable researchers to examine and further understand the conceptual construction of chemistry knowledge (Del Carlo, 2007).

In addition to studying the behaviors, interactionists understand that practice, physical action, is the result of a minded activity. Each step consists of what Meltzer (2003) termed stages of mind. Operations begin with a disturbance to an individual's equilibrium - impulse. Upon the initial pulse, the mind moves into the second stage of perception. Once the mind has perceived the third stage manipulation begins. The two intermediate steps – perception - merging of stimuli with past experiences - and manipulation - deciding how to proceed - resolve physical observations with mental understandings. Finally step four (consummation) occurs when the mind is stable once again, and the action is complete (Meltzer, 2003). This description merges the concept of mind originating from psychology and self from educational research into one construct of understanding. The use of an SI framework is useful for developing understandings of knowledge that is constructed socially and interpreted individually based on past experiences and current environment. Figure 2 provides an overview of the SI framework.

Research Questions

Middle Tennessee State University (MTSU) has grown into the Carnegie classification of doctoral/research intensive recently (Shulman, 2001). Most published research studies concerning GTAs training occurred at universities traditionally ranked as doctoral/research extensive. The Graduate College at our university has progressed from the humble beginnings as a state normal school opened in 1911 to a state teachers' college (1925) offering four-year Bachelor of Science degrees, to a master's granting university in 1952. The university continued to grow, and in 2010 the College of Basic and Applied Science along with the Graduate College transitioned the Doctor of Art's degree in chemistry education into three cutting-edge interdisciplinary Doctor of Philosophy (Ph.D.) programs: Mathematics and Science Education, Molecular Biosciences, and Computational Science.

My master's research looked at the pedological practices of chemistry high-school teachers after a professional development. I was curious about the impact of a professional development on GTAs identities as chemistry instructors. I wanted to understand how my peers perceived themselves as chemistry graduate teaching assistants' their role identity as a GTA, and the impact on beliefs about the professional development.

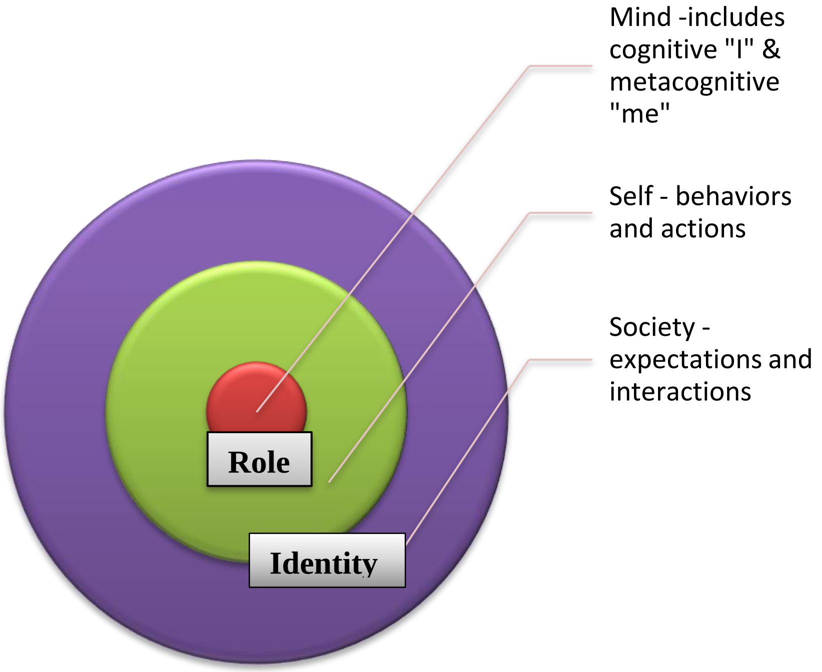


Figure 2. Increasing complexity of the SI framework. Each section of the framework is represented mind - the center being dictated the role which becomes self when not participating in minded-behavior. Self interacts with others to create a society which contains the expectations and interactions with others to form an identity.

The specific questions that guided this study included:

1. What were graduate students’ beliefs about their professional roles as GTAs, specifically their roles as instructors in undergraduate chemistry laboratories?

2. What impact did a multi-week professional development training have on GTAs perceptions of their role-identity in the laboratory classrooms?
3. What were the graduate students’ opinions of the professional development content?
4. How did the use of talent themes as defined by the Clifton StrengthFinder Assessment (CSFA) (Clifton & Nelson, 2010) affect the GTA practices or understandings of their role-identity?

I addressed these questions using qualitative research methods that were chosen to explore chemistry GTAs’ professional role-identity. As a chemistry GTA at MTSU, I served as a participant observer, completing the professional development alongside other chemistry GTAs in the chemistry master’s program or the interdisciplinary Ph.D. programs. I had also taken classes with several of the participants in the past. Half of GTAs were asked to focus their participant reflection based on a chemistry education content article (Bodner, 1991), while the second half were asked to use their identified talents themes (Rath & Conchie, 2008) as a reflection lens on teaching practices. The qualitative nature (Phelps, 1994) of my study allowed the story of currently developing chemistry GTAs to be told in the context of the dynamic classroom environment as teachers and as students in their professional development of science teaching.

Terms of Study

To support graduate students at MTSU as they complete their studies, the College of Graduate studies provides stipends to students. The Chemistry Department employs its graduate students as GTAs in introductory chemistry and physical science labs. Lab coordinators oversee the curriculum and instruction of the laboratories for introductory undergraduate courses. As GTAs in previous semesters, we typically met with the laboratory coordinator for the classes we were assigned once at the beginning of the semester to receive our teaching materials, and again at the end of the semester to return our documents.

As GTAs, we were responsible for enforcing safety, overseeing the undergraduate students as they completed their laboratory assignments throughout the semester, and grading the reports each week. The documents provided by the lab coordinators included a briefing, which summarized the experiment, along with a copy of the student's instructions from the lab manual they purchased and a grading key. We were responsible for grading the reports that the students turned in at the end of class, returning the reports the following week after recording the scores. Each coordinator had a slightly different procedure for turning in grades, from twice a semester to emailed weekly.

In the Spring of 2017, the department supported the implementation of a mandatory professional development for all GTAs teaching freshman-level labs. I used the model provided by Marbach-Ad et al. (2015) as a framework to plan the six workshops as a way to assist in GTAs growth and development as chemistry teachers. To connect to those GTAs who might not see themselves as teachers, we facilitated the idea that as graduate students in chemistry, undergraduate students see GTAs as leaders and experts in chemistry. The needs of followers from the text *Strengths Based Leadership* (Rath & Conchie, 2008) provided a strengths-based foundation for the workshop, as GTAs explored ways of giving chemistry students hope, compassion, stability, and trust.

The recruitment of participants from the chemistry department GTAs for phenomenological evaluation occurred in Spring of 2017. Although many introductory lecture and laboratory chemistry courses at MTSU used a traditional teacher-centered format - a few professors taught their own laboratory sections. In the freshman-level chemistry laboratory courses, students were required to complete an experiment each week and turn in specific pages from their lab manual at the end of class. Each lab contained students from multiple lecture courses involving different instructors; therefore, GTAs did not know what information their students had previously discussed, and this information was not the same for all students in the laboratory.

CHAPTER TWO: LITERATURE REVIEW

This section highlights the literature on the expectations and practices of chemistry graduate teaching assistants (GTAs) development of teaching expertise. I started by using the role and identity research pertaining to GTAs as a way to understand graduate students, and then on to develop an understanding of the expectations associated with the professional identity of chemistry GTAs. Professional development literature specific to chemistry GTAs was sparse, so I broadened my search to include the professional development of all science GTAs, science teachers, and successful training programs when necessary. Within this review, I set the stage for the methods I used to develop the GTAs cases by synthesizing models and theories from social constructivism, cognitive psychology, and strengths-based psychology.

The SI (Symbolic Interactionist) framework from sociology, presented in Chapter One, integrated with findings from science education, business management, and psychology helped to form the conceptual understandings of terms essential to development of this study. Society, identity, self, role, and mind are vital components of the SI framework, all of which have meanings in the everyday world. The precise use of terms within this investigation purposefully builds an understanding of GTA development during a research-based intervention.

The SI framework allowed the learning environments and scholarly development to be considered from a holistic perspective based on the design, implementation, and reflection associated with an intervention; in this case a professional development for chemistry GTAs. The role-identity of GTAs is unique and formed as they navigate their way through the academic environments. To the best of my knowledge, the combination of so many diverse fields of study to define GTA role-identity has not previously been performed. The theories and models presented are varied and not inclusive of intersecting role-identities that participants continued during the study, at home and in other areas of their lives not related to teaching and learning. While participating in this study, the GTAs fulfilled the expectations of the university and the chemistry department by performing roles as students, researchers, and laboratory instructors. This chapter aims to help bridge the gaps between psychology, sociology, and educational research by laying a foundation for an interdisciplinary understanding of the SI theoretical framework.

Role

The role is a conceptual representation of ourselves taken to fulfill an identity. When GTAs enter the classroom, self takes on the identity of the mind’s perceived actions of the GTA to enact their roles as laboratory instructors. Although the analogies I will continue to use relating to chemistry may not be applicable to the general public the importance of chemistry in society hopes you will become more interested in the subject. I find the model of an atom continues to be applicable within the SI framework; if we look at the mind as the nucleus self as the electron cloud, the role is the force from the center of the mind that influences the actions of the self on the outside world. The GTA’s identity forms the base for the role enacted as a laboratory instructor.

Parson (1952) identified the role with a structural-functional view, in which self is an actor with a goal inside a defined system with situational parameters. Within the social structure, role has expected behaviors and is what an individual does in social action. In a given social system role has status based on its position relative to others within the system. Goffman (1963) explored the role from an interactionist view. In this perspective, role is a projection of self that the mind managed during interactions. Status positions, rights, duties, learned attitudes, and behaviors are each associated with the role that changes with situations and environments. Stryker (1980) explained that roles allow individuals to conceptualize themselves in various settings as others. He attributed this ability to reflexive thinking. Role taking provides the mind with a way to imagine future responses of others, which self continuously adapts during interactions. Turner (1962) focused on the iterative process of role making. He explained that selves are confident in their role once the assumed roles are relatively stable as long as an interaction does not challenge the framework (Dolch, 2003). The role of a graduate teaching assistant is the part of identity that is formed in the mind of each GTA as he or she instructs chemistry laboratory courses. While not explicitly examined for science education, Jazvac-Martek (2009) researched the role identities of doctoral students as they transitioned from students to academics.

Jazvac-Martec (2009) explored the role identities of nine education doctoral students/candidates over a two-year longitudinal study at a doctoral/extensive university in Canada. All of the participants were enrolled full-time and were in the process of working on their dissertation; five participants completed their Ph.D.'s while participating in the study. Each participant planned to move into academic positions in higher-education. Jazvac-Martec (2009) followed the SI theoretical framework and collected qualitative data. Each participant completed logs of their weekly experiences that captured critical moments of their academic experience, a pre-interview questionnaire and two semi-structured interviews. After extensive analysis of the data, the researcher recommended more investigation into the role identities of GTAs.

Jazvac-Martec's (2009) findings indicated that doctoral students oscillated between the student roles - being a GTA, a research assistant, dissertation proposal writer, novice researcher, and the academic roles - collaborating with faculty, engaging in scholarly discussions, receiving feedback on proposals, and working on publications. The GTAs felt that they were academics when they collaborated and linked with others on an intellectual level made them feel a part of a larger collective. To acquire the feeling of being an academic the role must be supported, acknowledged, and verified by others. Moving to an academic role required doctoral candidates to move away from accepting an implicit hierarchy, which moved them beyond student status. He found the positive experiences that assisted students in their growth were rarely conferred by their supervisor; rather the supervisor facilitated the agency of the student to interact with people that would assist their development (Jazvac-Martec, 2009). When students had a sense of agency they were responsible for their behaviors, actions, and interactions with others and no longer felt that someone else was responsible for their role. In chemistry education, the ties between the role of teaching in student-centered learning environments and the impact of understandings necessary to be successsfull in scientific practice were found when preservice teachers used inquiry techniques (Sanger, 2008). Facilitating interactions between learners is a skill essential for all student-centered instructional methods and the inchluding instruction with GTAs facilitating problem-based chemistry laboratories.

The only specific research on the tertiary experiences of chemistry students that I could find in searching multiple scholarly databases was a phenomenological exploration of first-year doctoral chemistry students by Sandi-Urena et al. (2011). They researched the impact of the learning environment on thirteen first-year GTAs who were chemistry doctoral students, as they took on the role of laboratory instructors. The GTAs attended a doctoral/research-extensive university, the learning environment constructed at the university required the GTAs to implement a well-documented successful curriculum that utilized cooperative problem-based laboratory projects (Cooper, 2009). The researchers developed a semi-structured interview protocol that had three main parts, to explore previous experience as chemistry students and teachers. The goal of the protocol was to describe the laboratory experience for their students and to allow the GTAs to explain why the evidence from research on problem-based learning environments indicated that students had better problem-solving skills after participating in the labs. All of the GTAs had departmental training for a day and a half that introduced them to problem-based learning; however, the training included department policies and procedures and was not exclusive to teaching and learning topics. The GTAs had continued support throughout the semester in the form of weekly meetings led by the GTA faculty coordinator. The meetings were mandatory and included twelve experienced GTAs. The environment in the laboratory environment required the GTAs to implement a student-centered approach to instruction, which enabled them to be active participants in the learning environment.

Researchers found that three core dimensions - epistemological reflection, metacognitive engagement, and affective engagement - revolved around the central interconnecting factor of the learning environment. The researchers found that chemistry GTAs teaching in problem-based settings had increased epistemological growth, brought about by teaching experiences that created a cognitive and affective imbalance (Sandi-Urena et al., 2011). In SI terms the GTAs experienced an imbalance between mind and self when acting in the collaborative learning environment. The researchers supported several others (Sanger, 2008; French and Russell, 2002) who indicated that the benefits of implementing student-centered learning environments triggered epistemological reflection and metacognitive development of the teacher.

The role of being a teaching assistant was categorized by Jazvac-Martec (2009) as being associated with being a student, while Sandi-Urena et al. (2011) found that enacting the role of a GTA in the student-centered learning environment increased their skills as academics. It is interesting that the student identity included teaching when so many have equated the ability to teach with having an expert understanding. As Sandi-Urena et al. (2011) stated: “many would maintain that teaching is the ultimate learning” (p. 98). As the GTAs took the role of laboratory instructor, their mental construct of teaching and learning grew (epistemological development).

Epistemological reflection model. Sandi-Urena et al. (2011) found that chemistry GTA increased their growth in epistemological understanding when overcoming difficulties in teaching students using problem-based instructional techniques and reflecting on their understandings. GTAs wanted to share their experiences and knowledge with students, but in doing so they needed to understand their strengths in a teaching context. Sandi-Urena et al. (2011) aligned metacognition and what they termed the Epistemological Reflection Model (ERM), which was derived from Baxter Magolda's (2004) theory of self- authorship.

The self-authorship theory was based on evidence collected and summarized from Baxter Magolda's (2004) 16-year longitudinal study describing her personal growth in the conceptual understanding of knowledge as she conducted psychological research on personal epistemological development. Baxter Magolda (2004) used her experiences that began with research on epistemological development of 151 first-year college students to illustrate growth into self-authorship. She explained that participants needed more than required education (up to and including graduate school) to become the authors of their narrative. Personal epistemology included beliefs about self, learning, classroom, and domain-specific knowledge. Personal epistemological development was found to include domains of cognition, identity, and relationships when individuals explored the world using *I* as a central construct in any context. Allowing self to be pivotal regarding content was a core assumption for individuals to grow epistemologically. The other assumptions necessary for growth-producing environments were that knowledge was complex and socially constructed, and authority, as well as expertise, are shared among peers to mutually create understanding during intellectual development. The epistemological transformation was catalyzed when an individual questioned his or her existing assumptions and integrated new perspectives allowing for a more complex understanding of the natural world (Baxter Magolda, 2004). The descriptions she used of constructivism is consistent with Appleton's (1993) report of student understanding, which will be discussed further in Chapter Four.

I used the patterns Baxter Magolda (2004) found in the thoughts and behaviors of individuals as they progressed through their understanding of knowledge in four phases to create the summaries in Table 1. The stages of assessing personal intellectual development began in the first phase, in which knowledge was thought to be absolute and generally attained from an authority (absolute). As Baxter Magolda (2004) developed understanding through collecting evidence instead of information, she progressed toward the second phase of development in which uncertainty was encountered (transitional). Baxter Magolda's uncertainty was very similar to the uncertainty described by Appleton (1993) to explain students' conceptual development of understanding in a science classroom. The uncertainty sparked a dissonance, and understanding of knowledge became transitional - while some knowledge could be absolute, other knowledge could be held independently. The third phase of development required participants to explore systems to manage the uncertainty (independent). In this phase, knowledge was thought to be individually held. It was interesting that Baxter Magolda (2004) found patterns that were different for males and females and that each level (except the final contextual level) indicated that society could play an important part in constructing an understanding of knowledge development. Gender is a social construct that is separate from the physiological term of sex.

Table 1.
Epistemological Differences in Ways of Knowing

Ways of knowing	Absolute	Transitional	Independent	Contextual
Students	Obtain information from teacher	Shift from acquiring knowledge to understanding	Think for themselves	Offer defensible solutions
Teachers	Communicate information clearly	Focus on understanding and application	Promote independent thinking	Connecting others to knowledge
Peers	Share material & explain information to each other	Used to explore information and understandings	Sharing views and expanding ways of knowing	Continually looked to for support and guidance
Evaluation	Show teacher that knowledge was acquired	Understanding over memorization	Avoidance of judgment on opinions of others	Challenge students to carefully ponder understandings
Feminine pattern	Receiving- listening & recording answers	Interpersonal- sharing views & connecting to others understanding	Interindividual- struggle to not subjugate self to others views	External goals, plans, & strategies from integration of previous patterns
Masculine pattern	Mastery – showing interest actively seeking answers	Impersonal- defending personal views focusing on self-understanding	Individual – struggle to listen to others perspective	
Knowledge	Is static and understood by authorities	Is absolute in some areas & uncertain in other domains	Is uncertain	Exists in context and is judged by evidence related to that context

In the final developmental phase, knowledge was contextual and required a rebalancing to incorporate new perspectives. In chemistry GTAs, Sandi-Urena et al. (2011) encouraged research into the alignment between the theory of self-authorship and understanding of science teaching.

When an individual has reached the highest level in their epistemological development, they experienced agency over the roles they assumed and had authority in their understandings. In this way identity, which is a construct that is impacted by society and self, becomes the responsibility of self to the mind of the individual. Baxter Magolda explained that "becoming the author of one's life meant taking responsibility for one's beliefs, identity, and relationships" (Baxter Magolda, 2004, p. 40). Participants in Baxter Magolda's (2004) research involved in a longitudinal study that examined beliefs about knowledge in a collaborative partnership, with the researcher. She found that participants came to a "crossroads" when internal and external influences collided; creating a need to examine their internal self-definition. In a collaborative partnership, growth occurred when learners were validated as knowers. This collaborative partnership allowed the participants learning to be situated in their own experience, and together with the researcher, they deconstructed and reconstructed their way of knowing. The interactions the individuals have with others are the foundations of the society in which their identity is shaped. Baxter Magolda's research indicated that understanding self as an authority was important to the agency of the individual over personal role-identity.

Self. Self is a topic researched in psychology, education, and sociology. In this section of the literature review, self-intertwines the ideas for each field of study. The theory of self-authorship differs from the prevalent approach of self-efficacy in education. The growth in understanding of knowledge allows individuals to have agency in their identity, relationships, and beliefs in any situation (Baxter Magolda, 2004). Self-efficacy is contextually based on the performance of a specific task and has been adapted from Bandura's (1997) social cognitive theory to become a significant factor regarding teaching behavior and student outcomes (Ashton & Webb, 1986; Hanson, 2002). The concept of self and the relationship between beliefs about abilities associated with teaching and learning is referred to as teaching self-efficacy. Self-efficacy is not the concept that interactionists use; instead, self-has a "sense of substantivity" (Weigert, 1975) with unique characteristics from other objects including emergence and reflection.

The union of self-authorship and self-efficacy can be facilitated with an understanding of self as a construct within the SI framework. Self is recognized symbolically by the grammatical usage of the pronoun "I" as an actor (Harre, 1998). Self attaches personal empirical evidence gathered from encounters to support definitions of socialization, self-presentation, impression management, and to create meanings, to organize into social movements, or to reconstruct society (Weigert & Gecas, 2003). Self interacts with the social environment as a process, producer, and product, cognitively and emotionally. "Features of self-include: empiricity, historicity, reflexivity, agency, and constructivity. Such features make self an open project personally, historically, and culturally – a core pragmatic theme" (Weigert & Gecas, 2003). Although in most situations teaching experience increased teaching self-efficacy for GTAs regardless of discipline (Tollerud, 1990; Liaw, 2004), this was not always the case as with the work done by Burton, Bamberry, and Harris-Boundy (2005). As self can be thought of as an open project, the alignment of epistemological development (and corresponding changes in beliefs, instructional strategies, and practices) indicated that while acting in any role, self-efficacy increased for the participants in Baxter Magolda's (2004) study because they were asked to reflect on their beliefs about knowledge. Sandi-Urena et al. (2011) did not examine the self-efficacy of their chemistry GTAs; instead they found a relationship that existed between learning environment, metacognition, and epistemological development, which resulted when GTAs were allowed time to reflect on both their knowledge and beliefs related to their activities as a laboratory instructor. DeChenne, Enochs, and Needham (2012) described the contextual differences of science, technology, engineering, and mathematics (STEM) GTAs from GTAs in other disciplines and worked to develop an instrument that could reliably measure STEM GTA self-efficacy.

DeChenne et al. (2012) created an evidence-based instrument that measured STEM GTA self-efficacy and examined the factors that impacted development (DeChenne et al., 2015). They created the STEM GTA-teaching self-efficacy scale (TSES) instrument, which was based on previously developed teaching scales with modifications based on teaching aspects specific to STEM GTAs' who were rarely involved in the planning of the courses. The inventory they developed contained 28 – five-point Likert scale statements related to GTA self-efficacy, the instrument was administered to GTAs at five universities throughout two years. The researchers conducted quantitative, correlation and factor, analysis on the responses from 253 participants and found that two factors, learning environment self-efficacy and instructional strategies self-efficacy, were positively correlated to GTA overall teaching self-efficacy (DeChenne et al., 2012).

Because self is a multi-layered and dynamic concept that incorporates many aspects of roles outside of teaching and learning science that the link between self-authorship and the nature of science is not readily apparent, the SI framework does not limit GTA beliefs about teaching and learning to only personal experiences that relate to ability. Instead self can be interpreted through many lenses such as self-as-desire, ideological self, and linguistic self (Lindesmith, Strauss, and Denzin, 1999). Self as a producer continually monitors actions and discourse. Self adapts in the present (Perinbanayagam, 2000) to the impositions of others acceptance or rejection of self-narrative (Holstein and Gubrium, 2000). Self as a product refers to the “me” moment (Kuhn, 1954) linking self and social system to role-identities (McCall & Simmons, 1966). Self is a feeling object that can experience positive and negative feelings related to interpersonal dynamics (Denzin, 1984). Emotions are experienced when an individual’s valued self-concept is either affirmed or challenged (Higgins, 1987). Substantivity also distinguishes self from identity in that self-experiences and understands the agency in which “I” is aware and acting in the present moment. Self proposes identities, while others impose identities (Strauss, 1959). The SI representation of self incorporates the social systems that impact the dynamic self, allowing for added depth to the outcome space that related GTA laboratory teaching experiences with epistemological and metacognitive growth.

Graduate teaching identity as a construct deserves further evaluation regarding Baxter Magolda’s (2004) development of self-authorship and agency of beliefs and relationships. Identities are defined as stable objects that allow selves to categorize and function within specific parameters of social situations (Weigert & Gecas, 2003). The sense of substantivity refers to how well self-aligns with the role taken to form an individual’s identity. Although, self-emerges through micro-developmental and macro-evolutionary processes allowing interactions with ever more generalized others through the process of role-taking and role-making (Deegan, 1999) when individuals exhibit epistemological growth, they transition from the belief that knowledge is finite and stable to the understanding that knowledge is infinite and dynamic. As most of us that have written an extensive literature review can attest, we can always find another paper to read or question that could be answered, which is a rational explanation for the epistemological development in graduate students. Interestingly, Sandi-Urena et al. (2011) found that GTAs actively teaching problem-based labs increased their skills as researchers as they struggled to assist students in completing experiments. An individual actively struggles to realize self through social identities (Strauss, 1959), in a student-centered learning environment GTAs struggled with implementing teaching strategies and still experienced epistemological development.

Society. The identity of chemistry GTAs contains several roles, and Jazvac-Martec (2009) recommended that supervisors be made aware of the graduate students shifting identities and the need for the roles of academics to be supported in informal venues where they can share their work and experiences in meaningful ways. He also recommended workshops be constructed that help graduate students examine their sense of agency. He wanted to research to be conducted on the variable manifestations of student role identities in academic roles. Jazvac-Martec (2009) encouraged empirical exploration of role identities development in conjunction with interventions to determine the applicability of such responses. Herrington and Nakhleh (2003) looked at the definition of effective laboratory instruction through the lens of students and teaching assistants that helped to define the role of chemistry GTAs more precisely as members of a community of practice.

Interactions are essential to the formation of communities of practice that promotes agency to create a society in which the GTAs are valuable members. In the SI framework society is shaped by individual selves that "exist in a system of social relationships" (Schneider, 1975), much like people exist because of the interactions between many complex molecules. Society exists because of the interactions between others. The emphasis is on the social acts and gestures of individuals that form the basis of collective action. People's actions make society possible through an understanding among individuals, and cooperation with them. Acts build upon acts to create all aspects of society past, present, and future.

Selves take roles and develop mesostructures of identity in which individuals agree to honor their shared past, present, and future experience. The mesostructure is dynamic and interpersonal, linking macrorealities to microprocesses. Macrorealities are the conceptual understandings as visualized by an individual within a social structure. Mesostructures are defined as agreements and enduring commitments made by representatives of social structure (Maines, 1982). In this way, the individuals create a temporal nexus of lines that fit together, in agreement with others, to generate the knowledge and skills associated with an identity. Identities, that act within a society, promote those who have a shared narrative which validates the mesostructure of community, while act upon act continues to create the identity framework (Katovich & Maines, 2003). GTAs interact with many mesostructures during any given day, allowing them to adapt and change their perspective of the macroreality. So, there is importance to understanding the expectations related to being a chemistry GTA, as a lens for understanding identity.

To get an idea of the Herrington and Nakhleh (2003) defined laboratory teaching effectiveness for their study as the qualities that useful laboratory teaching assistants (TA) should possess, the characteristics, activities or behaviors that demonstrate the merits and the positive effects perceived regarding the GTA actions. The study took place at a doctoral/research-extensive university in the midwestern United States through the voluntary completion of questionnaires. The study participants were from an introductory chemistry class for science and engineering majors. Students and GTAs that participated in the study responded a Likert survey mid-semester and open questionnaire to obtain their ideas for teaching effectiveness. Fourteen GTAs responded eleven were chemistry students, and the course was set up with eleven experiments that were conducted in three-hour blocks once a week. After analysis, Herrrington and Nakhleh (2003) identified four areas in which effective GTAs were believed to be knowledgable, procedural techniques and safety, chemistry concepts, how students learn, and teaching. Effective GTAs allowed their students to work through the experiment and supported their learning by asking questions and guiding them, not sitting and watching. The authors concluded that training programs should "provide GTAs with ways to help students make connections between lecture material and laboratory experiments" (Herrington & Nakhleh, 2003, p.1203). In using the students to help determine the parameters for chemistry GTAs understanding of knowledge they had agency over others, moving out of the role of chemistry GTAs and into the SI concept of self regarding their identity as chemistry graduate students.

Identity

The identity of chemistry graduate students starts with the expectations associated with having a doctoral education with a chemistry concentration. In December of 1999, a roundtable with representatives from many areas of the chemical sciences including the not-for-profit, academic, and industry sectors was held to discuss issues pertinent to graduate education in the 21st century (National Research Council, 2000). The focus on graduate education was a result of the changing demands of the workforce. The shifts in society were due to what Peter Eisenberg (Columbia University) referred to as the "knowledge revolution" already impacted the expectations of graduates after completing their classical education. Due to the changing paradigms in society brought on by the digital revolution, J. Michael White (University of Texas Austin) observed the need for chemistry graduate students to obtain skills that allow them to work collaboratively as part of interdisciplinary teams (National Research Council, 2000).

Edel Wasserman (DuPont and the American Chemical Society) pointed to the need for individuals to understand their strengths in an educational setting. He highlighted that graduate education should allow students an environment to learn from their mistakes, enabling them to “renew themselves continually over a decades-long career” (National Research Council, 2000). The identity conveyed by this council is that of a problem solver who understands how to use their knowledge and skills to work with others. The expectations put together by the committee are only a piece of the chemistry graduate student identity proposed by individuals that are a significant member of the greater community of chemistry practice. Contextually chemistry GTAs enact the role that they believe most fits the status of a laboratory instructor.

Herrington and Nakhleh (2003) compared the conceptual representations from students and GTAs and created an example of characteristics important to the identity of a successful chemistry laboratory instructor, the science teaching role GTA’s enact to fulfill their identity. “Identity establishes what and where the person is in social terms… (self) Is situated - cast in the shape of a social object by acknowledgment of individual participation or membership into social relations” (Erickson, 1956, p. 57). Identity within a social structure is not only a definition given by self, but must also be a mutually shared meaning by interactants within the structure (Mead, 1934). Identities consist of internalized role expectations (Kuhn & McPartland, 1954) continually monitored and renegotiated. Micro-level individual and macro-level structured society processes allow personal identities (Vryan, Adler, and Adler, 2003) that impact the structure and routine of a standardized role (Goffman, 1963). While an individual may exhibit multiple identities (Stryker, 1989), each is relatively stable and exist in a hierarchy according to the salience of the identity (Stryker, 1980). Essential to the establishment of an identity are constraints presented by social conventions, relationships, culture, and institutional roles (Vryan, Adler, and Adler, 2003). We have already discussed some of the differences in the graduate student role identity versus academic role-identity, which indicated doctoral students relied on social interactions to validate their identity (Jazvac-Martec, 2009). Interestingly, when the knowledge domains presented by Herrington and Nakhleh (2003) were compared to the professional knowledge domains of teachers (Figure 1) students and GTAs expected their laboratory instructors to have mastery of all, except for one assessment, of science teacher professional knowledge domains. Knowledge is inevitably tied to the concept of mind, which I discuss further in the next section.

Mind. I have referred to the concept of mind several times in the literature review, and again research on this concept crosses the disciplines of education, psychology, and sociology. In the past century, the idea of mind has continued to grow to include current theories of the biological and physiological process related to the brain. Strauss (1978) explained mind as a verb; in that mind is a form of purposive behavior for which thinking is synonymous. Mind occurred only in certain situations, such as selective perception, problematic situations, and when considering the natural and societal influences on sources of mind (Meltzer, 2003). In chemistry education literature the ability to plan, monitor, and reflect upon your actions is defined as metacognition and has been a found to be an essential aspect of understanding scientific concepts (Francisco, Nicoll, & Trautmann,1998; Rickey & Stacy, 2000; Tsai, 2001; Shraw, Brooks, & Crippen, 2005; Cooper & Sandi-Urena, 2009). Sandi-Urena et al. (2011) examined the impact of the learning environment on promoting metacognitive development; their findings indicated that teaching a problem-based laboratory caused GTAs to struggle with their representations of knowledge. The authors noted an affective component associated with the GTA implementation of problem-based laboratories that required a deeper understanding of the experience that grow GTAs into their role.

The multiplicity of forms that mind takes include thoughts, ideas, understanding, and deciding, among other mental processes. In early works on the mind Dewey (1905) noted the impact of personal interest in retaining attention allowing individuals to pick out some characteristics while ignoring others, indicating that interests, needs, and past experiences shape and select perception. Life is an ongoing activity made of many acts; stimuli are selected purposefully to further action (Troyer, 1978). Abstract thought, a minded behavior, allows individuals to socially create significant symbols, which are recognized by others, with previously assigned intrinsic meaning (Blumer, 1981). Mind undergoes continuous adaptation based on surroundings. Minded behavior arises when an unexpected problem interrupts the flow. Prus (1999) explained that mind is continually trying to keep up with a mesostructured that is updated by others regularly; problems are inherent to the activity. When something blocks an action undertaken by self, mind imagines alternative activities, with “self” participating as other, and prospective outcomes that delay activity. Reflexivity allows mind, “me,” to envision possible futures in which self,” I,” take a role and cognitively interacts with generalized others. “Me” has internalized social definitions and ideas of what “I” will do in future situations; however, “I,” is the part of self that remains uncertain (Hanson, 1986). Metacognition is the ability to engage your mind in the planning, enacting, and reflecting on your self-engagement during a task, such as completing an experiment.

Biologically, mind evolves in a Darwinian fashion, and this accounts for part of the foundation of the brain. Baldwin (1986) explained that while biology accounts for human potential, minded behavior requires verbal socialization with others before developing the internal dialogue of mind. “I” and “me” are both a part of the mind and cannot lie to each other, making “I” fundamentally different from any others in social scenarios (Gur & Sackheim, 1979). The interaction between self and others has the potential to create emergent behaviors that are not in accordance with what “me” planned to do (Mead, 1934). In other words, the mind does not explicitly control “I” in social situations. The mind is continually adapting to the environment hence the emergence of behavior (Blumer, 1969). Meltzer believes the converse of Descartes’ philosophical dictum: “I think therefore I am” Meltzer believes “I am, therefore I think” (Meltzer, 2003, p. 262). For the symbolic interactionists, concepts essential to mind are “selectivity, blocked-act, delayed responses, self-indications, role taking, internal conversation, and significant symbols. To speak of any one of these elements of mind is, necessarily, to imply all of the others" (Meltzer, 2003, p. 265). The thinking part of ourselves tries to monitor and maintain a role that self enacts - we think. In a chemistry analogy, mind is the nucleus of the atom, in that without the central positively charged super dense core that we are just beginning to understand, the electron cloud would not be able to interact in ways that create the world we observe.

Professional Development

As noted by Golde and Dore (2001) or the majority of graduate students teaching science have little training in pedagogy the access to training is not chemistry specific. Teaching professional development (TPD) programs are commonly used to help individuals increase pedagogical content knowledge by promoting the understanding of learning theories that are relevant to teaching any content. To evaluate TPDs available for science, mathematics, technology, and engineering GTAs, Connolly, Savoy, Lee, and Hill (2016) defined relevant core features of TPD as related to the themes of organizational context, program features, and program pedagogical practices. Stacy (University of California Berkley) noted the importance of training graduate teaching assistants in research-based chemistry educational practices (National Research Council, 2000). Graduate education in chemistry provides students with a foundation to develop themselves as professionals, educators, and mentors (Lambert & Tice, 1993; Bieber & Worley, 2006). Professional developments are designed to help GTAs establish their identity within the mesostructure of chemistry education.

Participation in TPD can help individuals to relate to peers, creating a sense of community. There GTAs were able to become collaborators in developing instructional techniques to overcome student learning difficulties. Collaborations sometimes developed into research partnerships. Even after moving into positions at universities, the effects of TPD engagement should be correlated to reports of using more evidence-based practices and higher confidence for teaching undergraduates. The TPD also allowed GTAs time to interact informally with professors to explore career goals. Exceptions were evident when faculty advisors were encouraged research as a primary responsibility with priority over teaching. In this way, advisors become a significant other with the ability to impact GTAs' identity (Connolly et al., 2016). Beyond academic settings, companies also work to develop their employees, and the strength philosophy promoted by Gallup has positively impacted companies globally by helping companies work together and grow their innate talents (Clifton & Harter, 2003).

Talents. Talents are naturally occurring patterns of thoughts, feelings, and behaviors that when used in conjunction with an individuals knowledge and skills allow people to become great in their roles (Rath & Conchie, 2008). Positive psychology researchers tend to focus on developing character strength and highlighting what is right with people (Peterson & Seligman, 2004) to increase productivity and efficiency. Clifton and Nelson (2010) provided a guide to finding and developing strengths as a philosophy of business and management. Clifton continued researching how people became successful and happy in their life while assistin in the development and implementation of coaching strategies for top executives. He was named the father of strength-based psychology in 2002 by the American Psychological Association (Rath & Clifton, 2004).

Clifton's work with strength researchers helped in the development of an assessment indicating an individual's highest talents, which when used with skills and knowledge become one's greatest strengths. Liesveld, Miller, and Robinson (2005) explained how great teachers used their talents in classrooms and highlighted strategies that can be used with each talent to become a better educator. Asplund, Lopez, Hodeges, and Harter (2009) explained talents as the way that an individual intuitively interacts with the world around him or her. In this way, talents are an innate part of each person and for this study will be used to define the self. Through a talent coaching model, Clifton used his company (Gallup) to forward the development of leaders in a variety of - business, government, and educational settings. Their research indicated that the identification and successful integration of talents into the role performed resulted in a more informed view of self (Asplund et al., 2009). People do not always recognize how their talents impact their interactions with others, which is also true of self.

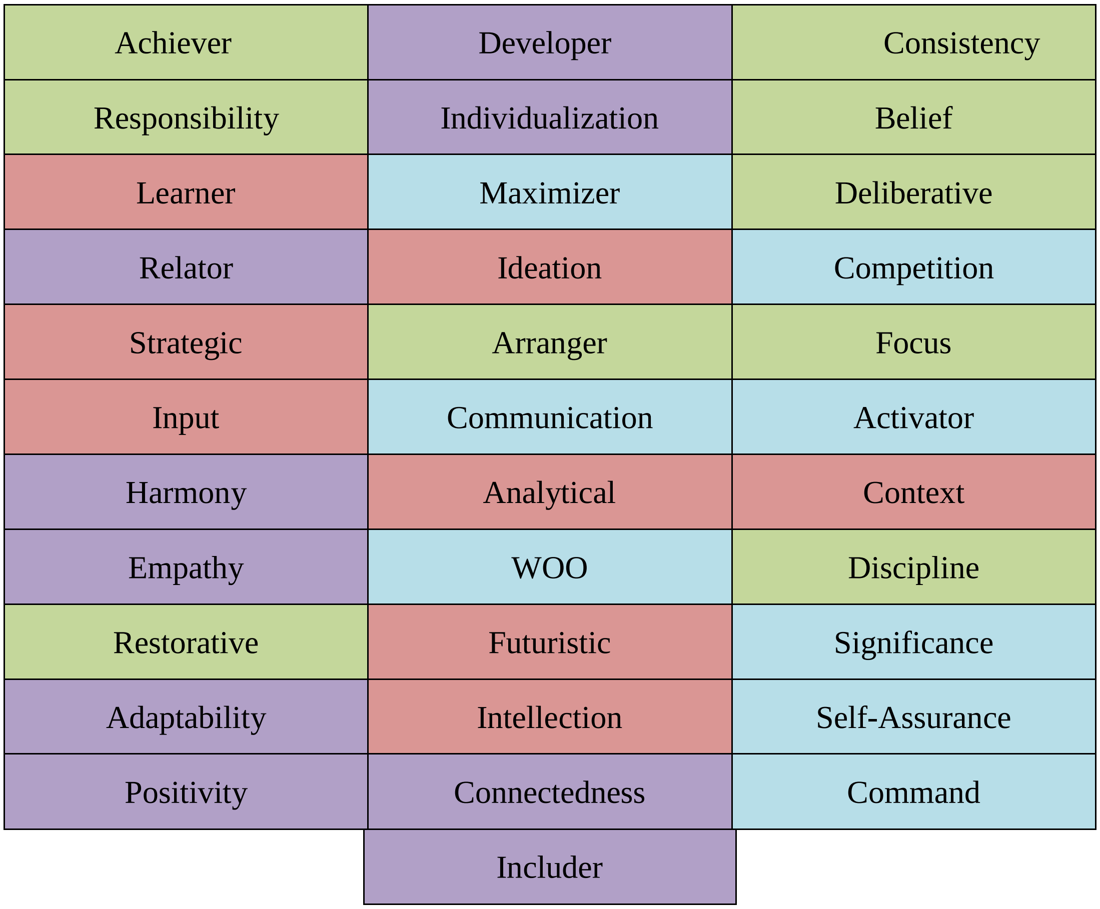
Clifton, along with several leading scientists at Gallup, have worked for decades on an assessment that probes the natural tendencies people have, which they develop into "strengths." Gallup refined the definition of a strength as a repeatable task that can regularly be accomplished with near perfect performance. To acquire near-perfect performance, individuals must integrate skills and knowledge gained from the world with their innate talents. When the talents are developed and identified, people are mindful of this behavior (Louis, 2011). The Clifton StrengthsFinder assessment (CSFA) ranked an individual's talent themes according to the most dominant patterns of talent (Hodges & Clifton, 2004). The assessment continued to be effective for increasing engagement when used in conjunction with coaching professional development for the leaders (Rath, & Conchie, 2008). Talent is defined as naturally occurring and consistent patterns of thought, feeling, or behavior that can be applied in productive ways, a theme is when several of those talents cluster together (Asplund et al., 2011). Figure 3 grouped the talents themes into four leadership domains of "relationship-building," "influencing," "strategic thinking," and "executing."

The leadership domains emerged from research conducted on followers – that they found determined people followed when leaders provided hope, stability, compassion, and trust (Rath & Conchie, 2008). An analogy using chemistry may be relevant - talents are the building blocks of self, in the same manner that elements are the building blocks of matter. Elements combine to make molecules through interactions between atoms that we call chemical reactions, changing one substance to another. Many variables contribute to such a creation, the internal structure of the two atoms, how much energy they have stored, etc. Variables external to the atoms can impact the reaction as well, such as the presence of another substance or if the atom has already formed a bond with another atom. Of course, this is a simplified explanation of the complex phenomenon, just as talents are a simplified representation of the complex interactions within individuals. The number associated with each talent is the talent theme reported abundance relative to the least common talent theme to appear in the top five, command.

RB	Relator (5.84)	Harmony (4.14)	Empathy (3.97)	Adaptability (3.63)	Positivity (3.47)	Developer (3.38)	Individualization (3.20)	Connectedness (2.55)	Includer (2.54)
I		Maximizer (3.03)	Communication (2.79)	**W**inning **O**thers **O**ver (2.64)	Competition (2.32)	Activator (2.13)	Significance (1.34)	Self-Assurance (1.03)	Command (1.00)
ST		Learner (6.00)	Strategic (4.78)	Input (4.22)	Ideation (2.89)	Analytical (2.69)	Futuristic (2.62)	Intellection (2.57)	Context (1.89)
E	Achiever (6.78)	Responsibility (6.05)	Restorative (3.69)	Arranger (2.82)	Consistency (2.44)	Belief (2.42)	Deliberative (2.32)	Focus (2.19)	Discipline (1.52)

Figure 3. The relative distribution of the top five talents according to the leadership domain. Talent themes in leadership domains, RB (Relationship Building), I (Influencing), ST (Strategic Thinking), E (Executing), from most abundant talents on the left to least abundant on the right (relative abundance to Command the least common talent theme reported in the top five), n=13,557,165.

Gallup (2016) provided a Team Frequency report (n=13,557,165) of the number of times a talent was given in the top five reported talents ranked in Figure 4. Figure 4 lists the talent on the top left, achiever being the most frequent moving down each column and returning to the top, positivity was in the top five of more individuals than developer, and includer more than consistency, and ending on the bottom right with command.



Achiever	Developer	Consistency
Responsibility	Individualization	Belief
Learner	Maximizer	Deliberative
Relator	Ideation	Competition
Strategic	Arranger	Focus
Input	Communication	Activator
Harmony	Analytical	Context
Empathy	WOO	Discipline
Restorative	Futuristic	Significance
Adaptability	Intellection	Self-Assurance
Positivity	Connectedness	Command
	Includer	

Figure 4. Relative frequency of talent themes reported in the top five. Talent themes in order of most common (top left) to least frequent (bottom right), n=13,557,165. The color denotes leadership domain: executing, strategic thinking, relationship building, and influencing.

The rank of talent relative to the others were each coded with purple for the relationship building domain, light blue for the influencing area, red for strategic thinking, and green for the executing area. In their research with leaders, Gallup found that the most successful people surrounded themselves with a team that had each of the leadership domains represented (Rath & Conchie, 2008).

Experts within Gallup claim that everyone has some level of each talent (Liesveld et al., 2005), just as each atom has some degree of electrons. As chemists, we have derived complex mathematical formulas to represent the probability of an electron being at a place in one instant in time. The precision with which we can measure and understand electron movement continues to create miraculous technology. The more researchers understood about talents, the more precisely they were able to gauge which talents are most likely to develop into strengths for an individual. Clifton believed that an individual could spend his or her entire lifetime developing any top talent themes and still not have reached the potential of any talent (Clifton & Nelson, 2010). Because individuals are most likely to grow in areas where they naturally succeed, they should be able to understand which areas they are not great at and partner with others to overcome difficulties. The accurate use of talents is achieved by a strategy called “name it, claim it, aim it,” which allows people to have a language and strategy to attain goals and lead others.

The talent approach connects the concepts of self and mind by expanding the self to include an understanding of innate patterns of thoughts feelings and behaviors. The “name it, claim it, aim it” strategy of strength development is like the research previously presented from psychology, education, and sociological perspectives. When individuals understand how they use their talents, knowledge, and skills to complete their role consistently with near perfect performance successfully, they are considered to be using a strength. Strengths development aligns with the epistemological development model proposed by Baxter Magolda (2004). In the naming phase, an individual becomes aware of when they are using their talents; this would be a transitional understanding and they can move forward with the knowledge of how they will naturally fit into their role. Claiming a talent is consistent with Baxter Magolda's (2004) independent understanding, in which the individual becomes aware of not only the positive aspects of their talents, but also the potential to negatively impact a situation with their natural tendencies. Although Clifton and Nelson (2010) promoted a philosophy of strength, they did not recommend ignoring your weaknesses; in fact, they encouraged reflection on how your talents caused peers to interact. In the aiming phase, the contextual level of understanding - an individual can be the author of his or her destiny as he or she conceptually understand and can predict the impact of his or her talents, much like self-authorship.

In this research, my goal was two-fold: first to establish an understanding of GTAs epistemological and pedagogical knowledge and skills related to acting as a chemistry laboratory instructor, and then to positively impact their epistemological development by providing opportunities to enact and reflect on their science teaching skills and abilities.

CHAPTER THREE: METHODOLOGY

Conceptual Framework

Professional development for graduate teaching assistants (GTAs) has evolved into a practice that is becoming more prominent in academic settings, particularly in the sciences. The disparity in context and application of the literature regarding graduate teaching assistant professional development (GTAPD) programs and the effectiveness of methods makes accurately implementing programs difficult at best. Reeves et al. (2016) proposed a conceptual framework for researching GTAs. Although developed for biology, the theoretical underpinnings are also applicable to chemistry laboratory instruction. The structure relates to the outcome variables of GTA cognition, GTA teaching practice, and undergraduate student outcomes to the implementation of GTAPDs (Reeves et al., 2016). The conceptual framework here aligns well with the mind (cognition), self (teaching practices), and society (student outcomes) of the Symbolic Interactionism (SI) theoretical framework discussed in the previous chapters.

Reeves et al. (2016) indicated that GTA cognition included knowledge, skills, and attitudes toward or beliefs about teaching. Similarly, examples of GTA teaching practice included behaviors that related not only to in-class participation, but also items such as planning and assessment (Reeves et al., 2016). Actions, as well as intention, are necessary when constructing an understanding of the effectiveness of a GTAPD. In the SI framework, behaviors enacted by “self” are not completely independent of the mind (Mead, 1934). This well-established understanding serves to support the link between GTA cognition and practice, as the “mind” is related to “self.” The link between society and undergraduate students is not made as easily, although their opinions, as shown through evaluation, could be an essential component of informing the concept of GTA role-identity. To provide foundations relating to the SI framework, the methodologies selected for this study allowed GTAs to consider themselves as teachers. The details of the GTAPD were supplied from the triangulation of audio recordings and field notes from the instructor and myself. For this study, the outcome variables of GTA cognition and teaching practice were highlighted as being particularly important because of the relationship to the SI framework. This study examined undergraduate student outcomes only in the context of the evaluation of GTA identity regarding student perception of teaching practices.

Design

This qualitative phenomenological study was conducted during the Spring semester of 2017 to investigate the professional development of chemistry GTAs role-identity. This research was approved by the university internal review board (Appendix A). The participants were GTAs recruited from the chemistry GTA professional development, which was designed and implemented for this study. Each participant signed the informed consent (Appendix B) which was explained during the professional development introduction. As a GTA, I was a participant observer during the workshops, which were also video and audio recorded for future analysis. Artifacts collected during the workshop included in class reflections and results reported from the Clifton Strength Finder Assessment (CSFA). I recorded field notes and observations in a research journal during and after each workshop. This journal was referred to often during analysis and quotes were pulled directly from my notes during the GTA PD when it increased the richness of data presented. Multiple data points and the use of protocols, Teacher Beliefs Interview (TBI) (Luft & Roehrig, 2007; Addy & Blanchard, 2010) and Reformed Teaching Observational Protocol (RTOP) (Siwada et al., 2002) which each required agreement between two researchers, were used to ensure triangulation of data. To assist with the transcription, I used Easy Scribe software, which provided documents that were stored in Atlas TI. Atlas TI was the software used to complete coding on the participants in the study.

Creswell (2013) proposed the structure of writing phenomenological research followed, which was in turn derived from the highly specific format written by Moustakas (1994). Moustakas (1994) set out guidelines for what to include in a six-chapter written phenomenology. The composition differs slightly from other scientific writing, as it places autobiographical information about personal curiosities leading to the research in Chapter One. I combined the suggested chapters of three and four into Chapter Three, the methodology section, which began with the conceptual framework. Chapters Two (the literature review and aligning fields of study) and Chapter Four (presentation of data) remained the same, as found in most manuscripts. I presented the cases separately from the data collected during the professional development (Chapter Four) seperately from the cases containing the evidence gathered from each participant (Chapter Five). In the final chapter, I discussed limitations and delimitations, in the concluding chapter as suggested by Moustakas (1994), and as a result, delimitations, instead of in section three as I have observed in other qualitative research writing (Lampley, 2015). This format also aligned with how I trained in writing as a chemist.

Context

This study took place at a public/doctoral-granting research university in the Southeastern United States. The undergraduate population at the university was comprised mostly of students from within the state. STEM students had a higher ratio of international students than the total population of the campus (Table 2). There were eighteen GTAs assigned as laboratory instructors to various freshman level chemistry courses. Eighty percent of chemistry GTAs were international students.

Table 2. Contextual Population of International Students

Enrollment Data Spring 2017

Population	Number of students
University students	20,026
All International university students	975
STEM students	4,450
International STEM students	399

The chemistry department at this university used traditional teacher-centered instructional approaches for most courses. The professors prepared lectures and presented that information to the students through Power Point or utilizing the classroom whiteboards. The exceptions to teaching centered instructional courses were chemistry courses taught by the three professors in the department (two of which have doctorates in chemistry education) who supervised their own labs and the general chemistry laboratory coordinator, who has also started to implement process-oriented guided inquiry learning (POGIL) techniques. As GTAs, we were given the information about the laboratory sections we would teach sometime the week before or during the first week of Spring semester. As with the previous semesters, the GTAs were required to attend an informational meeting, where they meet the lab supervisor and the laboratory coordinators. The first meeting of GTAs took place on January 20 in the Spring of 2017.

The Chemistry department and my advisor supported the development of the workshops, which GTAs were asked to attend every other Monday beginning January 23. I proposed the professional development after completing my master's thesis on teacher implementation of student-centered curriculum and reading the literature about the previous success of GTA professional teacher training on student evaluations (Marbach-Ad et al., 2011). Based on my proposal and with the support of the director of our doctoral program, the chair of the chemistry department agreed to implement the workshop and provided the necessary resources - books, copies of articles, and a meeting place. When the department chair asked who would facilitate the workshop, my advisor agreed to share her expertise and knowledge gained over more than two decades as a chemistry teacher leader with the GTAs. We requested that any available faculty attend the meetings.

Participant Selection

The Chemistry Department provided six workshops for the GTAs. The chair of the department required the attendance of GTAs as part of their job requirements during the introduction to the workshops. Participants were recruited from the first seminar after the workshops had been explained. I presented the research study using a previously prepared and reviewed script (Appendix C). The participants who agreed to be interviewed and observed at the start and end of the semester signed the informed consent form. I used video equipment to ensure accurate recording of the data.

Nine of the eighteen GTAs in the course agreed to the observations and interviews. I video and audio recorded each class observed and each of the workshops conducted. The participants carried a recorder during observations, which I provided. Every undergraduate student, although not subjects of the study, was given the opportunity to opt-out of being video recorded at the start of each observation (Appendix D). The participants were given pseudonyms of an element, in keeping with the metaphor of self as an atom and the international diversity represented the chemistry GTA population (Table 3).

Interviews

I interviewed participants using the TBI protocol at the beginning and end of the semester. On January 31, I wrote an email to the participants requesting times for an interview. I continued to schedule meetings until March 2 the halfway point of the GTA PD workshops. The final round of interviews started with an email to participants on April 7 and concluded on May 5.

Luft and Roehrig (2007) created the TBI protocol to identify the development of teachers' beliefs about knowledge and learning,

Table 3. Participants Demographics and Teaching Assignment

Pseudonym	**Gender**	**Country of K-12 education**	**Degree pursued**	**Laboratory Courses Taught**
Carbon	Female	Nepal	Master of Science	General Chemistry II
Silicon	Male	Nigeria	Master of Science	General Chemistry I & Topic in Physical Science
Bromine	Male	Bangladesh	Master of Science	Introduction to General Chemistry I & Topics in Physical Science
Hydrogen	Female	Bangladesh	Master of Science	General Chemistry II
Sodium	Male	India	Doctor of Philosophy Molecular Biosciences	Consumer Chemistry
Iodine	Male	United States of America	Doctor of Philosophy Molecular Biosciences	General Chemistry II & Topics in Physical Science
Chlorine	Male	Vietnam	Doctor of Philosophy Computational Science	General Chemistry I
Cobalt	Male	India	Doctor of Philosophy Computational Science	Introduction to General Chemistry I & Topics in Physical Science
Fluorine	Male	Nepal	Doctor of Philosophy Computational Science	General Chemistry II & Chemistry for Consumers
Lithium	Female	United States of America	Doctor of Philosophy Mathematics and Science Education	Topics in Physical Science & Introduction to General Chemistry II

which are constructs of self and mind in the SI framework. Herman-Kinny & Verschaeve (2003) encouraged interviews as a part of SI methodology with the goal of understanding participants’ constructs of identity and role. Luft and

Roehrig (2007), with participants that were in-service teachers, and later Addy and Blanchard (2010), with science GTAs, identified and monitored changes from traditional to reform-oriented, using beliefs from one of five instructional domains.

The TBI was designed to elicit teachers' cognitive and affective beliefs that cannot be attained with observations or survey data. Luft and Roehrig (2007) developed the protocol after reviewing the literature related to teacher beliefs and determining the questions that allowed teachers to construct the most detailed personalized responses. After an iterative process of revision and reflection, the final interview contained eight items. The questions were then given to experienced science teachers, and their responses were used to obtain five emergent categories: traditional, instructive, transitional, responsive, and reform-based (Luft & Roehrig, 2007). They provided exemples of responses for each group and each question. I used the examples provided by Luft and Roehrig (2007) to code the responses from my participants. The two-person procedure for coding the interviews was followed to ensure the validity and reliability of the instrument. The Cronbach alpha for internal consistencies within the survey was reported at 0.70 for the following questions:

1. How do you maximize student learning in your classroom? (learning)
2. How do you describe your role as a teacher? (knowledge)
3. How do you know when your students understand? (learning)

4. In the school setting, how do you decide what to teach and what not to teach? (knowledge)

5. How do you decide when to move on to a new topic in your classroom? (knowledge)

6. How do your students learn science best? (learning)

7. How do you know when learning is occurring in your classroom? (learning) (Luft & Roehrig, 2007, p.43)

The TBI was used in the assessment of science GTA beliefs by Addy and Blanchard (2010). Some modifications were made to Luft and Roehrig's (2007) original protocol so that they were more appropriate for laboratory instruction.

(1) How do you maximize student learning in your laboratory?

(2) How do you describe your role as a laboratory instructor?

(3) How do you know when your students understand?

(4) In the laboratory setting, how do you decide what to teach and what not to teach?

(5) How do you decide when to move on to a new activity in your laboratory?

(6) How do your students learn science best?

(7) How do you know when learning is occurring in your laboratory?

(8) What are your final comments? (Addy & Blanchard, 2010, p. 1052)

The interviews were conducted using a modified version, as all participants were laboratory instructors.

Use of the TBI required inter-rater reliability between myself and another researcher, in this case, my research advisor. I audio recorded each of the participants, and after the interview the audio file was uploaded to my computer and renamed with the participant's element pseudonym. I transcribed each recording, removing any use of participants' names. After I completed the transcriptions, I coded each question for every participant before moving onto the next question until I finished coding the entire group of interviews. I completed the transcripts and provided my interpretations for each level of potential answers for each question. My advisor then coded the transcripts by the participant. After we had each coded a participant, we met and discussed any differences, until we agreed to the final assigned codes. I used the codes to create a TBI profile for each GTA, and when possible for both the initial and final interviews, to determine shifting belief patterns.

Classroom Observation

Participants in this study were observed as laboratory instructors twice, using the Reformed Teaching Observation Protocol (RTOP). A biology GTA from the Mathematics and Science Education doctoral program, Reid, and I conducted initial observations, which started on February 6, 2017 and concluded on February 16, 2017. We started the final observations on April 10, 2017 and ended the observations on April 20, 2017. The observations were conducted in person and interactions were recorded with video and audio. The sixty hours of recordings were used only to clarify any changes that occurred in the GTA's instructional behaviors. We discussed our RTOP ratings and agreed upon scoring for each participant directly following the observation whenever possible.

The RTOP was developed to monitor reformed teaching practices in the classroom (Sawada et al., 2003). The RTOP was designed initially to assist in teacher preparation, and the validity and reliability of the instrument in science classrooms has been well documented (Marshall, Smart, Lotter, & Sibu, 2011). Before conducting observations, we were both trained on the use of the RTOP to correctly score instructional practices. The RTOP form included areas for classroom descriptions, teacher background information, and places for detailed field notes. The instrument itself consisted of 25 statements which were rated on a scale from zero (never occurred) to four (very descriptive).

The designers of the tool provided complete descriptions for how to interpret each statement within the context of reformed teaching. The instrument reliably measures five categories essential to implementation of student-centered classrooms. Lesson design and implementation, propositional content knowledge, procedural content knowledge, and, communicative interactions and student's teacher relationships, inside the classroom environment. The five areas of the RTOP are also similar to the foundational knowledge domains of science teachers discussed in Chapter One, Figure 1. Scores in each category were highly correlated to science and mathematics teachers overall score on the instrument, with the propositional knowledge category of the RTOP being the least correlated to the overall scores (Sawada et al., 2003). Addy and Blanchard (2010) found the design of the laboratory structure was of particular importance. GTAs in their study scored lowest on aspects of the lab they identified as outside of their control. Sandi-Urena et al. (2011) also found the classroom environment to be essential for chemistry GTA's epistemological growth. During this study, I looked for structures that exhibited the GTA's practices of reform-based practices, although the laboratory design was outside of the GTA control.

Sawada et al. (2003) developed the RTOP to measure three categories important to reformed teaching. The division of lesson design and implementation contained statements that demonstrated the teachers' ability to be flexible based on student understanding. Teachers in a reformed classroom encouraged their students' divergent patterns of thinking, and instruction focused on a collective exploration of problem-solving while socially constructing knowledge. The content was subdivided into categories of propositional and procedural knowledge. Propositional knowledge included teacher behaviors that demonstrated understanding and conceptual connectivity of subject matter to the real world. Alternately, procedural knowledge behaviors focused on the student's interactions with the subject matter. The scientific reasoning was evident in the classroom because students were engaged in their understanding of content. The final category, classroom culture, focused on the relationships in the classroom. Reformed learning environments encouraged respectful and complex communication between students, as well as the relationships between teacher and students (Sawada et al., 2003). RTOP themes allowed for a more precise understanding of the GTA's instructional behaviors and changes during the semester.

Professional Development

In addition to the interview and observations, in-class reflections, from the participants, their talent themes, and their student evaluations were utilized to inform the development of GTA role-identity reported in each case study. The participants were asked to complete in-class, and out of class activities during the workshop. None of the participants finished the out of the class observational assignment. Several of the participants completed the CSFA and engaged in the workshop discussion regarding talent and leadership. Also, participant end-of-semester teaching evaluations done by the undergraduate students for the GTAs in spring 2017, after completing the professional development, were compared to the student evaluation from the same GTA and same course from Fall 2016 to monitor perceived changes in instructional behavior.

GTAs were asked to reflect on their classroom behaviors and teaching practices. Initially, this was to happen online, but only one GTA joined the Wiki, so the reflections were moved to in-class writing assignments. We randomly assigned the participants one of two reflection questions.

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? Discuss your answer and contrast your ideas to what Bodner said. Explain how using your knowledge of potential student misconceptions can help you better connect ideas in chemistry, so your students' understanding has minimal misconceptions.

The second question was adapted by our outside Clifton Strength Finder (CSF) expert to incorporate participants results. The question asked students about using their talents to address potential student misconceptions:

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? Discuss your answer and contrast your ideas to what Bodner said. Explain how using your individual talents, as defined by the Clifton Strengths Finder Assessment, can help you better connect ideas in chemistry, so your students' understanding has minimal misconceptions.

These reflections helped to inform the epistemological and pedagogical development of each participant regarding their knowledge about the Bodner (1991) article about graduate student misconceptions and their ability to address misconceptions their students might form during instruction. The adaptation of the question helped to determine if reflecting on talents resulted in different outcomes.

GTA participation in the workshop along with their end of class reflections informed the construction of GTA role. GTAs were asked what aspect of the workshops was beneficial, along with critical questions about their teaching practices. As the conceptual framework encouraged assessing student outcomes, I gathered the student evaluations for participants, as a way to ascertain the identity GTAs portrayed as they enacted their roles as laboratory instructors.

Participant-observer. The goal of a participant observer, as explained by Creswell (2013), was my acceptance into the social community of chemistry GTAs. This methodology has been well documented for use in qualitative studies. Although it was initially attributed to ethnographic studies (Creswell, 2013), the application in educational research is common. Socialization into the community allows the researchers to become familiar with the symbols and objects relevant to the group, which is a significant part of the symbolic interactionist model (Herman-Kinny & Verschaeve, 2003). Blumer (1969) summarized the rationale that best explains the importance of participant observation:

> The empirical social world consists of ongoing group life, and one has to get close to this life to know what is going on in it. If one is going to respect the social world, one's problems, guiding conception, data, schemes, or relationships, and ideas of interpretation have to be faithful to that empirical world (p. 38).

Understanding of the empirical world allows for sympathetic introspection, which explains people's actions with the additional comprehension of beliefs and motives (Taylor & Bogdan, 1998). As a participant observer, I completed the chemistry education professional development class with the other GTAs in the department.

At the onset of this study, I was in my sixth year as a graduate teaching assistant in the chemistry department at this university. I received my K-12 education in America. I have served as an instructor for most of the undergraduate chemistry labs assigned to GTAs. As a graduate student I continued to explore new teaching opportunities. In the 2015 to 2016 school year, I taught a dual enrollment General Chemistry I course at a high school near the university working in a professional learning community with a master teacher from the university to design and implement student-centered instruction.

I am a self-proclaimed reform-oriented instructor; my intent as an undergraduate was to become a chemistry teacher. I accepted work as a tutor and a learning assistant (LA) when the opportunities were presented to me in my sophomore year as an undergraduate. I was a certified tutor at the community college I attended while earning credits toward my undergraduate chemistry degree. I worked one-on-one with students attending introductory courses to assist in understanding content knowledge for two years. After transferring to a state university and completing the undergraduate Quantitative and Analytical Chemistry course, another student and I were asked to be LAs in class the following year, when the analytical chemistry professor implemented group learning and in-class assignments. We assisted students in-class as they worked through problems on computers using Microsoft Excel as a tool for data analysis. As LAs, we met with the professor teaching the course we worked in weekly. We also attended weekly meetings with the LA coordinator, who was the chemistry department's first associate professor with a doctorate in chemistry education, and LAs from other classes, including General Chemistry and Statistics. In this class, we read articles and discussed difficulties we had as LAs. In the workshops, for this study I participated as an experienced GTA, who set up recording equipment for every workshop.

My goal in this study was to relate to the participants and encourage positive epistemological reflection. In this way, I hoped to serve as a resource and guide to GTAs with less instructional experience during our workshops. Interestingly, I found it difficult to connect with chemistry GTAs. We taught in the same content area and even the same classes, in some instances; however, our research often kept us siloed in different buildings or areas of the same building, and I completed my coursework in 2014. I was no longer taking classes with my peers. Several of the participants were in other doctoral programs and remembered me from classes we had taken together.

As a participant observer, I took field notes in a journal during the class sessions that included reflections and relevant events. I later reflected on the sessions, and the records were compared to the class audio for additional information and clarification when necessary (Harper, 2000). Field notes were entered into the analytical software ATLAS as coming from Lithium, my elemental pseudonym.

Researcher qualifications. My career as a researcher in chemistry education started in 2009 when I began the literature review for my undergraduate thesis. The study was initially comparative. I surveyed students from general chemistry classes that were taught using different instructional techniques - one teacher-centered and the other student-centered. I also had originally intended to interview each of the professors about their choice of instructional strategies. Ultimately, I was only able to collect data from the teacher who had LAs in his student-centered classroom. I used quantitative analytical procedures to analyze the data I collected using a previously validated student interest survey and found that students believed that their laboratory experience were the most impactful to their interest in science. I presented the results as an undergraduate poster at the American Chemical Society's (ACS) Spring 2011 conference. The curiosity and excitement I still had regarding teaching and learning chemistry inspired me to continue researching as I earned a doctorate in chemical education.

I continued my work as a researcher as a graduate student with project TIME, later in 2011 at the start of my graduate school experience. I worked as a research assistant collecting qualitative research using RTOPs, interviews, and an observational protocol based on the curriculum presented during a summer professional development. The student-centered curriculum required teachers to adopt new instructional techniques. I presented research related to high-school science teachers at several conferences and published my first journal article describing their implementation fidelity. I continued analyzing the data in order to gather a conceptual representation of chemistry science teachers as they attempted to change their classrooms. The teachers showed trends of implementation related to their development as science teachers, I finished this research as part of my master's degree in 2016.

Before this study, my research focused on the practices of chemistry teachers or professors that were in service, and I was curious about the development of graduate students as teachers. As a graduate student myself, I was surprised at the lack of training required to be a GTA. As I had initially intended to be a high-school chemistry teacher, I was aware of the numerous courses in education and content needed before becoming a licensed teacher. I requested an opportunity to develop a GTA professional development. In the Fall of 2016, I asked for a meeting with the director of my doctoral program and the chair of the chemistry department in which we discussed funding and faculty support necessary. My advisor and I worked closely on the development of the content provided during professional development. We wanted to offer our graduate students the opportunity to acquire knowledge and skills that would serve them in the present (as chemistry GTAs) and in the future, regardless of where their paths might lead them after the completion of their degree.

Analysis

I started the research analysis in May of 2017, after collecting the data for all participants. The first phase involved sorting and filing the original documentation, which included the researchers' RTOP and TBI notes and participants' reflections completed during the workshops. I went on to rename the audio and video files from each participant with their element pseudonyms sorting each into their folder. Once each piece of data was labeled, I started with an overview of GTA practice. With a summary of each participants RTOP scores and a brief overview of the participants' high and low scores I presented initial results at the MSERA's (Mid-South Educational Researcher Association) annual conference in November of 2017. At this meeting, I received accolades for best research in progress. I presented the data again at a seminar on campus to the Mathematics and Science Education community (graduate students and faculty). It was there that we wondered if GTAs do not identify as teachers, can they assume that professional role-identity in the classroom?

While I had some idea of their practices, determining the beliefs was another hurdle. I transcribed the GTA interviews which concluded in May of 2018. Two participants, Carbon and Chlorine, completed interviews at the beginning of the semester and after the first workshop. My advisor coded each participant after I provided an evaluation key for each question, which had examples of GTA beliefs indicative of each level from traditional to reform-based. We would meet weekly to discuss our codes and come to an agreement on any changes that needed to be made. The interrater reliability began in May and was completed by August of 2018.

As a participant observer and co-developer of professional development, I collected artifacts during the workshops. These objects included audio recordings of each workshop and a standing video of most workshops, taken with my iPad or video camera on a tripod in the back of the room. I started the analysis of the workshops in June of 2018. I listened to and took notes on each recorded workshop. Before listening to each recording, I read and annotated the readings provided by Dr. Neon. To triangulate the data, I summarized each workshop from a combination of field notes taken from Dr. Neon and myself at the time of the professional development in the Spring semester of 2017. Dr. Neon reviewed and approved the summary of her workshop presentations in November of 2018.

I compiled the data for each participant into case studies, which were completed in February of 2019. I used the data collected from the field notes for the workshops, the initial RTOP, the initial TBI, the GTA engagement and reflections from the workshops, the final RTOP, and the final TBI. Each case contains a brief introduction to the participant, including their educational and teaching background. The various amount of participation between GTAs required case studies to provide stories as a reference point for their similarities and differences. I formatted answers to each of the research questions by reviewing the cases and specific data necessary for each GTA.

CHAPTER FOUR: PROFESSIONAL DEVELOPMENT

We participated in the professional development on Mondays, six times before the end of the spring semester 2017. Dr. Neon was providing professional development for chemistry graduate teaching assistants (GTAs) amid an already busy schedule, Figure 5.

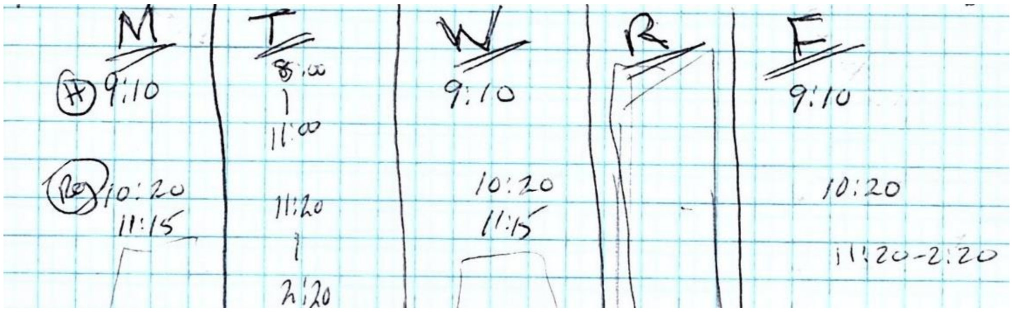


Figure 5. Dr. Neon's Spring 2017 Schedule (Neon, notes, Jan.11).

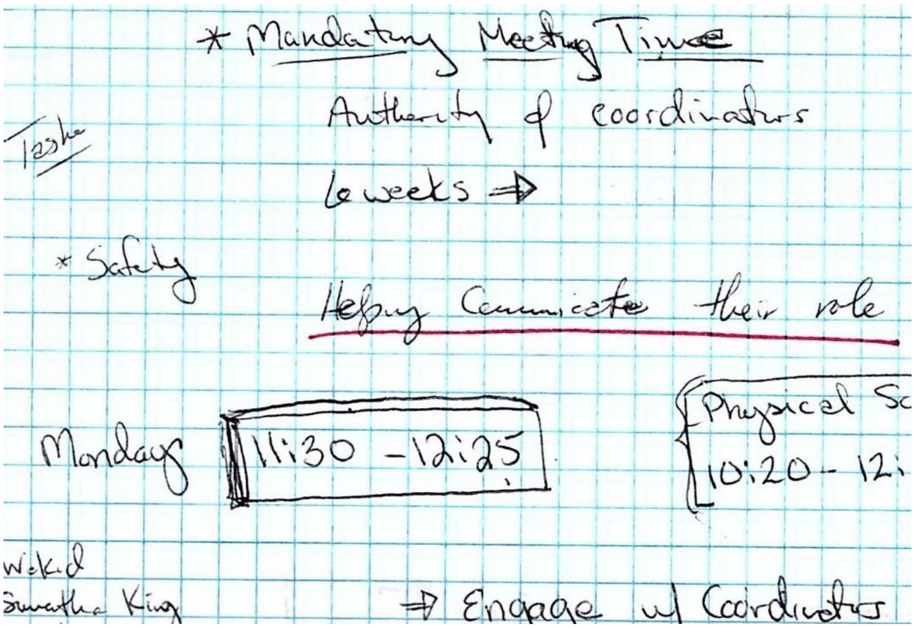
The professional development, supported through the chemistry department and conducted by Dr. Neon, was the central phenomenon of my study. By the Reeves et al. (2016) framework outlined in Chapter Three, the Workshop's were summarized after listening to a recording of the workshop, along with a summary of each outside reading assignment given after each session. Notes from Dr. Neon and me were used to support the narrative. Narratives of each of the GTAs that participated in the study are presented as cases in Chapter Five synthesized from observational and interview data collected at the beginning and end of the semester, when possible. The participants' involvement during the workshop and responses to reflections also helped to inform the story of each participant, using their elemental pseudonym. The workshops allowed me to observe and interact with my chemistry peers as a graduate teaching assistant (GTA) for the first time in my six-year career.

Professional Development Introduction

I want to start our story slightly before the workshops when I began taking field notes. I intend to provide my viewpoint as a subjective perspective. “We are a week away from the start of spring semester 2017, and I am honestly excited about data collection. I enjoy finding out why other people enjoy chemistry, and how each holds separate and unique constructs” (Frick, notes, Jan 9). I still feel similar to this more than a year later. I enjoyed the interactions I shared with my peers. We had fun talking about our understandings of chemistry specifically and knowledge in general. “I am excited about meeting all the chemistry GTAs. It feels a little weird to be classifying people, but I think baseline data will help me to gain clarity, as time goes on about raw and mature talents” (Frick, notes, Jan 9). I did play a unique role as a GTA participating in the professional development that I requested and helped develop. Although I had helped establish the experience as part of my research, I continued teaching as a GTA, so my role in the workshops was authentic in that way. The other GTAs were not entirely aware of my role as a co-conspirator in the design of the workshops. I noted the introductory information for the workshops in my field notes:

> I met with Dr. Neon today, directly after her meeting with the chair of chemistry. The workshops will be offered on Mondays from 11:30 – 12:25, the first meeting will be on 1/23/17. We have an estimate of 15 GTAs; although we only need a six-week course, the department may continue to use that time as a general meeting time for GTAs. The chemistry chair will attend the first meeting which all GTA's are required to attend. I supplied Dr. Ne with a list of the six topics, which she had printed out from the email and brought with her to the meeting. (Frick, notes, Jan 11)

In turn, the department had some expectations of Dr. Neon, Figure 6.



* Mandatory Meeting Time
Authority of coordinators
6 weeks ⇒
Tasks
* Safety
Helping Communicate their role
Mondays 11:30 – 12:25
Physical Sc
10:20 – 12:
Wicked
Samantha King
⇒ Engage w/ Coordinators

Figure 6. Department expectations of GTA professional development (Neon, notes, Jan. 11).

We spent a remarkable amount of time thinking and conversing about how best to implement the workshops. We wanted to keep the general format from a professional development that had previously been successful with chemistry GTAs, (Table 4) while employing strategies Dr. Neon previously used to encourage growth in pedagogical content knowledge for chemistry teachers. "Dr. Neon and I worked on the design of the workshop for two hours yesterday, thinking about ideas and finalizing the schedule. We have decided to have the class meet every other week" (Lithium, Jan 18).

Table 4. Initial Topics and the Revised Plan for GTA Professional Development

Date	Topic for GTA_TPD	Topic from Marbach-Ad et al., 2012	Reading	Assignment
23-Jan	Introduction	Introduction	Bodner, 1991	Reflection & CSFA
6-Feb	Student expectations	Evaluation	Rath & Conchie, 2015	Reflection & group/lab
20-Feb	Teacher expectations	Assessment	Appleton, 1993	Reflection & Teaching Observation
13-Mar	Learning in laboratories	Teaching strategies	Domin, 2010	Reflection & Analyze current lab for purpose and expected student outcomes
27-Mar	Communication for understanding	Communication	Johnstone, 1991	Reflection & How are you or the individuals you observed communicating information to students/ how was understanding exhibited
10-Apr	Rethinking laboratory design	Presentation skills		reflection & lesson redesign /adaptation

With the workshops starting in just a few days we were still working out our plans.

> I will be writing up a syllabus/ lesson plan for each of the classes today and forwarding it to Dr. Neon for final approval. I am setting up two Wiki's that will be for GTA reflection as they move through the TPD. I am still in the planning stages of lesson design for this part of the class. (Frick, notes, Jan 18)

It soon became evident that even I did not know much about the design of the workshops; I had proposed the idea which was now out of my hands and into the hands of the experts.

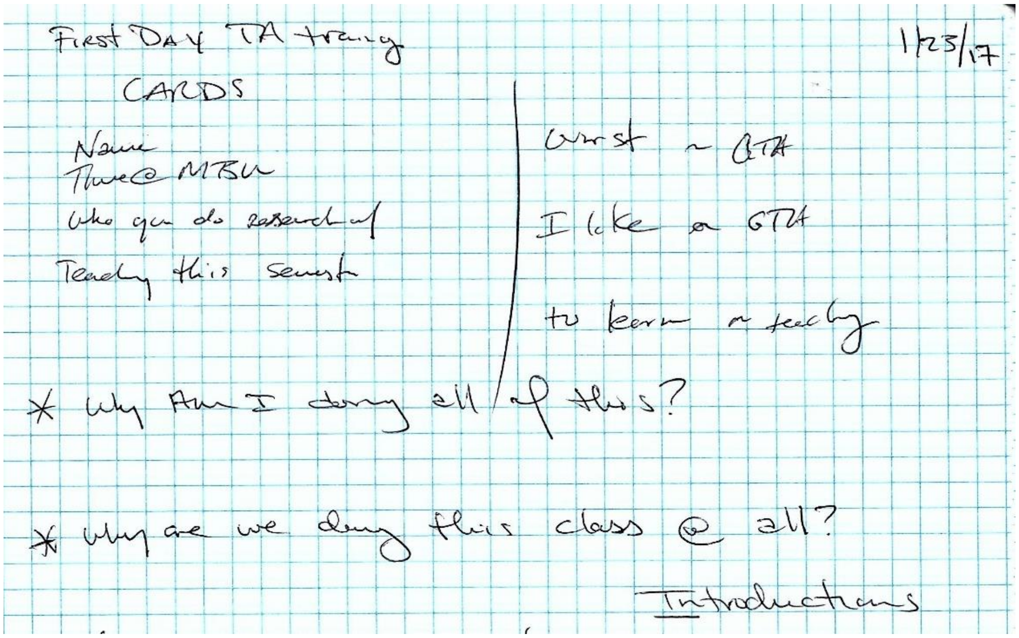
Department Introduction. At the start of each semester, the GTAs met with the laboratory coordinators and the laboratory supervisor to review the safety components of working in a chemistry laboratory with students, the chair of the chemistry department attended the meeting to introduce the workshops Dr. Neon would be instructing. "The last day of the first week of the semester, the chair will be meeting with chemistry GTAs at 2:00" (Frick, notes, Jan 20). The first meeting of GTAs took place on Friday, January 20, the first week of spring semester 2017. The GTAs filed into one of the general chemistry laboratories and took the place of students at the lab benches. Several individuals, mostly professors, stood at the front of the room talking amongst themselves. One of the group members stepped forward and introduced himself as the chair of the chemistry department. He also introduced the laboratory coordinators to the room of nearly twenty GTAs. The pseudonyms, I selected at random for the laboratory coordinators, were Dr. Helium, for general chemistry, Dr. Krypton, for the Introductory and Consumer Chemistry sections, and Dr. Argon, for Physical Science. Dr. Helium went through our safety training and the expectations we were to maintain for student safety. Important safety instructions included being sure students keep goggles on, hair pulled back, and arrive with proper clothing and shoes. Dr. Helium introduced the general chemistry laboratory supervisor. He explained that all the materials necessary for the students were in the drawers at the lab benches. He emphasized that the GTAs were responsible for making sure the equipment was cleaned and replaced adequately by their students in each class as other GTAs and professors use the same laboratory equipment for their students. He made us aware that all the chemicals and equipment we would need for the experiment would be set up and ready for us when we entered the laboratory each week. Dr. Helium expected GTAs to arrive between ten and fifteen minutes before our class started, to be sure the materials were ready. The chair explained the new workshops Dr. Neon was providing for the GTAs this semester. He introduced her as an expert in the field of chemistry education research and stressed the importance of creating great educational opportunities for our students. He thought we were lucky to have the opportunity to learn to teach from her. He presented Dr. Neon as an awarded chemistry professor dedicated to providing excellent learning opportunities for her students. He explained that all GTAs would attend the workshop unless their schedules made it prohibitive.

I began recruitment for my research after the introduction of the workshop as GTAs were meeting with their laboratory coordinators. I had already met with Dr.

Krypton previously in the week for my Introduction to General Chemistry II materials. Dr. Argon, the laboratory coordinator for Topics in Physical Science, was also introduced, although not in attendance she had reached out to those of us teaching her laboratories so we could meet at her office for the curriculum materials we needed at another time. I noted that day a thought that directly pertained to my interaction with laboratory coordinators. “To be honest, one of the difficulties I have is being truthful with my lab coordinator. As a GTA I do not want to be another burden for the professor” (Frick, Jan. 20). As everyone else filed out of the room, Dr. Neon and I discussed which GTAs had agreed to participate in the study, we were familiar with some of the GTAs, while discussing plans for the first meeting she would lead as part of the GTA professional development, on the following Monday.

Workshop One

“We get our first GTA TPD class today, and though I know what will be addressed and a vague idea of the topics, the main lesson plan is finalized by Dr. Ne” (Frick, Jan. 23). My thoughts were mostly focused on gathering data for my research, “I am excited to start setting up interviews with the GTAs” (Frick, Jan 23). In the workshop, “we filled out a card about who we are and what we do in chemistry” (Frick Jan 23). Dr. Neon explained that she was tasked with the opportunity to use her twenty-five years of experience in chemical education to help us be better teachers and wanted us to include on the card something we wanted to learn about teaching. She had already outlined her plan, as shown in Figure 7.



First DAY TA training 1/23/17

CARDS

Name
Time @ MBU
Who you do research w/
Teaching this semester

Worst ~ GTA

I like as GTA

to learn ~ teaching

* Why Am I doing all of this?

* Why are we doing this class @ all?

Introductions

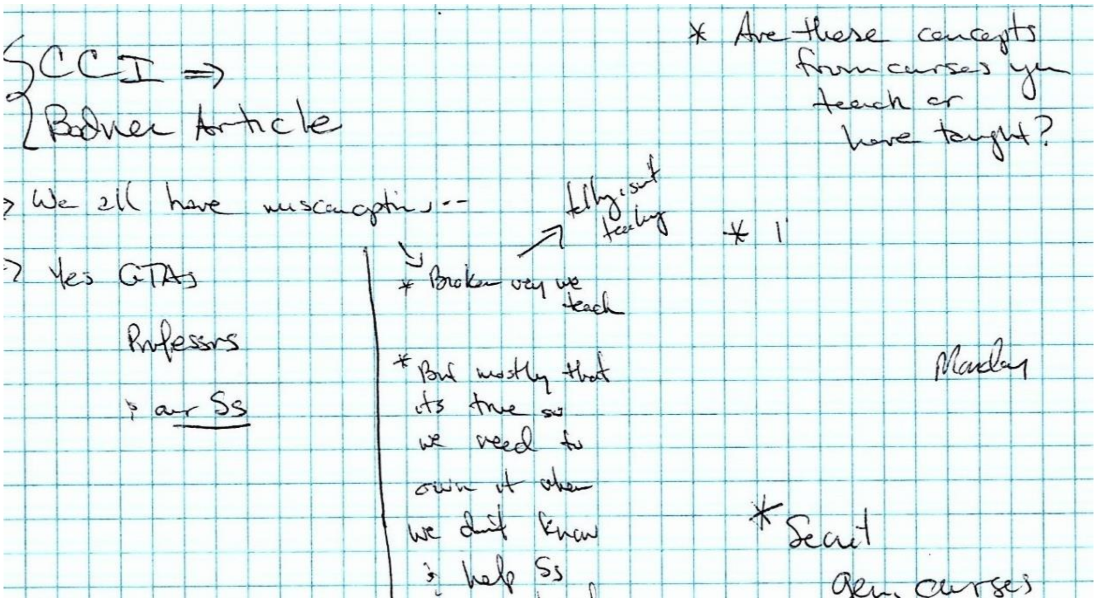
Figure 7. Outline for Workshop One (Neon, notes, Jan. 23)

I noted Dr. Neon’s rationale for providing the workshop, “our department depends on GTAs, as GTAs arguably have more impact on introductory chemistry students – kind of a big deal” (Frick, Jan. 23). Dr. Neon provided guidelines about how to be a better GTA included significant points, such as do no harm to yourself or your students in the lab, and the importance of learning your students’ names.

Dr. Neon modeled how to learn names in a class by having us introduce ourselves, along with something interesting about ourselves, to help her remember. She took time with each person, allowing them to pronounce names that were difficult for her to understand slowly. Something interesting about me, I enjoy playing board games, and

Dr. Neon brought up another interesting point about my board games. After teaching general chemistry as dual enrollment for a year at a local high school my students spent the night before their graduation playing games at my house. Dr. Neon felt it was apparent that I liked teaching and my students. Several GTAs noted that they either hated teaching or enjoyed teaching as their interesting fact about themselves.

The big item on our agenda for the first workshop, the concepts test, was finished in the remainder of our time. "We completed the Chemistry Concepts Inventory (CCI) and were given the Bodner (1991) article to read before our next meeting" (Frick, Jan 23). Dr. Neon wanted to help us understand that chemistry concepts are not universally recognized, even when working with experts, Figure 8.



CCI ⇒
Bodner Article

> We all have misconceptions --

> Yes GTAs
Professors
& our Ss

* Broken way we teach

telling isn't teaching

* But mostly that its true so
we need to
own it when
we don't know
& help Ss

* Are these concepts
from courses you
teach or
have taught?

* 1

Marclay

* Secret
Gen. courses

Figure 8. Ideas and questions from Workshop One (Neon, notes, Jan. 23)

The workshop started us thinking about our students, and the article we were given highlighted the fact that chemistry has many topics in introductory classes; in which, we likely hold our own misconceptions.

Reading One. The Bodner (1991) article addressed, what the results of the CCI highlighted, graduate students misconceptions about chemistry. Bodner worked with hundreds of chemistry graduate students and noticed that they held a variety of conceptual understandings about crucial topics in chemistry. Several decades later graduate students at another university had similar difficulties.

> I talked with Dr. Neon today about the results from the CCI. The scores ranged from six to nineteen out of twenty-three. I had a high score and still hold misconceptions. The reality seems to be that we all do in some topics…Dr. Neon said, high school teachers usually have higher scores on the concept inventory. (Frick, Jan 25)

Bodner (1991) explained that GTAs starting their graduate experience often held alternative conceptions. Through his years of working with GTAs, Bodner worked on developing a way to identify alternative concepts held by GTAs. The topics on the concept inventory have been typically covered in introductory undergraduate chemistry classes and included items related to phase change, the relationship between temperature and heat, what occurs when a chemical reaction takes place between elements in two separate phases and density. Bodner (1991) suggested that undergraduates did not have enough opportunity to apply their theoretical knowledge, which resulted in misconceptions that were incredibly resistant to instruction. “Instructor-driven misconceptions can be generated unintentionally when the limits of assumptions are not specifically defined” (Bodner, 1991, p.387). Great, now I am not only hurting my students’ chemistry concept with my inaccurate representations; I am also limiting them by not providing enough of the correct information. I know that we simplify a lot in introductory courses to make the material digestible, and in the simplification, we can leave out information that might be important to the students conceptual understanding. Providing the correct information at the right time to form appropriate knowledge is a balancing act that is maintained by the instructor.

As the weeks of the semester began to set a rhythm and our first week of teaching labs was underway, I reflected on some of the difficulties we have as GTAs. I wondered if a link could be made between pedagogical content knowledge (PCK) and chemistry content concepts. Perhaps the reason the high school teachers had higher scores on the CCI resulted from their having to understand students’ perspectives. “Would it be better to use a conceptual, top-down approach when teaching pedagogy to understand content” (Frick, notes, Jan. 25)? I found myself asking a lot of questions and continued to think about what information would best serve the GTAs.

> We have an accountability problem, as GTAs the expectations are low from lab coordinators. We are expected to come to the lab, hand out quizzes, and go

> through a predesigned experiment. We have no thought as to what would go into an experiment because it is not my project. Naturally, it can be challenging to know important content, or how to improve PCK. The class needs to be pedagogy focused on experiments in the laboratory. (Frick, notes, Feb. 1)

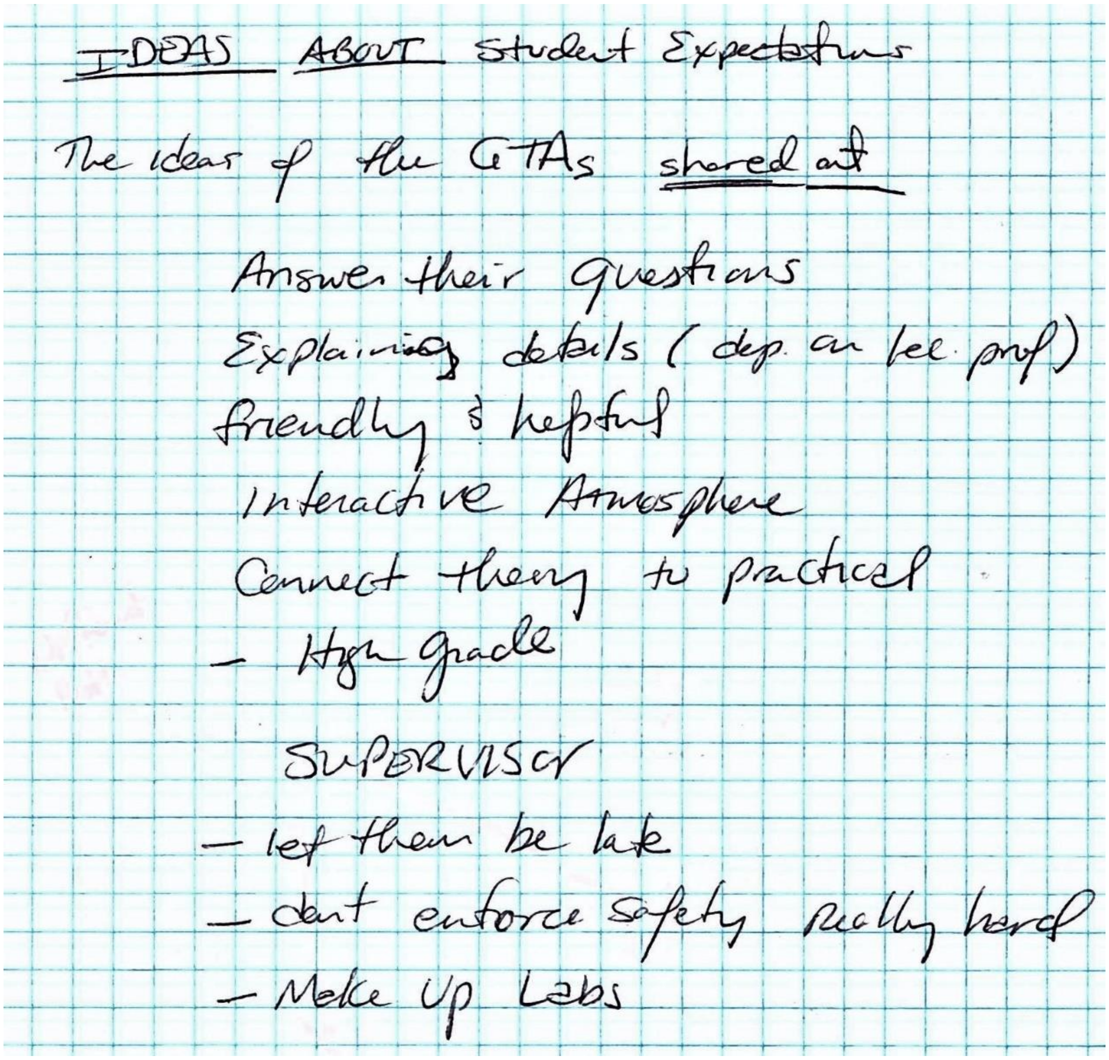
Of course, the semester began to pick up speed when all the planning was complete, and data collection started, which happened on the same day as our second newly designed professional development, where we discussed student expectations, and "our *Strengths* books are in" (Frick, notes, Jan 27).

Workshop Two

Dr. Neon provided PowerPoint slides for the workshops. First, we talked about student expectations, and then discussed misconceptions people have about chemistry topics. Although not part of her regular instructional strategies, Dr. Neon provided the slides after the GTAs expressed concerns about having a language barrier in their teaching. Dr. Neon suggested Power Points as an augmentation tool for effective communication. She modeled the instructional strategies she suggested for others. We started the workshop by acknowledging that a lot of people have an idea about what we do as GTAs, the professors teaching lecture, the lab coordinators, and even Dr. Neon, although they are likely not all the same. Dr. Neon encouraged our thinking about student expectations and sharing our thoughts with the class, as recorded in Figure 9.

We were able to think of a lot of things that we believe our students wanted from us during laboratory class:

> Students expect GTAs to answer questions, explain the details of the experiment, be friendly and helpful, provide an interactive atmosphere, connect theory to practice, give them high grades, be their supervisor, and let them do stuff when they are late. (Frick, notes, Feb. 6)



IDEAS ABOUT Student Expectations

The ideas of the GTAs shared out

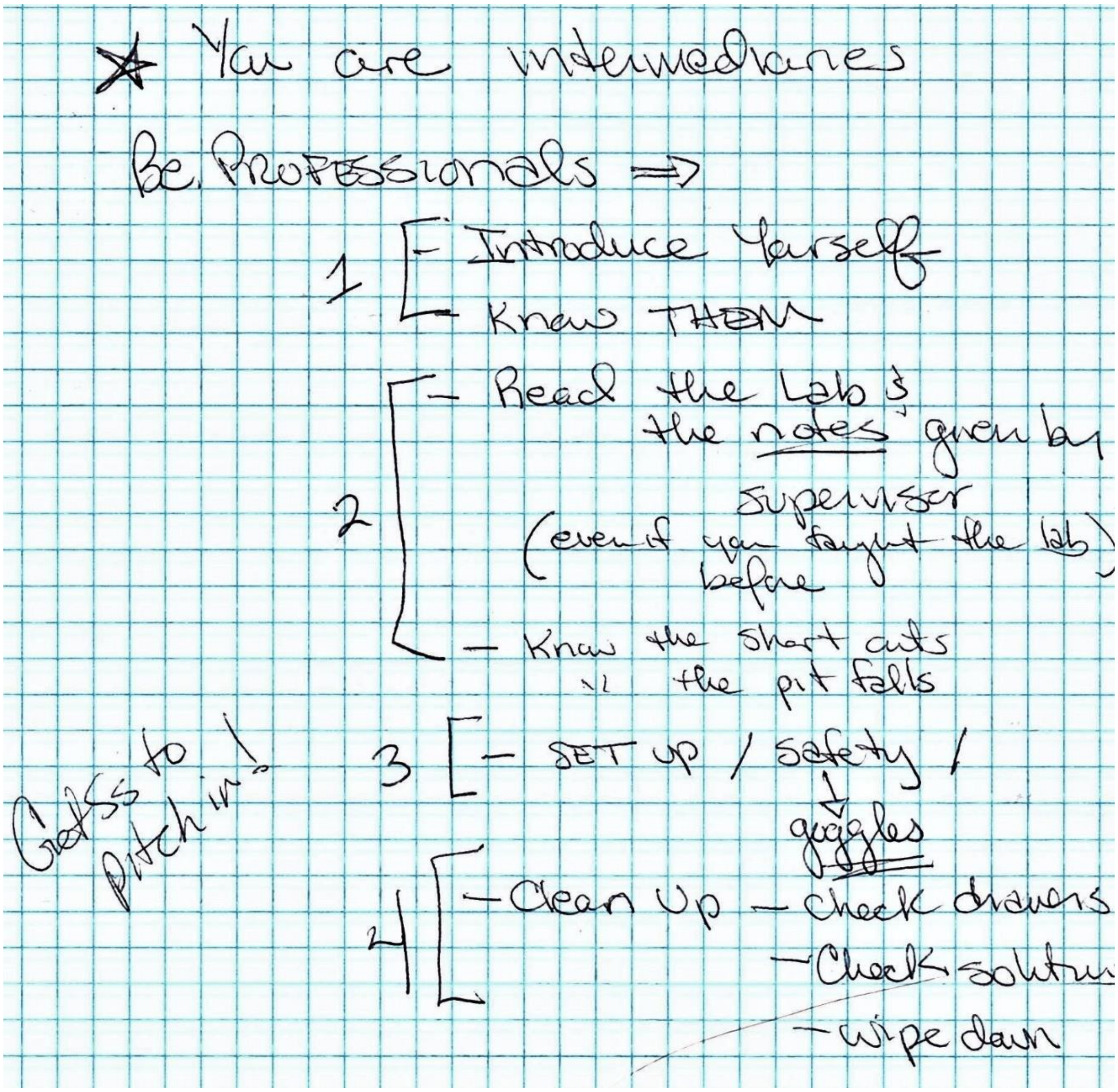
Answer their questions
Explaining details (dep. on lec. prof)
friendly & helpful
Interactive Atmosphere
Connect theory to practical
– High grade
SUPERVISOR
– let them be late
– dont enforce safety really hard
– Make Up Labs

Figure 9. GTA's ideas about student expectations (Neon, notes, Feb. 6)

Dr. Neon provided feedback as the GTAs presented their thoughts. For example, students expected you to not only have an answer, but have the correct answer, and that lab is one of the only places where students are provided the opportunity to talk about and interact with chemistry directly. Dr. Neon encouraged participation by calling individuals by their names and acknowledging the concerns brought up by GTAs. She thought some of the difficulties we had could be solved and said she would talk to the lab coordinators personally to determine if we had the authority to take points away from students for violations of lab protocol for example.

Let me explain. Dr. Neon was telling us that if we made a rule for a lab we had to enforce it equally. She gave the example of her allowing students to borrow goggles and complete the lab, rather than returning home to get their goggles or denying them access to the lab at all. She would subtract a point from their lab grade for the loan. We explained that the laboratory coordinators give us a grading key in which all ten points are pre-assigned, so we did not know the correct perspective of each lab coordinator on such a policy. Ultimately, we were expected to establish professionalism noting that students often make no distinction between Dr. Helium and us. In her planning notes, Dr. Neon summarized coordinator expectations, Figure 10.

“We are seen as an authority figure, so must have a rule” (Frick, notes, Feb.6). Dr. Neon foreshadowed points from the book “Strengths Based Leadership” (Rath& Conchie, 2008), as she stressed that although each laboratory coordinator had different expectations of their GTAs, we could enforce policy to meet the needs of students, as followers, Figure 11.



★ You are intermediaries

Be. PROFESSIONALS ⇒

1 [- Introduce Yourself
  - Know THEM

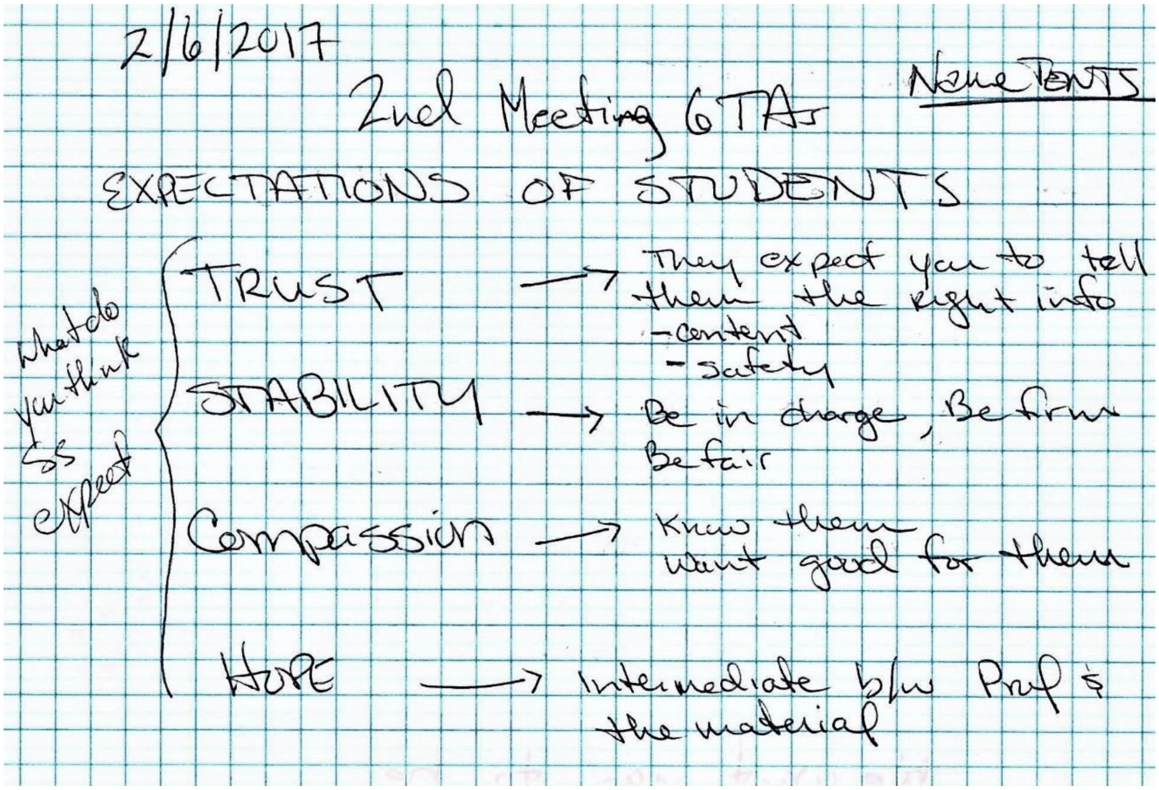
2 [- Read the Lab & the notes given by supervisor (even if you taught the lab before)
  - Know the short cuts & the pit falls

3 [- SET up / safety / → goggles

4 [- Clean Up - check drawers
  - Check solutn
  - wipe down

GTAs to pitch in!

Figure 10. Lab coordinator expectations for professional GTAs (Neon, notes, Feb. 3).



2/6/2017

Name Tents

2nd Meeting GTAs

EXPECTATIONS OF STUDENTS

What do you think Ss expect

TRUST → They expect you to tell them the right info
- content
- safety

STABILITY → Be in charge, Be firm
Be fair

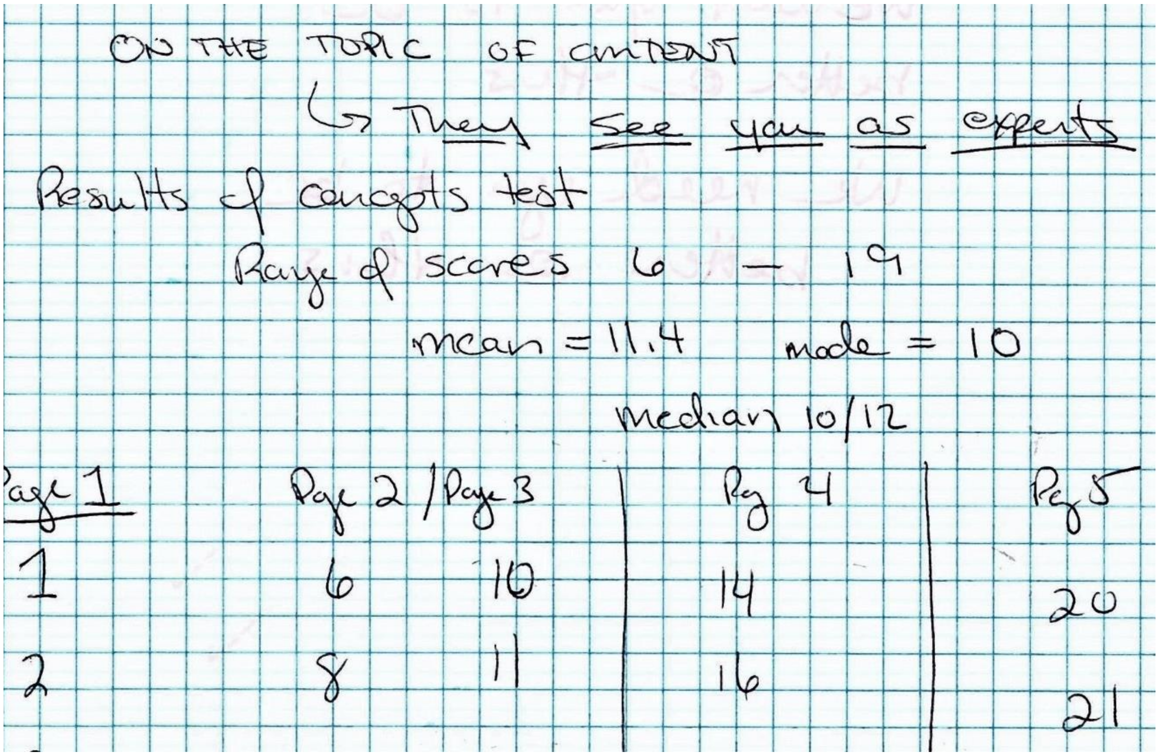
Compassion → Know them
want good for them

HOPE → Intermediate b/w Prof & the material

Figure 11. Summary of student expectations from Dr. Neon (Neon, notes, Feb. 6).

“Trust – provide correct content information and safety. Stability - be in charge, be firm, be fair. Compassion – know students and want to help. Hope – being a bridge between the professor and the content understanding” (Frick, notes, Feb. 6).

Dr. Neon provided the results of the CCI to the entire class, Figure 12. Although she did not return our tests, she did let us know the items most commonly missed. She reported the mean, median, mode, and range, and said we could stop by her office to look at our test if we wanted to see our results. I will merely say, that on average, we knew half of the correct answers. At this point in the workshop, we went into groups according to the labs we taught and assigned a page from the CCI.

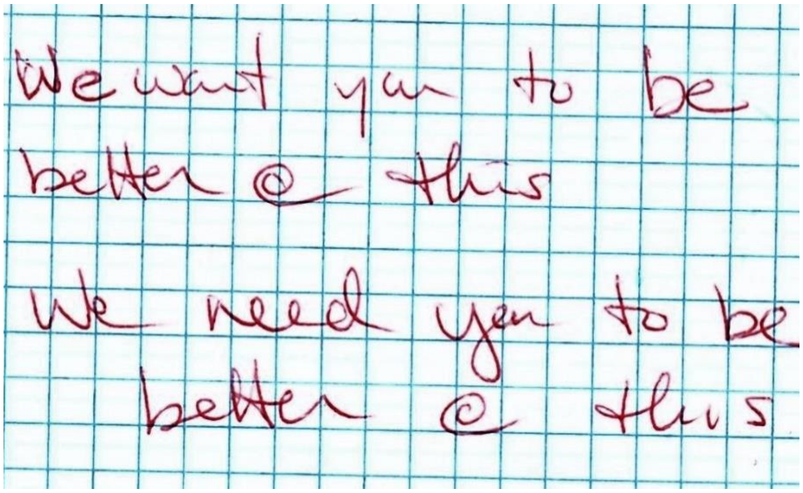


ON THE TOPIC OF CONTENT
↳ They see you as experts
Results of concepts test
Range of scores 6 – 19
mean = 11.4 mode = 10
median 10/12

age 1	Page 2	Page 3	Pg 4	Pg 5
1	6	10	14	20
2	8	11	16	21

Figure 12. GTA results from the CCI (Neon, notes, Feb. 6)

"Whiteboard, four problems or four sets of problems" (Neon, notes, Feb. 3), turned into groups of 3 or 4 in which each group worked out at least one question. Every question worked had been missed by forty percent or more of our GTAs participating in the workshop. We came to a consensus as a group before writing the answer on a whiteboard and presenting the solutions. As a class, we discussed misconceptions and were presented with the opportunity to grow in our understanding of several chemistry concepts. We talked about solubility, conservation of particles in a chemical reaction, amount of mass in a mole, and phase changes. Dr. Neon explained the mission of the professional development, after noting the amount of time GTAs interact with students as being arguably higher than the professors, was to be better at our jobs as teaching assistants, Figure 13.



We want you to be
better @ this
We need you to be
better @ this

Figure 13. Objectives for the professional development of GTAs (Neon, notes, Feb. 6)

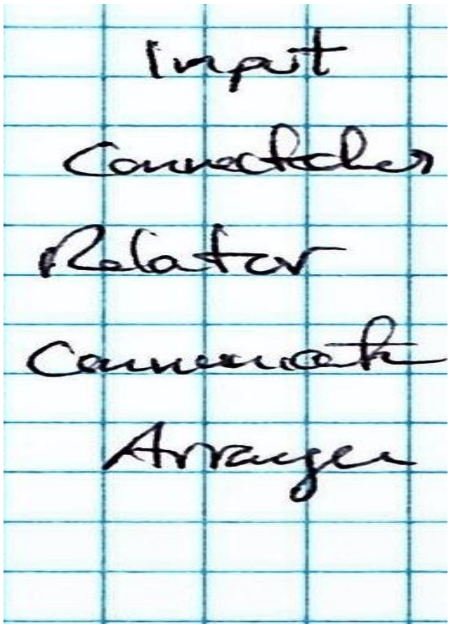
As we concluded our presentations, Dr. Neon asked each person to take a book and complete the test, before coming to the next workshop, in two weeks.

Reading Two. The book "Strength Based Leadership: Great Leaders Teams and Why People Follow" (Rath & Conchie, 2008) is a report of research conducted at the

Gallup Corporation. When purchased, the book includes a code for the analytic assessment of talents, developed and refined over decades while researching what made people great at their jobs, the Clifton Strengths Finder. Rath and Conchie (2008) explained how Gallup has been studying human behavior for seven decades and how they have used that knowledge to improve leadership, through coaching, over the last four decades. Their findings indicated that people great at their role know what they do well, their strengths, and where they need a team to increase their effectiveness, their weaknesses. In conjunction with operating in an area of strength, great leaders also surrounded themselves with a group of individuals that they felt contributed to their success. Interestingly, almost everyone believed they were a good leader, out of a thousand people Gallup polled, 97% thought of themselves as above average leaders.

Leaders have the chance to impact the lives of others positively, and during our lifetime we will have many opportunities to be a leader. While many people claim they know how to motivate others, if they are not focused on their talents and to develop themselves, they can have the opposite effect. Ineffective leaders can cause disengaged followers (Rath & Conchie, 2008). After focusing for decades on leaders, Gallup switched their focus to followers, conducting ninety-minute interviews with detailed protocols to determine what leadership traits motivate others. First, they found that the leaders were not “well-rounded” rather they had cultivated their talents in one of the four leadership domains previously discussed. Their leadership teams; however, were “well rounded,” as they were composed of individuals with dominant talents in the other three leadership domains. Leaders recognize the value of their team and themselves (Rath & Conchie, 2008).

The analytical power of Gallup was introduced to me with a book I purchased at the bookstore from the recommendation of a friend in 2013. I was intrigued by the results and launched the book, Strength's Based Leadership, onto campus in a book club set up with faculty and graduate students from the Mathematics and Science Education doctoral program summer 2015. The director was kind enough to purchase the books for anyone willing to attend, my colleagues and I explored our results; my top five Strengths are in Figure 14.



Input
Connectedness
Relator
Communication
Arranger

Figure 14. Lithium top five talent themes (Neon, notes, Feb.20)

We had three meetings and Gallup's insights were perceived as accurate, by those in attendance. The Strengths movement has continued to progress, and in July 2017, with funding from the Chemistry Department, I attended the first Clifton Strengths Summit in Omaha, Nebraska. I completed the assessment twice, once in 2013 and again in 2015. Although the test-retest reliability was reported as being high (Asplund et al., 2009) I had some major medical problems in between the two that had changed my perspective a lot. Gallup attested that the order of my talents might shift, but the talents I have dominant are stable, after adolescence. The talents in my top five did not change, and the order only slightly, in 2013 communication was in position two and connectedness was number four. I feel that this was due to the maturation of my talents, I find myself focusing on forming relationships with others, more than on talking with others, currently.

Workshop Three

The third workshop consisted of two parts the first led by Dr. Neon and the second by an invited speaker; we took the opportunity during our off week to reflect on the progress of the GTA professional development and plan for the remaining workshops. GTAs had not completed any of the online reflections, as they had not accessed the Wiki. So, we discussed incorporating reflection questions into the remaining workshops, as GTAs did not attempt to access the online Wiki. It was also evident that we did not have chemistry faculty, willing to volunteer time attending the workshops. To involve a greater community, we invited a local bank manager to speak with us about the results of our Clifton Strengths Assessments. She was an active participant of several community leadership groups and the founder of the local Strengths Meet-Up. Figure 15 shows Dr.

Neon's planned flow, leading up to our speaker. I had participated in classes previously in which Dr. Neon had used the game Petals Around the Rose as a discrepant event; however, I had not recognized the pattern yet. She continued to roll the dice and say the numbers until I picked up on the way the numbers were tied to the design on the dice.

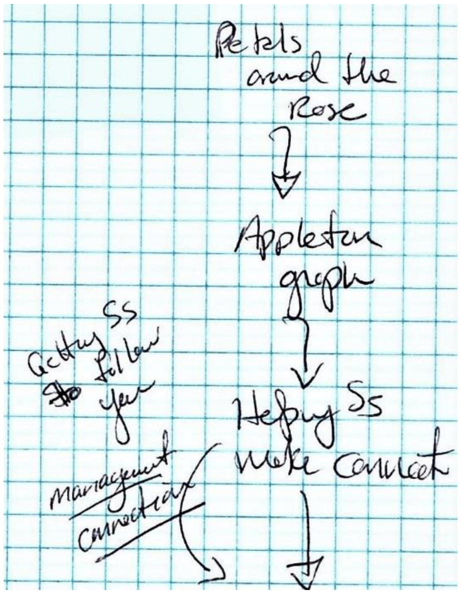


Figure 15. Flow chart from Dr.Neon, notes, Feb. 13

The frustration felt from not understanding the situation was what helped to introduce the concepts about potential ways students can deal with that frustration. Appleton (1993) provided four exit strategies students take based on the idea that knowledge is constructed within the mind of an individual. Dr. Neon provided Figure 16, which is strikingly similar to the figure Appleton supplied in his article, if less detailed.

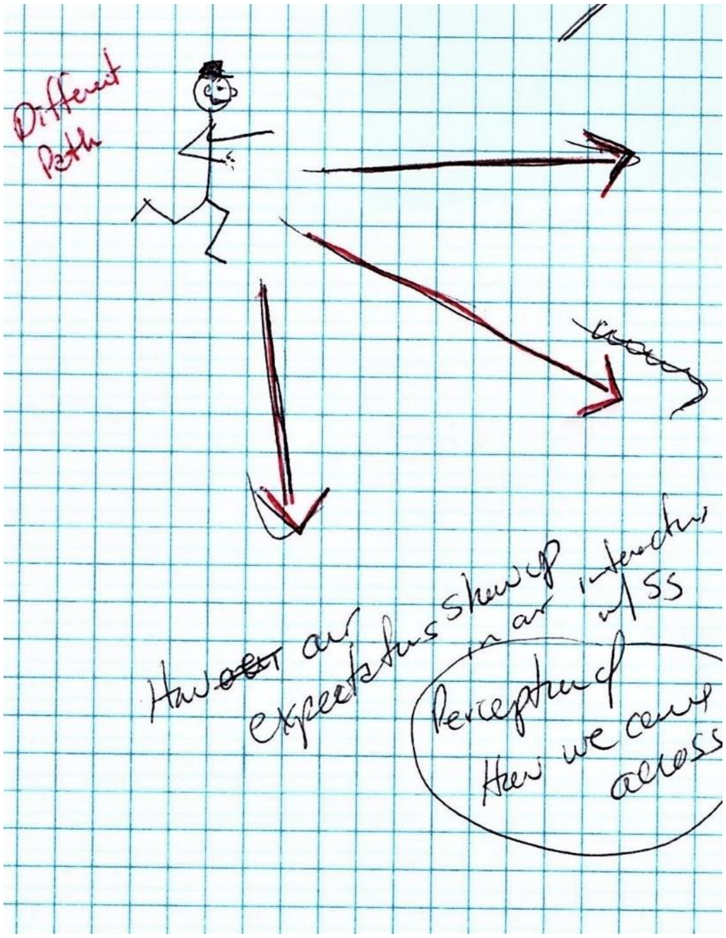


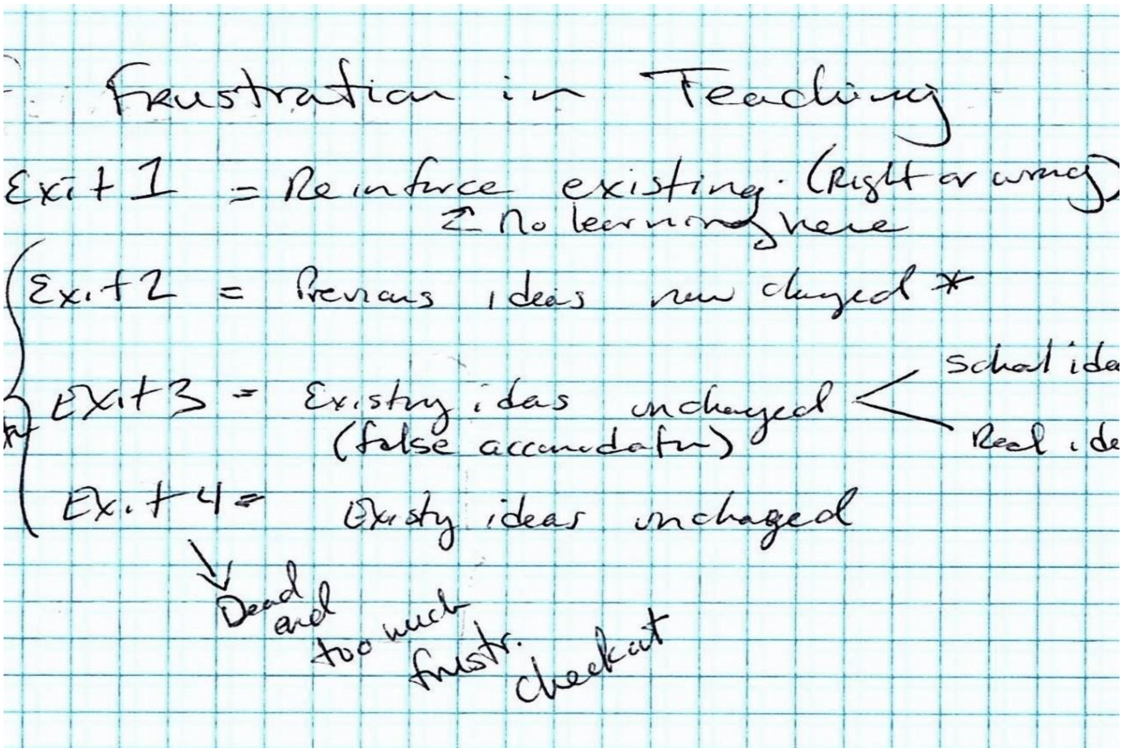
Figure 16. Representation of the potential exits a student can take when faced with a discrepant event (Neon, notes, Feb. 13).

My focus leaving the meeting was not on the activities of the workshop, but on creating an observation rubric.

> Tie the rubric to discrepant events. Identify a frustrated student; what do they look like? How does the GTA resolve the situation? Is the frustration leading to new

> ideas or exits? What kind of questions are asked by the instructor and students? Record examples of each with a checklist for observing others. (Frick, notes, Feb. 13)

The actual workshop started with Dr. Neon rolling five six-sided dice under the document camera so that every GTA could see the results. She asked "How many petals around the rose? Waited and demonstrated the answer was eight" (Frick, notes, Feb. 20). The game continued as she rolled five more times 8, 4, 2, 8, 10. She rolled again, and this time asked if anyone had a guess? A couple does, 2 or 8, they are wrong. The answer was six. She repeated herself more slowly and louder this time, petals around the rose. She rolled another five times, 8, 4, 4, 2, 4. This time when she asked she tried telling us another way the game is played, Polar Bears Around the Fishing Hole. How many polar bears around the hole? Some students guess 6 or 8. To be sure people know she is not just making up the answers, she points me out and asks me, how many petals around the rose? I said four, I was correct, and she rolled again, this time when she asked me, 2. I was wrong. She told me to be careful, and I looked again 4. She rolled three more times and asked me each time. Each time I was correct, 4, 0, 4. The point of the exercise was to put us in a situation our students feel every day when they do not understand. "Managing frustration – if our students are not frustrated, they are not learning. As instructors, our job is to manage anger and uneasiness. If students are sad or unhappy when leaving the lab, they have a negative learning association" (Frick, note, Feb. 20) Dr. Neon was ready for the GTA frustration and handed out the article with each of the exit strategies shown in an illustration. Dr. Neon summarized the points as shown in Figure 17.



Frustration in Teaching

Exit 1 = Reinforce existing. (Right or wrong)
≥ No learning here

Exit 2 = Previous ideas now changed *

Exit 3 = Existing idas unchanged < Schol ide
(false accomodation) Real ide

Exit 4 = Existy ideas unchaged
Dead end
too much frustr.
Checkout

Figure 17. Potential student exits when faced with frustration (Neon, notes, Feb.20).

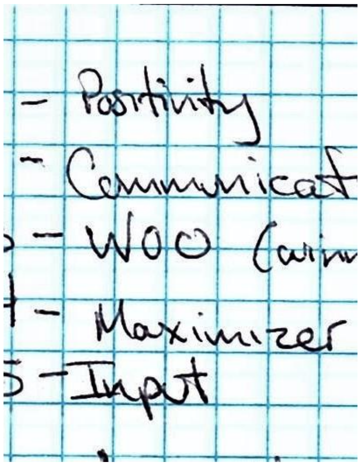
Each person deals with frustration slightly differently, and the four exits in Figure 17 were common when students get frustrated learning chemistry.

> Exit 2 is perfect – we rebuild conceptual thinking. Exit 3 the student figured out, the concept is put in the box, what the professor likes to hear. Our job is to manage learning situations…difference between learning and just saying what needed to be said. (Frick, notes, Feb. 20)

As Dr. Neon spoke of the different exit strategies, she continued to roll the dice and explained that some students take exit 1 and we do not know, because they seem sure that the concept was one they thought they already knew, and the original ideas were left unchanged. Exit 4 seemed the hardest; the stick figure in the article had slumped shoulders and looked sad; the student knows they do not understand and leaves the class still not understanding. Exit 1does not experience much frustration, the student either came in knowing the right answer or the student thought they knew the answer and we failed to uncover the shortcomings in their concepts and in exit four we do not resolve student frustration. At this point in the demonstration, Dr. Neon changed her questioning tactics; she wanted us to focus on the data. She asked what we noticed about each answer and continued rolling. One GTA started guessing, 10. The solution was 2, but notice that seven would be a bad guess. She acknowledges that the GTAs could be on to something, as Dr. Neon rolled four more times, others started to produce the correct answer. She pointed out to the rest of the class that the solutions could not require any mathematical manipulation, we were giving the answers too quickly, with no time to process. As the majority of the GTAs began to nod along with the answers to the game of Petals Around the Rose, Dr. Neon reiterated the idea that the help she gave to us was not the answer. "To make the problem simpler add questions" (Frick, notes, Feb. 20).

As the game ended, Dr. Neon encouraged us to understand the figure in the Appleton (1993) article; it could be life-changing. With that conclusion she introduced our guest, Tiwana, to speak about leadership. Tiwana launched into an explanation of the growth she had seen in herself over the past six years since focusing on her strengths. For example, she had doubled her income. Tiwana had each GTA write the results from their CSA (Clifton Strengths Assessment) on the whiteboard as they entered the room before the workshop began. The talents provided by each participant will be part of their case. Tiwana helped people download the Gallup Strengths app on their smartphones if they had not brought their results. As she started her section of the workshop, Tiwana noted that two people had deliberative as a talent theme and encouraged them to look at their personalized Strengths Insight report provided with your assessment results. She explained that the other dominant talent themes would cause your talents to behave slightly different as they developed into strengths – both would still know all the potential dangers associated with their chosen path forward. People high in the deliberative talent weigh the potential impacts before moving forward with their execution of tasks. She asked if they thought this sounded like them and both GTAs agreed this was true of the way they behaved.

As she talked about the domains of leadership Gallup identified as Strategic Thinking, Influencing, Executing, and Relationship Building, Tiwana revealed her story of wanting to be a recombinant geneticist, and talked about the way she had felt as a student. Tiwana had mostly Influencing dominant talents. She wrote her top five on the whiteboard Figure 18. Tiwana explained that when she started college, her positivity was immature and came across to others as not understanding their needs because when people came to her with a problem, she responded: “it is fine, and everything will be okay.” People did not see this as a leadership strength.



- Positivity
- Communicat
- WOO (Win
- Maximizer
5 - Input

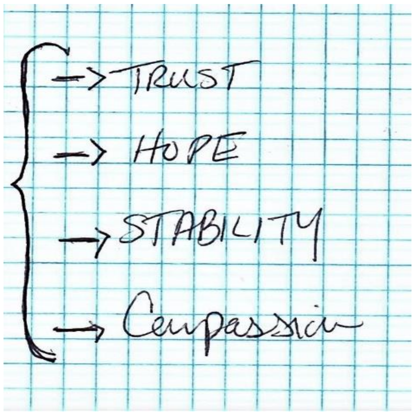
Figure 18. Tiwana’s top five Strengths (Neon, notes, Feb. 20)

Positivity falls in the relationship building domain and allows others to feel joyful about themselves, Tiwana matured her talent into an advantage through understanding that not everyone felt the same way she did, they did not think everything was going to be okay. Now, Tiwana helps people see how they can have a positive impact on a situation and in this way, she helps her team move forward, while not always saying everything will be fine, she still leads with positivity.

She stressed to GTAs the importance of noting your students’ feelings. She explained that three of her dominant talents were in the influencing domain, which is all about moving people forward and she did not feel like a fit in science, although Tiwana acknowledged science could use more Influencers – she found her place in business. Tiwana felt that WOO (Winning Others Over) was one of the real reasons she did not stick with her science major. She did not think that her instructors liked her. Tiwana thought the key to keeping herself, and many others with similar talents, involved in science was in the value that was placed on her potential contribution by her introductory instructors. She encouraged the GTAs to think about how their talents impacted the classes they taught.

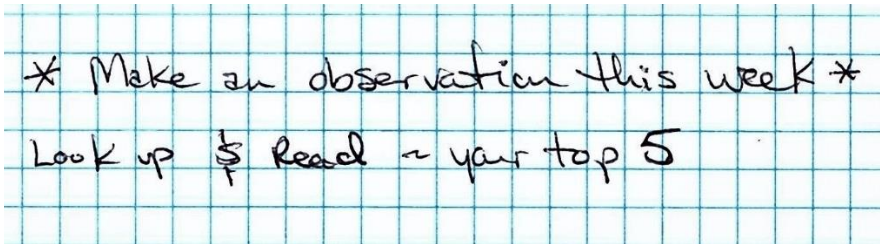
She asked if anyone had questions and when no one responded, she named others with talents like hers and asked for their stories. She attempted to engage the class with questions and waited until someone would answer or she would ask another question about someone specific. She picked talents and would tell a story about someone she knew with that talent and how the talent was seen in their patterns of thoughts and behaviors as they interacted with others in society. GTAs seemed to think the description she gave about them, based on her knowledge of their Strengths alone, was accurate. She concluded by explaining the results Gallup had gathered relating to followers and highlighted the leadership pillars, Figure 19.

Dr. Neon wrapped-up the workshop by tying Tiwana’s final explanations back to teaching and explaining that her mind was blown by Gallup’s findings of followers. The needs of followers were the same needs as the students in chemistry laboratories. As teachers, she encouraged us to look into our talents. The next meeting would be after spring break, and Dr. Neon had a couple of tasks for us before we met again. Figure 20. We were encouraged to observe another GTA or professor teach and look for how they acted during the class. Dr. Neon gave us and observational outline (Appendix D) and explained we would talk about our observations in the next workshop. “Think of things you can provide to others that allow them to follow. The takeaway – not a waste of time to understand who you are and how you reflect” (Frick, notes, Feb. 20).



→ TRUST
→ HOPE
→ STABILITY
→ Compassion

Figure 19. Gallup’s pillars of leadership (Neon, notes, Feb. 20)



* Make an observation this week *
Look up & Read ~ your top 5

Figure 20. GTA assignments at the end of Workshop Three (Neon, notes, Feb.20)

Dr. Neon added, as we were packing up, that she had spoken to the laboratory coordinators and we did have the power to take points away from students that were not following laboratory guidelines, safety procedures, or cheating. In our classrooms we were the authority and, as long as we were following department guidelines, our coordinators would have our back if the student complained.

Reading Three. Dr. Neon described Ken Appleton as being bilingual in chemistry and education; therefore, the descriptions of educational, developmental theories he adapted were to help chemists teach from a constructivist's perspective. Appleton used Piaget's (1978) model of mental schemas to explain that each student does not come to class as a blank slate. Instead students have already formed concepts of how they believe the world works. Students already have cognition, feelings, and skills before entering our course and to be successful teachers, according to Appleton (1993), we must examine student preconceptions. He asked readers to take time to reflect on the learning that occurs when a student experiences a novel situation which activates a context-dependent, schematic response. The result of the new idea is a disequilibrium, or as Baxter Magolda (2004) stated a moment of epistemological reflection, if the evidence does not fit the learner's prior knowledge. Appleton (1993) presented the four potential exits students could take in a learning situation Exits 1 and two were attributed to what constructivist term, assimilation, and accommodation. In Exit 1, assimilation, the student acknowledges the event and leaves with their mental schema about the event unchanged because it fits their current schema; alternatively, exit 2, accommodation, the student recognizes the difference and changes their mental schema to include the new ideas presented during the event. He went on and explained in detail interventions teachers could use to help students avoid taking Exits 3 and 4. Appleton suggested encouraging communication about the encounter between students while allowing them to produce tentative answers.

He warned against asking questions that required specific answers from students, instead have students provide solutions that help them to see the logical relationships. Appleton (1993) emphasized the importance of valuing all responses, which was best accomplished when teachers provided questions with multiple solutions. He offered a twenty-step procedure for transforming teacher practice. As I read through the steps he provided, I realized that it looked a lot like what Dr. Neon did with us as we played Petals around the Rose.

I continued working with ideas from the workshop through the week, and I struggled to align the conceptual accommodation of the theory presented in Appleton's article into the SI (Symbolic Interactionists) framework, using the ideas of encountering a novel situation. "I want to try to explain this idea of being uncomfortable when expected to answer a question which is not understood" (Frick, notes, Feb. 24). I explored combining the ideas from the SI framework to the reading:

> SI- *Self* is made of *me* and *I. I* works to attain goals, in this case, to answer the question, how many petals around the rose - an unexpected situation. *Self* is trying to answer the question correctly, and there is only one correct answer. *Self* gathers relevant or perceived relevant information. Some people are energized by this task while others are frustrated. (Frick, notes, Feb. 24)

The mind is wholly found within the self; therefore, I used the four terms from Meltzer's (2003) concepts of mind, in conjunction with Appleton's theory of disequilibrium, to build an understanding of the SI equivalent. As a reminder, Meltzer's four stages of mind are impulse, perception, merging, and consummation. At the point of disequilibrium, Appleton explained that the students had a mental schema which did not include the event - I do not know how to play Petals Around the Rose. The mental schema was formed by the cognitive *me.* As a result of the novel situation, *I* produced an impulse which caused the mind to perceive something different. Cognitive dissonance occurred during the third act of the mind, merging. The exits provided by Appleton were four possible options for the conclusion of Meltzer's fourth stage of mind, consummation.

Workshop Four

During the month between workshops, I finished up observing each of my participants and reflected on my teaching practices. "We did have my room observed as well, although we decided to have another peer (familiar with the instrument) complete the interrater observation" (Frick, notes, Mar. 2). As a participant observer, I just did not feel comfortable scoring my teaching; it seems unlikely that I could separate the bias from what I thought should happen to what I observed.

> They came and observed my Physical Science class this week. We made lemon batteries in class and took readings that were either positive or negative. We talked a little about electrons being negatively charged. The students seem to understand or fill in the blanks easily. (Frick, notes, Mar. 2)

My perceived biases did not stop me from reflecting on my ideas about the class. "My students are getting better at working together to answer the problems" (Frick, notes, Mar. 2). While the fact that students were getting answers was good, I focused on developing relationships between students. “When I thought about my behaviors in class yesterday, I enjoyed interactions with many students and was happy to hear that most were trying to understand what happened in their lemon batteries” (Frick, Mar 2.). So, although I did not complete the observation assigned in the previous workshop, I had observed half of the GTAs before, and several of the department’s professors, as part of graduate course work I had previously completed. “I am interested to see the results of the GTA observations. It will be interesting to know their thoughts on others, and teaching in general” (Frick, notes, Mar. 6). The reflection was not always positive,

> I am not sure that I am doing a great job fitting in socially with the participants. I am usually very comfortable, but during class, our differences (language or culture) keep us from really forming and working together as a community. I believe it is a product of the relationships our mentors hold with one another and with each of us. In our last meeting, we introduced talents and had each GTA write their results on the board. I have deliberately been trying not to isolate my participants during class. I do not want to impact the results of this study that much. (Frick, notes, Mar. 9)

No matter how much I did not feel a part of the group our goals for teaching still aligned. “Because I place such a high value on relationships, I am impressed with Fluorine and Carbon, they work hard and are both intelligent. I hope that they can find value in the lessons we have planned for them” (Frick, notes, Mar. 9).

So, before I knew it, the month had passed, and we met again and discussed our in-class observations. “Today was our first day back from spring break, and we had a workshop. Dr. Neon discussed exit strategies and had us answer questions in small groups before sharing as a class” (Frick, notes, Mar. 13). We were grouped at lab tables according to which class we taught. Each group had a small whiteboard. Dr. Neon summarized Appleton’s exits into brief statements:

- Exit 1: Existing ideas reinforced (right or wrong)
- Exit 2: Previous ideas now changed
- Exit 3: Saying the “right” thing but no real change in ideas (False accommodation)
- Exit 4: Knows that current ideas are wrong but gives up. Opting out of learning (Neon, powerpoint, Mar. 13)

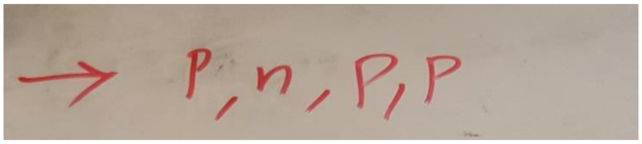
After a brief restatement of the exits, she went on to the questions which focused this workshop.

- What is something you observed in the teaching/learning environment in the last two weeks that made an impression on you (either positive or negative)?
- Describe an example of a student(s) opting out of learning either in your class or someone else’s. What type of exit is that based on the Appleton article? What might you do to keep students engaged?
- Describe an example of a student(s) falsely accommodating. What is a strategy for checking for false accommodation?

- What type of positive learning interactions did you observe this semester in any teaching/learning environment?
- What are issues that have come up in class that you weren't sure what to do with?

(Neon, powerpoint, Mar. 13)

Each group discussed the questions, and Dr. Neon walked from group to group engaging in the conversation by asking questions or telling stories. Figure 21 was how one group answered the questions or at least the first question. Of the four group members, only the second one reported a negative impression of the observation. The discussion continued for the GTAs in group one; however, their written work stopped there.



→ P, n, P, P

Figure 21. Group one's answers to the questions from Workshop Four

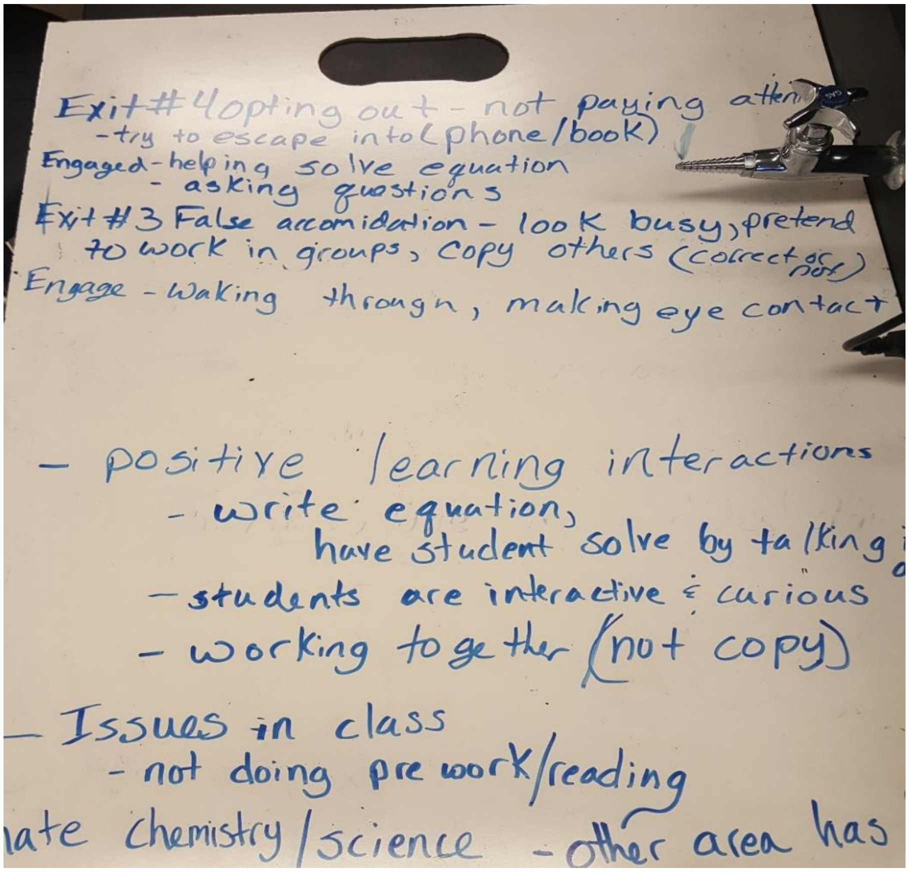
Group two answered all the questions that group one did not work on their whiteboard. They started by discussing Appleton's exits and talked through ways to engage students that did not pay attention in class or pretended to work as a part of a group while copying the answers. While the majority of issues the group mentioned were related to negative student perceptions, group two noted that positive learning environments were a result of students being engaged and curious, Figure 22.

Each group spent a different amount of time on each question, and the remaining groups answered all of the items on their whiteboards. Group three was impressed when students enjoyed the experiment and understood the concept. The also noted student learning in taking Appleton's second exit, they attributed student engagement to the instructor monitoring and checked for false accommodation by asking questions. As shown in Figure 23, they also had issues with students turning in work that they did not complete.

The fourth group spent a lot of time discussing learning environments and thought positive leaning interactions included students being more attentive to their briefings and when students could explain the significance of a plotted graph. Group four also noted graphing, when discussing classroom issues. They observed students plotting their graphs on scientific calculators instead of how they were told in the lab manual, Figure 24.

Dr. Neon brought all the groups back together as she explained that the best way to change a learning environment was to establish the guidelines and expectations at the beginning of the class that way students generally except that this is just how your class operates.

Dr. Neon had set the stage for professional development as a place of interaction and conversation from our first workshop. While the groups worked, she pointedly asked questions about what people had observed. The group discussion focused on the topics relating to students, Figure 25.



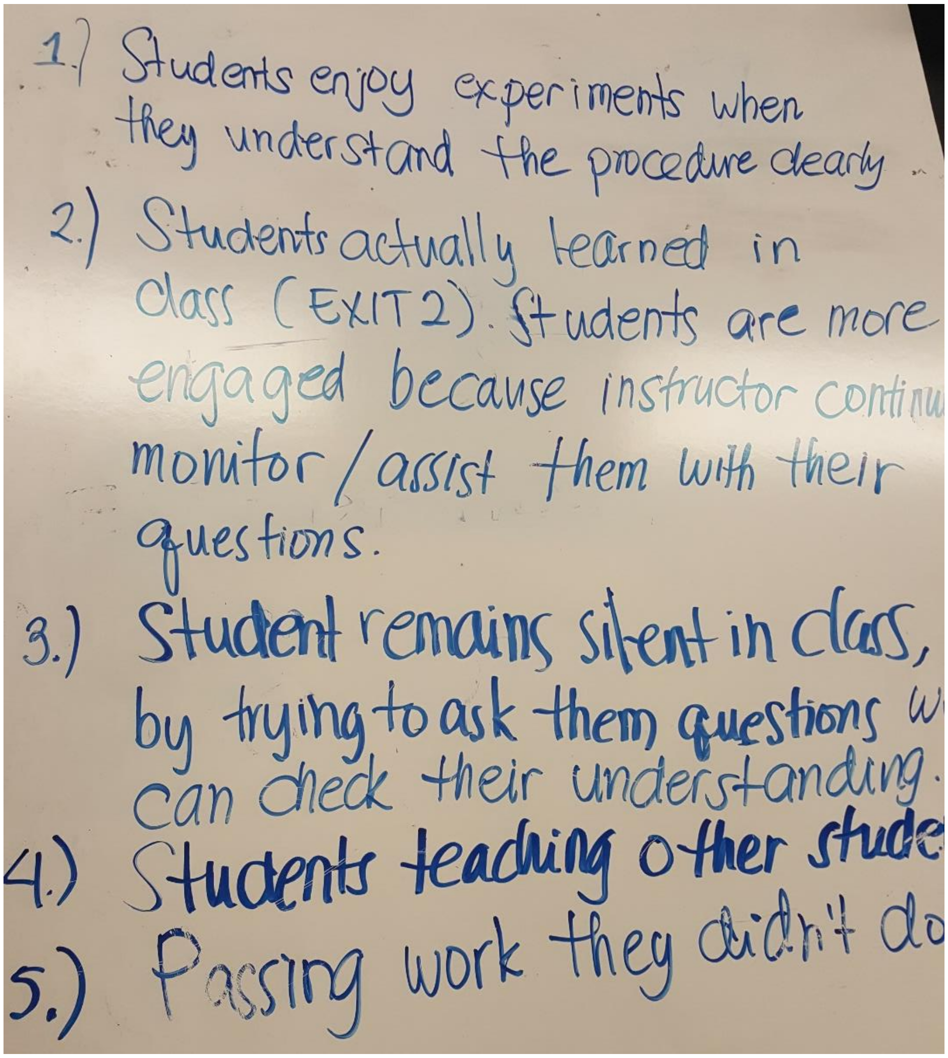
Exit #4 opting out - not paying atten
-try to escape into (phone/book)
Engaged - helping solve equation
- asking questions
Exit #3 False accomidation - look busy, pretend to work in groups, copy others (correct or not)
Engage - Waking througn, making eye contact

- positive learning interactions
- write equation,
have student solve by talking
- students are interactive & curious
- working together (not copy)

- Issues in class
- not doing pre work/reading
ate chemistry/science - other area has

Figure 22. Group two's answers to the questions from Workshop Four

Although the whiteboards show an array of issues, my notes indicated the "GTAs tend to focus on what is wrong with student learning. Students are copying, looking at others' papers and not working in groups. They feel that the students in PS (Physical Science) hate chemistry/science and love music" (Frick, notes, Mar. 13).



1.) Students enjoy experiments when they understand the procedure clearly.

2.) Students actually learned in class (EXIT 2). Students are more engaged because instructor continu
monitor / assist them with their questions.

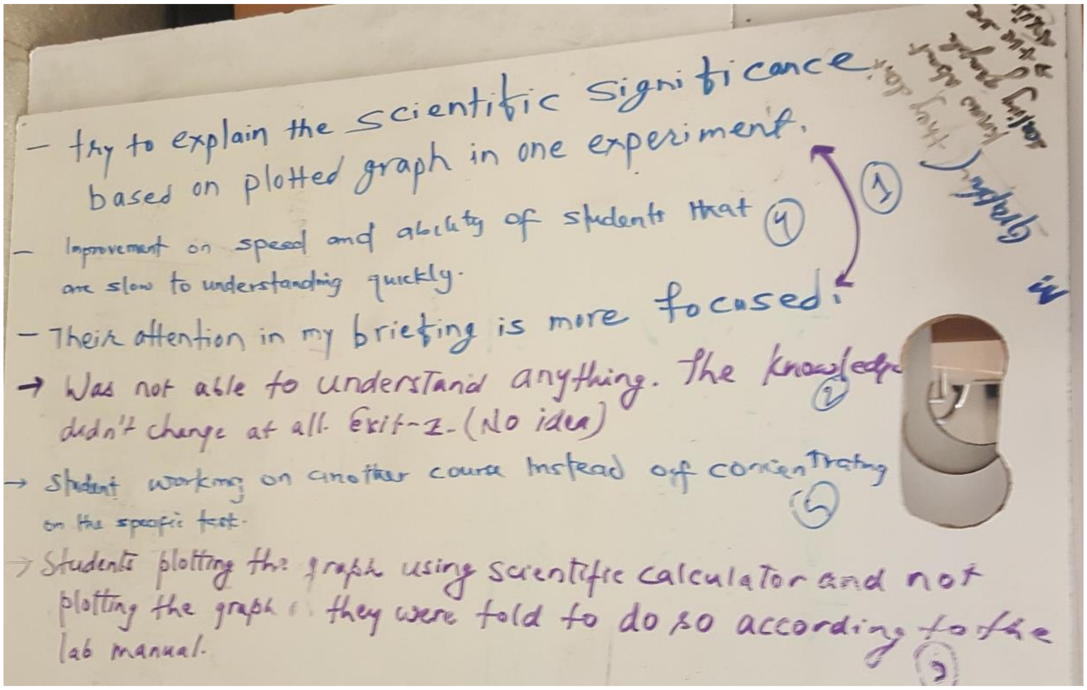
3.) Student remains silent in class, by trying to ask them questions w
can check their understanding.

4.) Students teaching other stude

5.) Passing work they didn't do

Figure 23. Group three's answers to the questions from Workshop Four

I had slightly different feelings than my peers. PS was one of my favorite labs to teach because the students were unfamiliar with science and a lot of learning occurred. At the end of the fourth workshop, my interaction with other chemistry GTAs had me interested in their level of engagement with professional development.



- try to explain the scientific significance based on plotted graph in one experiment. ①
- Improvement on speed and ability of students that are slow to understanding quickly. ④
- Their attention in my briefing is more focused.

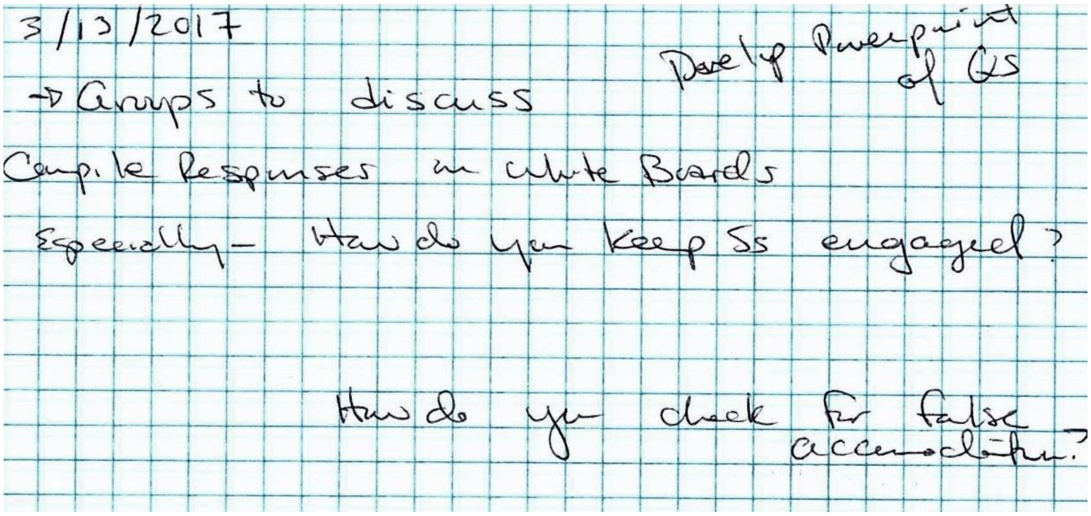
→ Was not able to understand anything. the knowledge didn't change at all. Exit-2. (No idea) ②

→ Student working on another course instead of concentrating on the specific task. ⑤

→ Students plotting the graph using scientific calculator and not plotting the graph. they were told to do so according to the lab manual. ③

Figure 24. Group four’s answers to the questions from Workshop Four

“I am not sure the GTAs are all engaged in their teaching. Dr. Neon paralleled teaching to completing work in the chemistry lab, explaining that critical assessment and problem-solving skills are beneficial skills for both” (Frick, notes, Mar. 13). To help GTAs understand the variety of laboratory curriculum, Dr. Neon moved us forward into thinking about different types of laboratory instruction with a new article.



3/13/2017

Develop Powerpoint of Qs

→ Groups to discuss

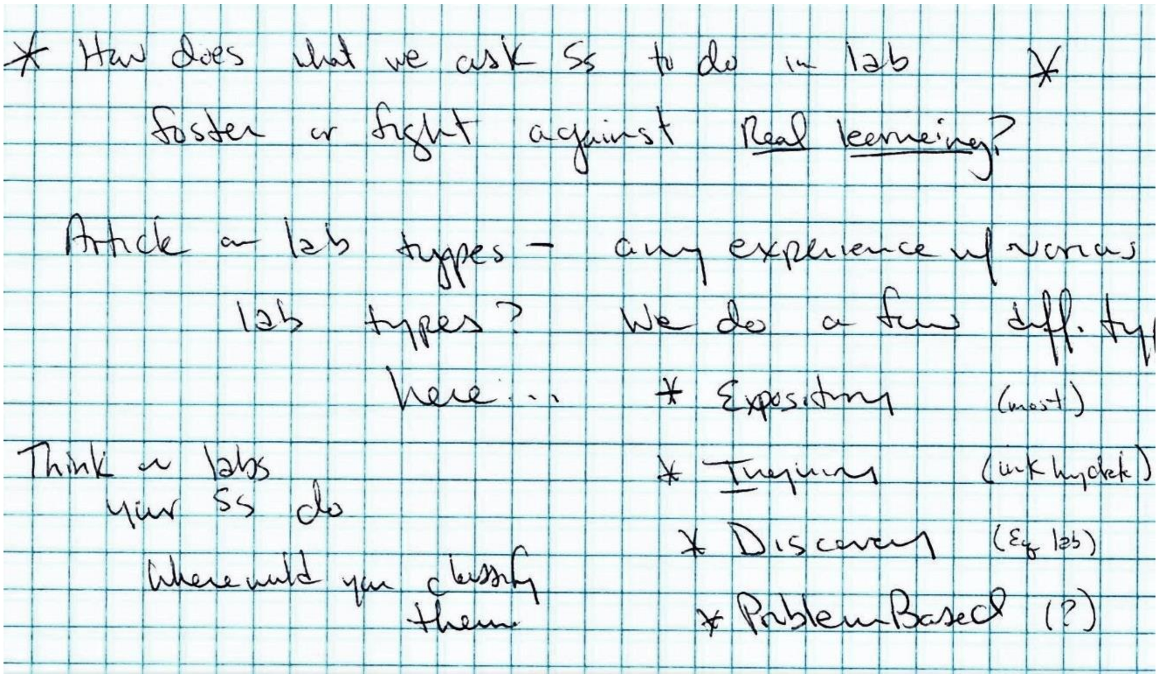
Compile Responses on White Boards

Especially – How do you Keep Ss engaged?

How do you check for false accomodation?

Figure 25. Focused questions for group discussion (Neon, notes, Mar. 13).

Reading Four. As we were discussing potential exits our students might take and how to avoid students misinterpreting their evidence, Dr. Neon was thinking of new questions for the GTAs, Figure 26. Domin (2007) conducted a phenological study to determine differences in students' perceived cognitive development, after taking his problem-based class for the first semester and continuing to another professor's expository laboratory experience for the second semester. Figure 27 was Dr. Neon's interpretation of Domin's taxonomy for lab styles. The comparison of problem-based laboratories to expository laboratories style allowed Domin (2007) to isolate differences to student-generated procedure and procedures already gives. Both methods included pre and post-lab activities with predetermined learning outcomes and importantly both used a deductive approach to reasoning. Figure 28 was Dr. Neon's explanation of the processes related to a deductive laboratory experience.



* How does what we ask Ss to do in lab *

foster or fight against Real learning?

Article on lab types – any experience w/ various lab types? We do a few diff. typ

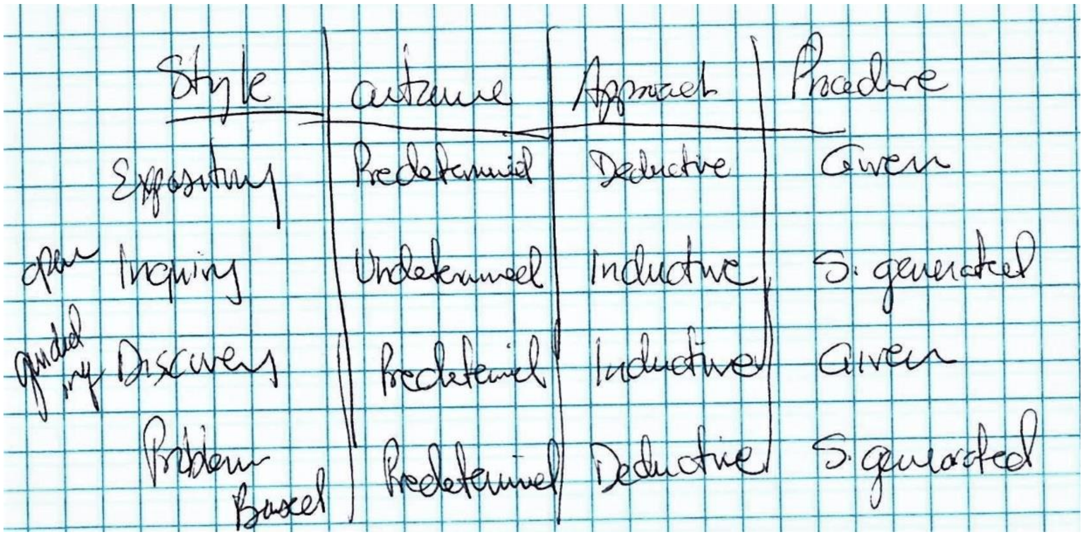
here...

- * Expository (most)
- * Inquiry (ink hydrate)
- * Discovery (Eq lab)
- * Problem Based (?)

Think on labs your Ss do

Where would you classify them

Figure 26. Dr. Neon's classification of lab types for introductory classes (Neon, notes, Mar. 13)



	Style	outcome	Approach	Procedure
	Expository	Predetermined	Deductive	Given
open	Inquiry	Undetermined	Inductive	S. generated
guided inq	Discovery	Predetermined	Inductive	Given
	Problem Based	Predetermined	Deductive	S. generated

Figure 27. Domin's taxonomy for lab styles (Neon, notes, Mar. 23).

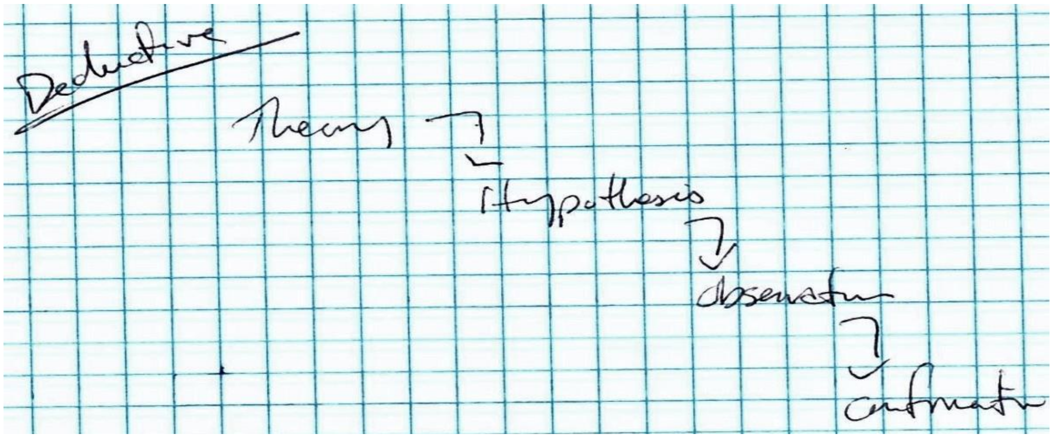


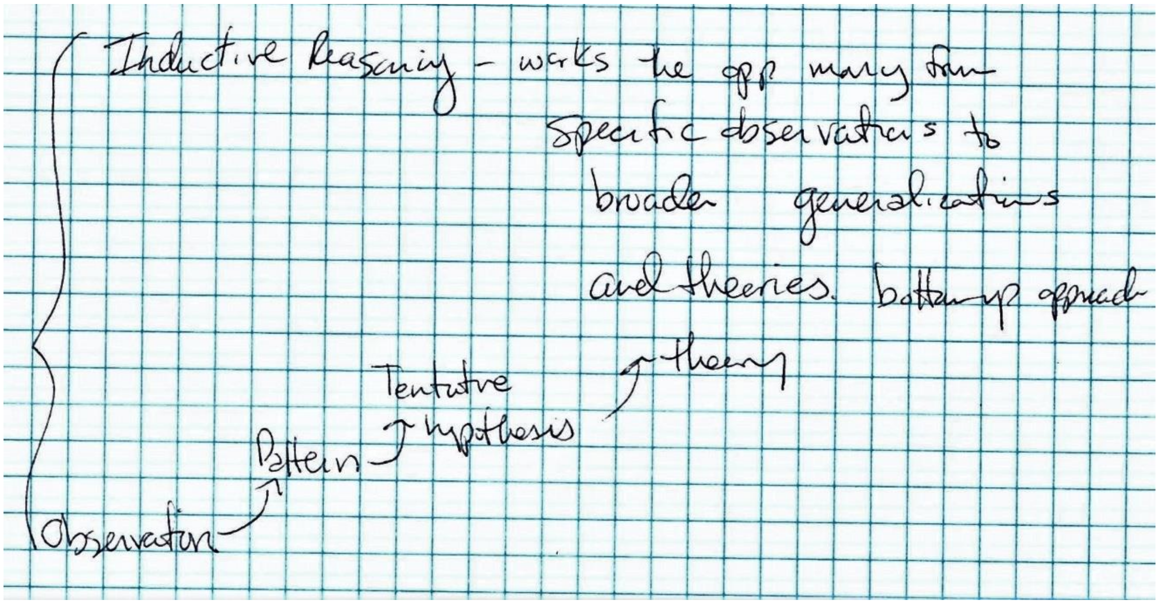
Figure 28. A deductive approach to the laboratory (Neon, notes, Mar. 23)

Ultimately, Domin found two variables were essential to student cognition regardless of which style they preferred. All students needed time to reflect on their laboratory experience and how it connected to the theory from class. Students also needed to participate in argumentation, which infrequently happened during expository laboratory experiences. Students that preferred the problem-based lab highlighted the cooperative nature. Domin encouraged educators, regardless of the type of lab, to allow students opportunities to complete the experiment, reflect on how it connects to preexisting schemas, and allow interactions that challenge students to evaluate their understanding after completing the investigation.

Workshop Five

I arrived early with the copies of our new article, and Dr. Neon ran through her ideas for the workshop. We had previously talked about how best to engage the GTAs, and she had found a demonstration to join them in generating questions that she wanted to use as a platform for the Johnstone (1991) article that discussed the difficulties associated with learning science. First, we reflected on the Domin (2007) report and reviewed the labs that we used in our department, during which time the set-up for the demonstration also occurred. Dr. Neon had also prepared eight PowerPoint slides to guide the workshop discussion. As the GTAs arrived, Dr. Neon already had a Florence flask with water heating on a hot plate. She also had a table similar to Figure 27 on the overhead projector.   The GTAs asked about the ice in a bin next to the water, which had started to boil, and Dr. Neon explained that it was for a little later.

We started by thinking of the labs we had taught this week and would be preparing next week. “Last week’s lab in Physical Science was a determination of an unknown acid and this week is making soap” (Frick, notes, Mar. 27). Of course, with the number of GTAs in the workshop, this amounted to eight different labs, not including the ones Dr. Neon taught. The majority of the labs we taught were expository where we connected the students to the theory that was previously shown and used a deductive approach. One of the GTAs suggested that the lab taught in the first-semester general chemistry for science majors was a problem based or perhaps inquiry because the students were being asked to make connections between different variables using inductive reasoning, Figure 29.



Inductive Reasoning - works the opp way from specific observations to broader generalizations and theories. bottom up approach

Figure 29. Inductive reasoning in science laboratories (Neon, notes, Mar. 27).

Dr. Neon asked for clarification of the lab in question. We explained that in the lab, the discovery of an unknown hydrate, the undergraduate students work in groups to write procedures for determining the identity of the unknown salt and the number of moles of water contained within the crystalline structure of the salt making it a hydrate. On closer examination it appeared that the lab was most likely the discovery style because the students had previously conducted labs with the procedures, they needed to complete the lab.

Dr. Neon asked what the difficulty might be with open-ended labs or with students generating their procedures. The GTAs suggested lab would take too long and be too difficult for students, and students would not be able to apply principles to the processes. Dr. Neon noted that in her labs the difficulty was usually in having students come up with something new to try. She let us know that after three decades of using open procedures students would still think of new ways to investigate their surroundings. She used the opportunity to talk about the investigation, particularly about how to generate questions and the difficulty with creating good questions. She thought questioning was one of the most essential skills for a teacher.

As she moved forward with the demonstration, Dr. Neon wanted us to think about questions. Dr. Neon walked to the center of the room and turned off the hot plate. As she placed a stopper in the top of the flask, the water had stopped boiling. Before inverting the container through an iron ring on a ring stand, she wrapped the stopper with Duct tape – not wanting the hot water to come out. After the Florence flask was securely placed in the ring stand, Dr. Neon put baggies filled with ice on the upside-down bottle. The water now filled the neck of the flask, a clear water line could be seen across the center of the glass bulb, and the bottom of the container was now atop the ring stand. As the ice in the bags melted, the water in the container began to form bubbles. The GTAs started to talk amongst ourselves, and Dr. Neon reminds us to develop questions about the demonstration, not answers. "Why are the bubbles forming? Is the system closed? What is the purpose? What is the relationship between the quantity of ice, the amount of water, and the number of bubbles?" (Frick, notes, Mar. 27) These were examples of the questions we thought of; however, the first question asked by Bromine, after 3 minutes of wait time, was "heat is transferring, am I right?" Dr. Neon allowed the GTA to explain his thoughts, before she moved to another GTA and got their questions, without indicating if he was correct or not. As she gathered queries, she noted that we were asking a lot of open-ended questions, which was not what she usually encountered in her work with in-service and pre-service teachers.

Dr. Neon explained that good questions could lead to experimental design. She highlighted the differences between items that were “one answer – close-ended versus open-ended questions” (Frick, notes, Mar. 27), which continued discussion. She also distinguished between lower order, fact-based questions like “what is in the bubbles?”, And higher order, evaluation-based questions such as “how do you define boiling point?”. She encouraged us to avoid asking rhetorical questions, ones we answered ourselves, as well as to avoid questions that were right or wrong - yes or no. She let the GTAs know that if you ask a question and stop to look around the room for 7 or 8 seconds, someone will speak up to fill the uncomfortable silence. After telling the GTAs some tips and tricks for questions, the GTAs wanted an explanation for the demonstration. It was obvious we did not have a group consensus about what was happening when Dr. Neon asked the question, “what is in the bubbles?”, And four different answers, water vapor, hydrogen gas, oxygen gas, and air were given by the GTAs. She encouraged us to continue asking questions, and other GTAs began to answer. Dr. Neon did not provide answers, she did refocus our attention with questions like, “what should be in the flask?” and “is there anything different about the top of the flask?”. Soon the GTAs were able to give the mathematical definition of a boiling point; vapor pressure is equal to atmospheric pressure. The reason Dr. Neon had boiled the water was to eliminate all the air molecules from the flask, leaving the water boil for twenty minutes had left mostly gaseous water molecules in the flask. Once sealed and cooled the pressure inside the flask was different from normal atmospheric pressure. As the workshop wrapped up, she gave each student a copy of her tips for questions.

- Learn and Use students' Names.
- Make it clear that you want students to participate (try not to ask rhetorical questions).
- Avoid asking leading questions—You know a question that has the answer strongly suggested in it.
- Avoid yes and no questions or be sure to follow them up with the opportunity to explain. Ask students to explain when their answers are right and when their answers are wrong.
- In class discussion, use a series of questions to build complexity instead of hitting them over the head with a multiple layer question right from the start.
- Use a mixture of closed and open questions
- Allow time for students to respond **– Waiting 5-10 seconds** after asking a question increases student response. If after 10 seconds you need to rephrase this go for it but don't resort to answering your question.
- Don't interrupt students—really try to understand what they are saying, even if it is not what you were hoping they would say.

(Neon, PowerPoint, Mar. 27)

She explained that students have a lot to think about when we ask them questions, and Johnstone (1997) theorized that part of the difficulty students have in building understandings in chemistry comes from the fact that chemists have a schematic representation that is three dimensional. The dimensionality comes from points that experts automatically combine with scientific understanding of the relationships between symbols, macroscopic demonstrations, and particulate (molecules, atoms, electrons) interactions formed from previous information.

Reading Five. After working as a chemistry educator for decades, Johnstone (1991) questioned the practice of teaching unifying scientific concepts to students in laboratory experiments. The difficulty pupils had in learning prompted Johnstone to reflect on the transmission system and the nature of knowledge, regarding the cleverly constructed educational apparatuses designed to connect content to a student in science classrooms. Johnstone proposed considering the entire educational environment regarding how the student receiver learned Figure 30. Johnstone proposed four hurtles that contributed to the difficulty of students developing scientific understandings. First was the simple inability for people to make sense out of concepts which are not tangible such as atoms, bonds, and electrons. The nature of the message in science classrooms, which proposed concepts, such as waves, moles, and energetics, were supposed to help receivers “see,” form a mental visualization of the idea. Johnstone suggested that perhaps these representations were more exciting for the experts teaching the course than the layperson trying to interpret the experience. He explained the relationship in term of expert and novice understandings of the formation of science concepts.

Johnstone explained that expert scientist in every field had constructed a multilevel understanding of nature (Figure 31). He placed anything easily sensed or seen at the macroscopic level. At the particulate level, he included electrons, atoms, and cells while the symbolic level included elemental, mathematical, and genetic representations. An expert chunks all of these levels together when viewing and interpreting experimental data.

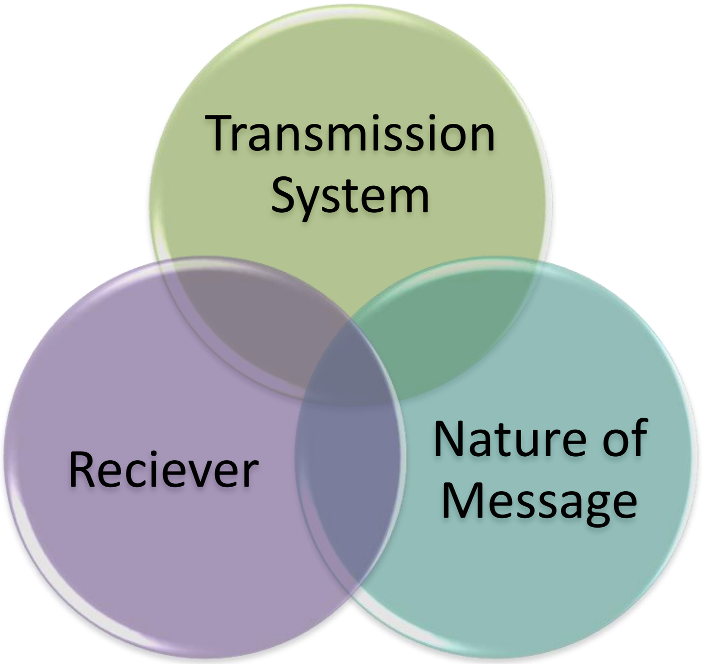


Figure 30. Johnstone’s factors are impacting the successful transmission of scientific concepts.

Students have not developed the capacity to understand all levels simultaneously. Students will not be able to form the multilevel meanings; their path travels the outside of the triangle seeing each spot as a separate entity. Introductory questions that associate all three levels may have little meaning to receivers developing scientific understanding. The final thing Johnstone highlighted, as a difficulty for learners was the large vocabulary used by the scientist. He particularly noted the conceptual challenges that arise with words used in common vernacular, such as volatile, which had a conceptually different meaning in science. Words such as soluble and insoluble used only scientifically, according to Johnstone cause barriers to students building and assimilating conceptual understandings.

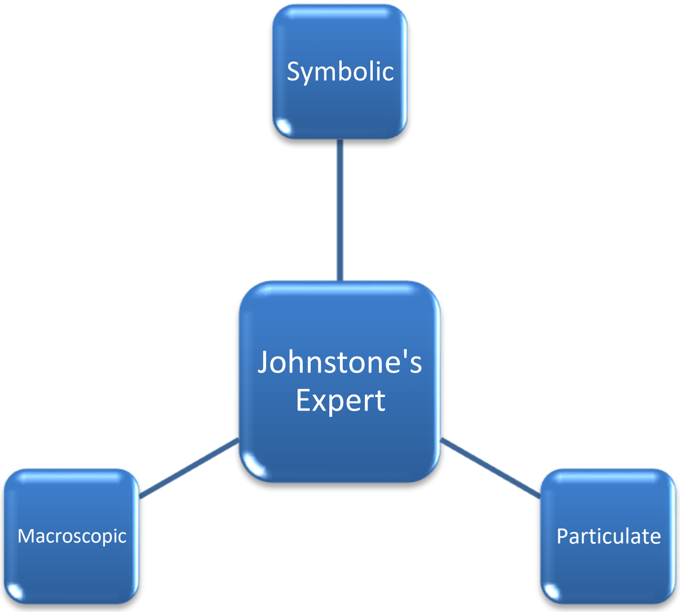


Figure 31. Nature of expert scientific understanding

Johnstone explained utilizing the information processing model grounded from research in cognitive psychology, which separates mind into conscious, working memory, and long-term memory, in reaction to events preceding a mental perception filter, to help expert chemists understand the perspective of learners, Figure 32. In the IP (Information Processing) model of cognition the physical, sensory perception takes in signals, which are mentally filtered beyond conscious thought, selective perception occurs when a message was flagged as important conscious thought began.

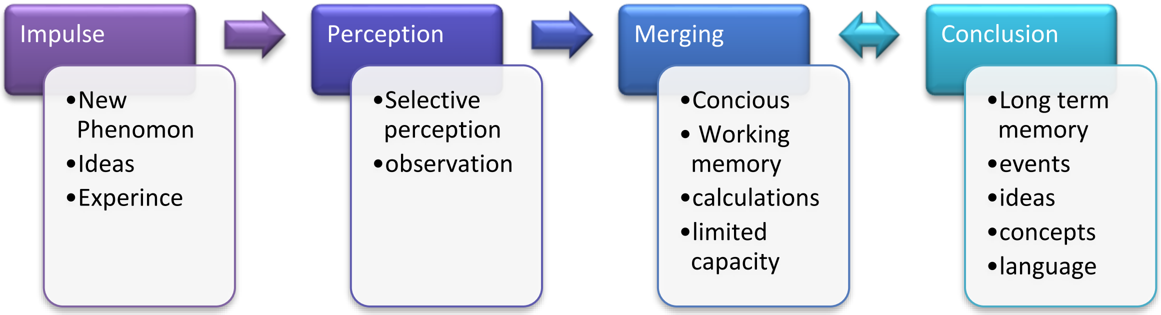


Figure 32. Alignment of Meltzer's (2003) stages of mind and the information processing model presented by Johnstone (1991).

Working memory has a capacity of five to seven bits of information, the thoughts and ideas processed through working memory are supported with concepts from long term memory, which holds all our prior experiences and appears limitless in capacity.

When Johnstone considered the limited size of working memory in conjunction with the multiple aspects of development associated with understanding science, he decided that the current transmission system interfered with the student's ability to construct their meaning which would allow the information to be stored in long-term memory. He thought the inability to make sense out of what was happening was demoralizing and demotivating for science students.

Workshop Six

Dr. Neon met with us, for the final workshop, on April 10, 2017. As she worked to start the projector, she asked if anyone had any experiences to share from trying the tips from the previous workshop on questioning, although she waited for nearly a minute, no one responded. She encouraged us to try – I noted, "the most transformative increase, wait time - seven seconds" (Frick, Apr. 10). Once the presentation was ready, Dr. Neon asked if people needed the article from the last workshop. She noted several GTAs that were not in attendance for the previous workshop and noted Chlorine and Iodine by name. The information from the Johnstone article related to teaching science in general; however, many of the ideas presented were easily demonstrated with chemistry topics.

Dr. Neon shared the expert concepts, "Johnstone talks about chemistry as having three components: Macroscopic, submicroscopic & representational. These three components are often a stumbling block for learning chemistry: chemistry operating on three levels but students seeing them as distinctly different (Johnstone, 1993)" (Neon, PowerPoint, Apr. 10). Figure 33 was the expert perspective. Dr. Neon pointed out that students cannot conceptualize all three levels simultaneously. Students build their conceptual understanding by connecting each leg along the triangle, Figure 33.

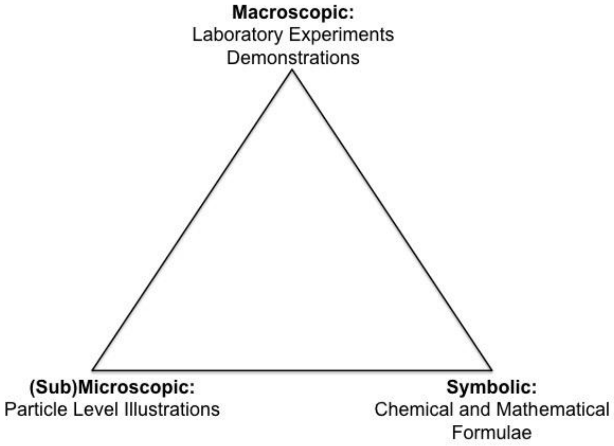
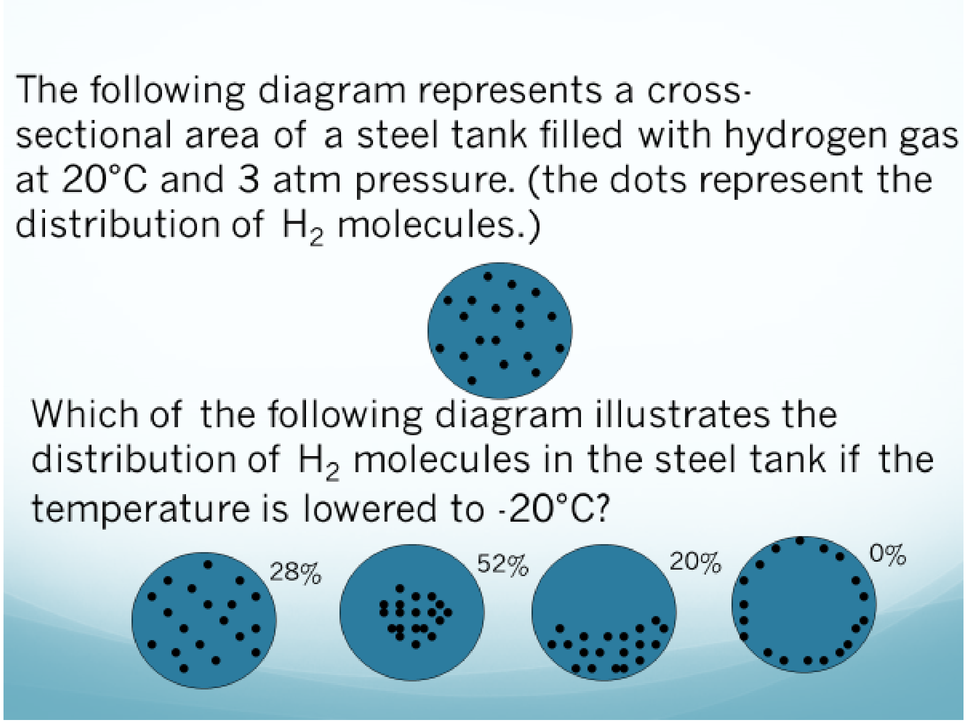


Figure 33. Johnstone’s triangle of three levels represented in expert scientific conceptualization.

To illustrate the amount of information students are expected to understand and utilize in chemistry, Dr. Neon referenced questions from her work with the CCI (Chemistry Concept Inventory), Figure 34. Dr. Neon used a classic gas law problem to demonstrate the difficulty students can have in understanding the particle level, even if they can reliably use the formula or as Johnstone said symbolic components. Figure 35 demonstrated student representation of the concepts related to pressure and volume. The molecules of hydrogen gas shown in the picture were all the same size, so most people assume that the particles will be closer together because in a steel tank the volume does not readily change. She wanted to know what did change and asked the GTAs what was happening with the molecules. Fluorine gave a concise answer, as he explained the temperature decrease resulted in lower kinetic energy. The particles move slower and have fewer collisions creating less pressure. The picture pretty much looks the same; speed was not represented in the snapshot observed in Figure 34.



The following diagram represents a cross-sectional area of a steel tank filled with hydrogen gas at 20°C and 3 atm pressure. (the dots represent the distribution of H_2 molecules.)

Which of the following diagram illustrates the distribution of H_2 molecules in the steel tank if the temperature is lowered to -20°C?

Figure 34. Question and percentage of individuals selecting each answer, data provided from Dr. Neon's previous research (Neon, PowerPoint, Apr. 10)

Gas laws were not the only topic in introductory chemistry courses that required students to maneuver around Johnstone's triangle. Stoichiometry is the ability to represent reactions using a balanced chemical equation. One such problem is shown in Figure 36 which required students to translate particulate representations into a balanced symbolic formula. Although the best way to represent the equation for the transformation that occurred would be described by experts with answer C, the answer most often chosen related to the exact picture.

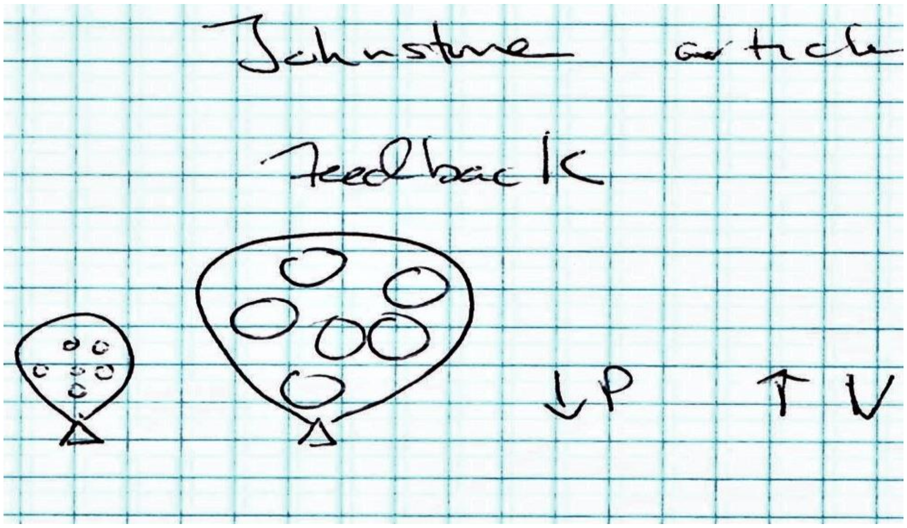
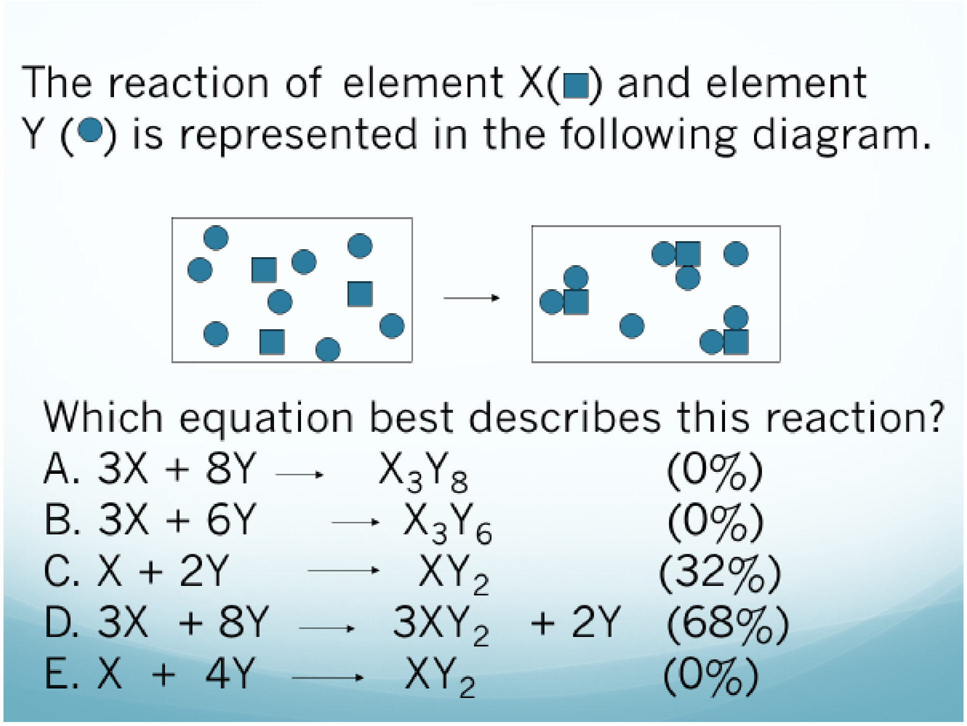


Figure 35. Pressure and volume inversely related, to students the increase in volume was related to particle expansion (Neon, notes, Apr. 10).

Dr. Neon admitted that this question needed better distractors, as three answers were never chosen so the assessment could be improved. Dr. Neon explained that as experts we merely show the equation and do not explain what happens to the leftovers. Balanced equations are not about specific instances - the recipe does not know how many ingredients we have in the cupboard.

Dr. Neon presented the idea that the things students do make sense to them, even if they might look stupid (which is a mean word) to us. Dr. Neon used the information processing model, Figure 37, to assist GTAs in understanding the student/novice perspective.



The reaction of element X(■) and element Y (●) is represented in the following diagram.

Which equation best describes this reaction?

A. $3X + 8Y \rightarrow X_3Y_8$ (0%)

B. $3X + 6Y \rightarrow X_3Y_6$ (0%)

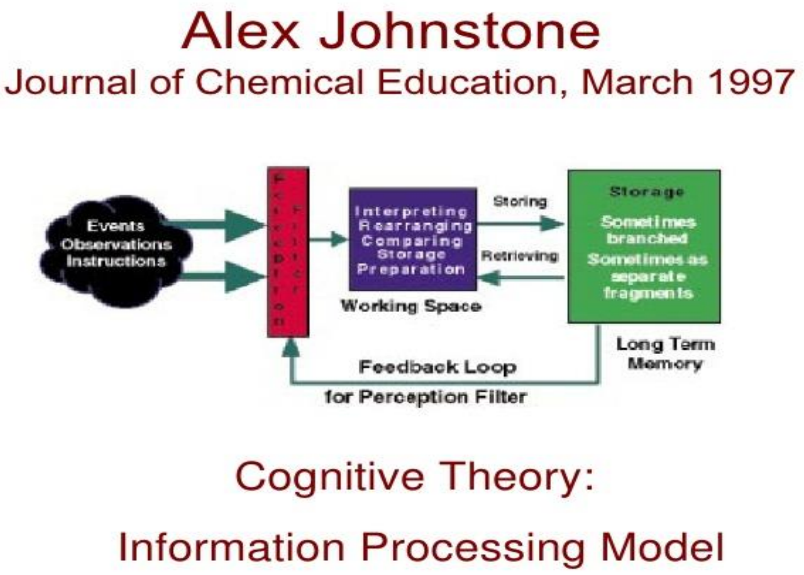
C. $X + 2Y \rightarrow XY_2$ (32%)

D. $3X + 8Y \rightarrow 3XY_2 + 2Y$ (68%)

E. $X + 4Y \rightarrow XY_2$ (0%)

Figure 36. Question about the transformation of X and Y atoms into compounds, with the percentage of answers.

We focused on the potential feedback loop already associated with understanding chemistry. After explaining all the difficulties with learning chemistry, it seemed that the feedback was “always crappy, chemistry is hard, and our self-talk/image, perception filter is influenced by our experience” (Frick, notes, Apr. 10). The roadblocks presented by the feedback loop to the perception filter create a stumbling block for students. If the GTAs remain aware of student difficulties, we can help students navigate the merging of their understandings with the evidence presented in the laboratory experiments.



Alex Johnstone

Journal of Chemical Education, March 1997

Cognitive Theory:

Information Processing Model

Figure 37. Information processing model of cognition (Neon, PowerPoint, Apr. 10).

Dr. Neon also highlighted the limited capacity of working memory, which can work with an average of five items at one time. Included in those items are concepts retrieved from working memory, as shown in Figure 37. Expert hold mental constructs about chemistry topics that contain more information about a problem, termed chunking when compared to a novice. So, for novices', different representations increased the cognitive demand. As Johnstone stated experts stand in the center of the triangle pictured in Figure 33, envisioning all three pieces as part of one greater knowledge construct; however, novices have three disparate pieces of knowledge they mentally juggle. "Working memory prohibits students from understanding. We probably don't remember how difficult the problems were" (Frick, Apr. 10).

As the workshop concluded, Dr. Neon reminded us that people spend their entire careers studying this stuff - teaching and learning chemistry. We can help our students to avoid taking early exits by remembering, "it is easy for us, and to novices chemistry, it is something they cannot do. Do not say that it is easy; show them it can be done" (Frick, notes, Apr. 10). Dr. Neon felt that the workshops had given her more empathy for the GTAs and lab coordinators dealing with learning expectations. Of course, she ended the workshops with some reflection questions:

- What did you think was useful?
- What would help you become a more effective GTA?
- What is one thing that you plan to try to improve your teaching?
- What do you think is your best quality as a teacher? (Neon, PowerPoint, Apr. 10)

The GTAs answers were included in their case studies (Chapter Five).

CHAPTER FIVE: THE CASES

Chapter Four presented my perspective of the professional development lead by Dr. Neon in Spring of 2017, Chapter Five focuses on the graduate teaching assistants (GTAs) beliefs, from the teaching beliefs interviews (TBI), and behaviors as laboratory instructors, reported using the reformed teaching observational protocol (RTOP) as they participated in the workshops. As previously stated, I had a diverse range of GTAs volunteer to participate in this study. The chapter is laid out starting with the master's students, Carbon in her first semester, Bromine and Silicon, both in the middle of their coursework, and Hydrogen, in her last semester as a GTA. The doctoral students follow Hydrogen, starting with two doctoral students from the Molecular Biosciences, Sodium with a background in biology and Iodine from chemistry. The next three doctoral students discussed are from the Computational Science program, Fluorine, Chlorine, and Cobalt. Finally, the chapter concludes with Lithium, from the Mathematics and Science Education program. Each case starts with an overview of the GTA, which includes student evaluation data for the course researchers observed whenever possible, followed by the results from the observations, workshop participation, and finishing with their teacher beliefs interview profiles. Although all ten GTAs worked in the chemistry department their teaching expectations varied somewhat based on the laboratory coordinator.

Unlike GTAs in discussed in Chapter Two, GTAs in this study were not asked to attend weekly meetings; they were expected to request assistance if they encountered difficulties. Each GTA taught multiple courses as discussed in Chapter Three, and reported to at least one of three coordinators, Dr. Argon, Dr. Helium, or Dr. Krypton. All the coordinators set safety guidelines and outlined notes for briefings that explained the experiments; as well as, providing copies of the student laboratory reports and grading keys. The laboratory coordinators were responsible for reporting grades to the lecture instructors, Dr. Argon and Dr. Helium expected GTAs to submit grades for their students twice a semester, midterm and final grades. Dr. Krypton had more detailed instructions and required GTAs to give a two-point quiz at the beginning of each experiment; she also provided PowerPoint slides for the GTAs to use during the laboratory briefing. Dr. Krypton also asked that her GTAs report grades to her weekly. Dr. Krypton's laboratory courses included all the chemistry courses for nonscience majors, three of the participants, Bromine, Sodium, and Cobalt were observed teaching in the courses she designed. Dr. Argon also coordinated courses for nonscience majors, although that course was physical science, and included topics outside of the chemistry content area. Iodine and Lithium taught laboratory courses for Dr. Argon when they were observed. The remaining six GTAs taught either the first or second semester of general chemistry which was coordinated by Dr. Helium. I wanted to provide an overview of the expectations of each coordinator to facilitate an understanding of the responsibilities given to each of the GTAs as they taught their laboratory courses.

Carbon

Carbon was in her first semester as a master's student. She introduced herself as Fluorine's husband; they had a four-year-old son. During class, as both of his parents were GTAs, their son sat and colored near the door to the lab where we met. Although she had been in the United States (US) for two years, this was her first-time teaching chemistry in the US. She actively participated in the workshop, shared the results of her Clifton Strengths Finder Assessment (CSFA), and completed both in class reflections. Carbon candidly discussed her difficulties in the introductory interview and the reflection interview. Reid and I observed Carbon in-person teaching the laboratory for the second semester of general chemistry, for science majors. The section we saw was the first laboratory of the morning.

Classroom observations. Carbon taught two sections of the laboratory for General Chemistry II. Dr. Helium was the lab coordinator. Both laboratories observed dealt with oxidation and reduction of elements during chemical reactions, commonly referred to as redox reactions. The students had access to the information they needed to succeed in the labs prior to coming to class to complete the work in the form of specific procedures spelled out in their laboratory manuals. Each reading started with an explanation of the topic and an overview of the scientific theory to be explored in the three hours they had to complete the laboratory assignment. The students were required to complete the investigation as described, collect data, and answer the questions related to the data collected. Before leaving for the day, students would remove the pages filled in with the data and answers from the laboratory manual giving them to the GTA. Ideally, the GTA using a grading key provided by the course coordinator, graded the assignment and returned the following week. As this was the second course in the series, students were potentially familiar with the procedure for completing laboratory assignments, even in the second week of the semester.

In each instance observed, Carbon provided explanations of the information her students needed to complete the experiments safely and correctly. This is supported by her comparatively high RTOP scores in the area of propositional knowledge, Figure 38. Although, the highest score that can be earned in each category of the RTOP is 20 and the overall total as high as 100, the average RTOP score for reformed science university professors was reported at 58.25 (Sawada et al., 2002) for instructors implementing reform-based teaching techniques. The briefings occupied approximately the first twenty minutes of class, in which Carbon worked an example of any necessary calculations on the white-board and told the students the key concepts they would observe while working through the experiment. Her total RTOP score for the first lab was twenty-four, well below the average for reformed instructors. Carbon did not sit at the front of the room waiting for students to ask questions, as indicated with the higher scores of six and seven in the area of student-teacher relationship. She walked around the room while the students worked on the experiment and her total final RTOP score was twenty-six.

In the first lesson we observed, Carbon introduced the experiment, “the qualitative analysis of anions” (Reid, RTOP, Feb.8). Standing in front of the class, she went on to explain the separation of ionic compounds into cations and anions, and the “description of anions dealing with the negative part of the two parts. First with a known and then an unknown to find out if the anion is present” (Frick, RTOP, Feb. 8). While explaining the experiment Carbon highlighted safety, "dealing with concentrated sulfuric acid…walk cautiously to slide the window of the hood" (Frick, RTOP, Feb. 8).

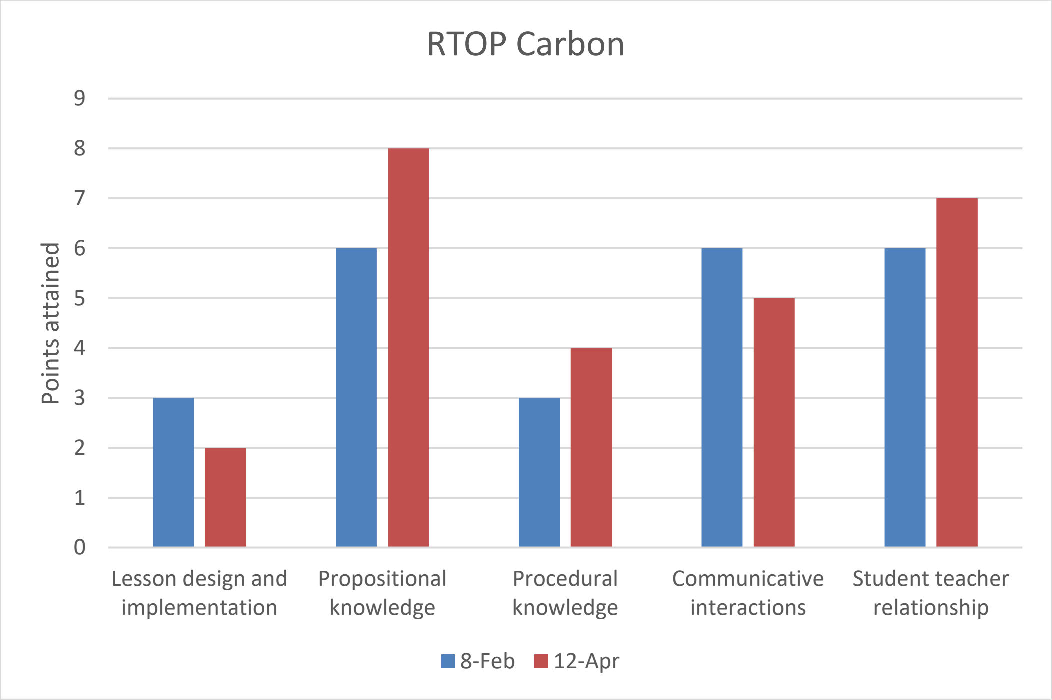


Figure 38. Carbon's initial and final RTOP scores. Each category had twenty possible points.

She also explained what the students would see as a result of the reactions, "tells what to look for, bubbles" (Reid, RTOP, Feb. 8) and the "brown ring is a distinct characteristic" (Frick, RTOP, Feb. 8). Carbon transitioned to write half reactions for each oxidation-reduction reaction. Carbon asked a question, as she transitioned to the written portion of the experiment. "What is a half-reaction? Anyone? – Waits 3-5 seconds and explains an example - three to five second wait time" (Reid, RTOP, 8 Feb.). She "shows students how to balance redox reactions by working four examples on the board - they move through half-reactions. Should be a loss or gain of electrons resulting in a more positive or negative transition" (Frick, RTOP, 8 Feb.). Carbon asked, "what side do we add the electrons? She asked the question several times – no answer. You balance by adding them on the right. It is very simple" (Frick, RTOP, 8 Feb.). She finished off her explanations by telling the students to "balance the charge, so molecules are neutral." And asking, "Which side do we need to add electrons to?" Carbon finished writing on the board and waited a couple seconds before providing the answer she wanted on the board. (Frick, RTOP, 8 Feb.), as seen in Figure 39. The students moved to gather materials, Carbon "reminds them to use larger test tubes today – be sure to use H_2SO_4. (She) walks to front bench and talks with students" (Frick, RTOP, Feb. 8).

Although the briefing focused on redox reactions the experiment focused on understanding the reactions and asked the students to provide evidence to indicate which cations were included in their unknown sample. As the students moved onto collecting and analyzing the data to complete their assignment, it was "obvious that the GTA wants to help her students understand. She walks from group to group answering questions and helping individuals work" (Frick, RTOP, Feb. 8). In laboratory courses at our university undergraduates that have completed the course previously and are recommended by their professor can act as teaching interns. This course had such an intern, he arrived about thirty minutes into the lab and "students ask him questions" (Frick, RTOP, Feb. 8).

Both the intern and the GTA acted as leaders during the lab. So, having an intern in class was confusing for an observer not familiar with the departmental system, particularly given the intern had on a lab coat also it might have been difficult for students to know as well.

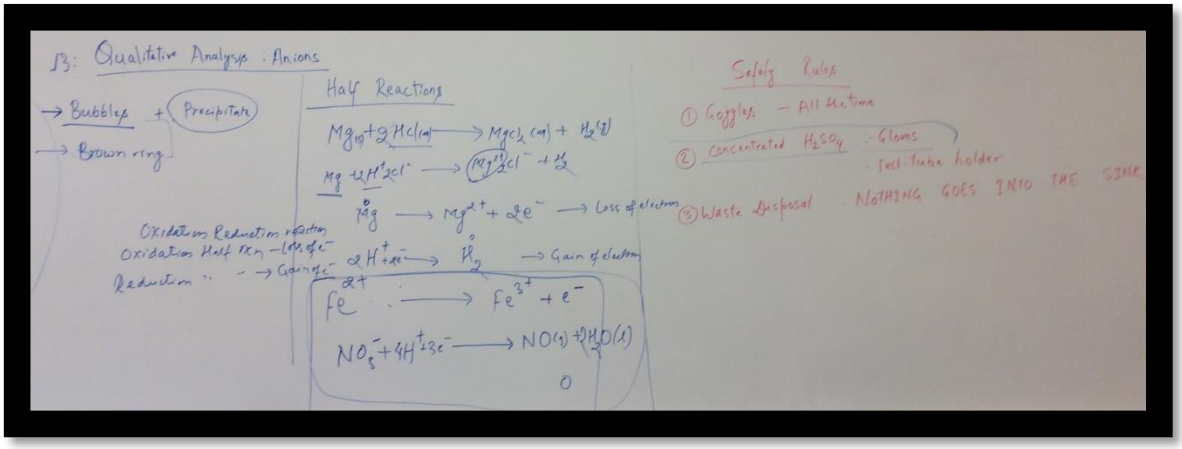


Figure 39. Carbon’s whiteboard after the initial lab briefing

“Two GTAs? One is in a white lab coat” (Reid, RTOP, Feb.8). Both assisted the students, “as groups begin to work on discovering the identity of the unknown, there is more focus on task completion” (Frick, RTOP, Feb. 8).

> The groups start discussing bubbles and precipitates – so, bubbles are a gas form? That is what they said, might want to ask. The intern explained, bubbles are not a precipitate, bubbles are a gas, CO_2. The intern tells students to give a good

> description, support your answers well. The student answers a precipitate question with, must be $CaCO_3$ because that is a solid. (Frick, RTOP, Feb. 8)

Several groups asked about the ring as they are trying to identify their unknown.

> I told the intern and GTA what Dr. Neon and I had talked about earlier in the week; more Iron is needed. The Fe is not combining to form the 'brown ring.' Students are unsettled, about science not working, elevated stress. (Frick, RTOP, Feb. 8)

The students were still struggling, so both the intern and the GTA continued to explain. "The intern pulls out his periodic table and walks the students through ion formation" (Frick, RTOP, Feb. 8). The previous examples support the numerical rating for student-teacher interactions Carbon received.

As the students became comfortable in class the number of communicative interactions increased slightly. After a couple of hours in class, the students begin to have a conversation, "discuss work-life balance with school and a seminar the student heard about with the topic how to study for upper division science classes" (Frick, RTOP, Feb. 8). The students felt comfortable enough to talk about their frustrations with one another.

> A student near me tells another that the intern upset her because he told her to she should have memorized the polyatomic ions last semester after she had tried to ask a question. Next time she will go to the GTA. (Frick, RTOP, Feb. 8)

Carbon encouraged her students to collect their data and interpret the results. “GTA tells the students that they still have enough time to retry the unknown reactions” (Frick, RTOP, Feb. 8) with nearly an hour left in class. She was correct as “the last groups are finishing washing and cleaning. GTA is walking and helping students – thanking them for cleaning up” (Frick, RTOP, Feb. 8), ten minutes before the scheduled end time for the laboratory.

In the final observed lesson Carbon taught about electrochemical cells, she started much the same way she had before. “GTA starts writing the reaction on the board and talking through the equation: $Mg (s) + CuSO_4 (aq) \rightarrow MgSO_4 (aq) + Cu (s)$” (Frick, RTOP, Apr. 12). She explained that “in displacement reactions those elements that are more reactive replace those that are less” (Frick, RTOP, Apr. 12). “Then she moved onto explaining redox reactions. She doesn’t stop to ask questions or check for student understanding” (Reid, RTOP, Apr. 12). After introducing redox reactions, she wrote another balanced equation on the board and asked:

> Can you tell me which element underwent oxidation and reduction? A student at the front lab bench answers and the GTA writes answer on board and moves to another example. She asked the same question, and another student from the same table answered. (Frick, RTOP, Apr. 12)

Carbon moved on to explain electrochemical cells and the experiment the students were to complete, only after she connected the theoretical ideas that included the dissasocioation of ionic compounds. “We will use two solution $ZnSO_4$ and $CuSO_4$, draws on the board the apparatus used in today’s experiment, a detailed diagram that included a salt bridge joining the two" (Frick, RTOP, Apr. 12). Figure 40 shows the researchers recorded interpretation of the drawing.

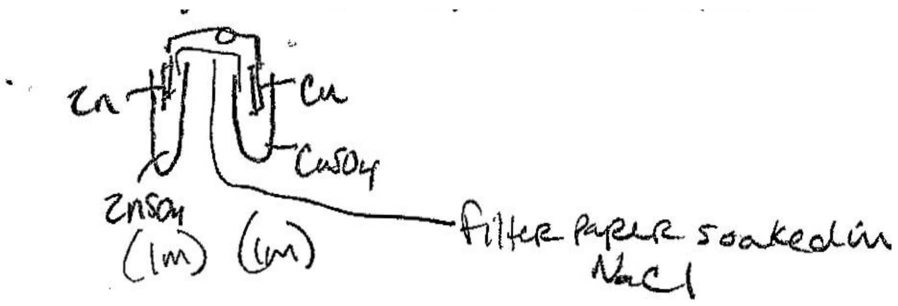
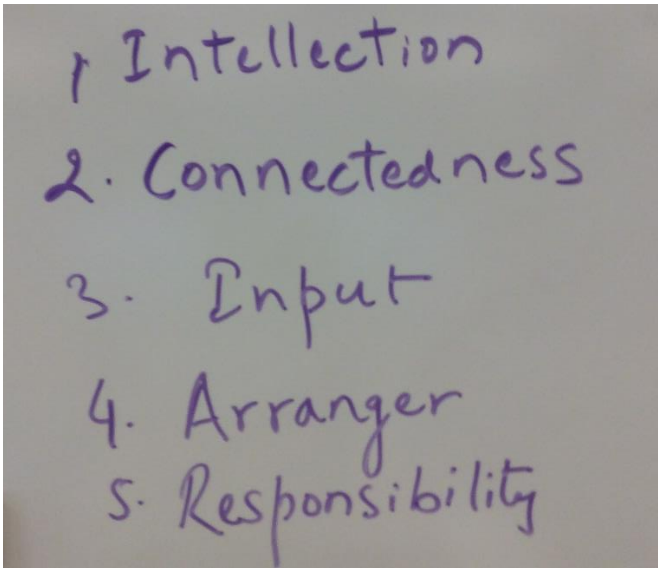


Figure 40. In class set up for the electrochemical experiment. (Reid, RTOP, Apr. 12)

Carbon explained to the students that they would "see some changes occurring as the solid metals act as an anode or a cathode. She tells the students they will have to draw this diagram. This is a voltaic cell; you will be changing concentration. You are asked to increase the voltage" (Frick, RTOP, Apr. 12). She continues by asking students how they might achieve an increase. "No response, students looking at phones, staring at GTA as she explains how to increase the voltage. She says the same thing in another way, and asks does the voltage increase or decrease? Carbon looks to the front bench from which the other answers have come" (Frick, RTOP, Apr. 12). Although she was asking questions and waited anywhere from 3 to 7 seconds, self-answers were most common. While it was obvious that Carbon tried to engage her students, "one student was on the phone and two others not looking at GTA – disconnected from the lecture" (Reid, RTOP, Apr. 12) which was the evidence for the points lost in communicative interactions and lesson design and implementation.

Workshops. Carbon attended all six workshops and completed the in-class reflections. In the third workshop, Carbon reported her talent themes, Figure 41.



1. Intellection
2. Connectedness
3. Input
4. Arranger
5. Responsibility

Figure 41. Carbon's results from the CSFA(Carbon, Feb. 20)

In Workshop Four Carbon was asked:

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? (Discuss your answer and contrast your ideas to what Bodner said. Explain how using your individual talents, as defined by the Clifton Strengths Finder Assessment, can help you better connect ideas in chemistry, so your students' understanding has minimal misconceptions.)

Carbon answered:

> When people have a higher level of studies, they might forget about the general level. This might create the problem of misconceptions because they might neglect or forget the basic things. The assessment has helped me to find out my strengths, such as Connectedness, Discipline, etc., which I can use to help students to minimize their misconceptions. (Carbon, reflection, Mar. 13)

When asked to fill out a teaching observation form, as an assignment that occurred between a multiple week break from the workshops, Carbon did not complete the formal request. Although she did not turn in a formal observation, Carbon did state during her interview that she observed a peer to help her understand the instruments used in the experiments she found the instrumentation was sometimes unfamiliar. She explained:

> On Monday, I have a class at 3:00 in the afternoon, right. So, I come here around 8:00 in the morning, and I have a friend. So, I used to be in his lab and see how the things work and how does that start. And so, that is the way I had to do it, for like three experiments. I think. So, I come earlier and observe his class, and then I use that knowledge in my class. (Carbon, TBI, Apr. 12)

Her observation was not focused on teaching techniques or on how to engage students, simply to determine the steps needed to complete the experiment. In the final workshop, Carbon reflected on the semester, and answered Dr. Neon’s questions:

- What did you think was useful?

> To know that students should be taught with more enthusiasm. You should start with the basic things. Make the learning environment very friendly and less complicated.
>
> - What would help you become a more effective GTA?
>
> Connectedness with the students. Try themselves to find the solutions to the problems.
>
> - What is one thing that you plan to try to improve your teaching?
>
> Try to remember the names of students from the very first day.
>
> - What do you think is your best quality as a teacher?
>
> My concern for the students' problems. (Carbon, Apr. 10)

After turning in her reflection, Carbon asked Dr. Neon some questions about the lab she was going to be teaching. The experiment was one that Johnstone had expressed concerns for in his article because electrochemistry required students to take an expert perspective. The analysis required students to conceptualize what is taking place to cause the voltage to occur between solutions containing zinc and copper, Figure 42. Carbon appeared concerned, about conveying concepts clearly and improving her teaching, which indicated that her responsibility was to provide information as in a traditional teacher-centered learning environment.

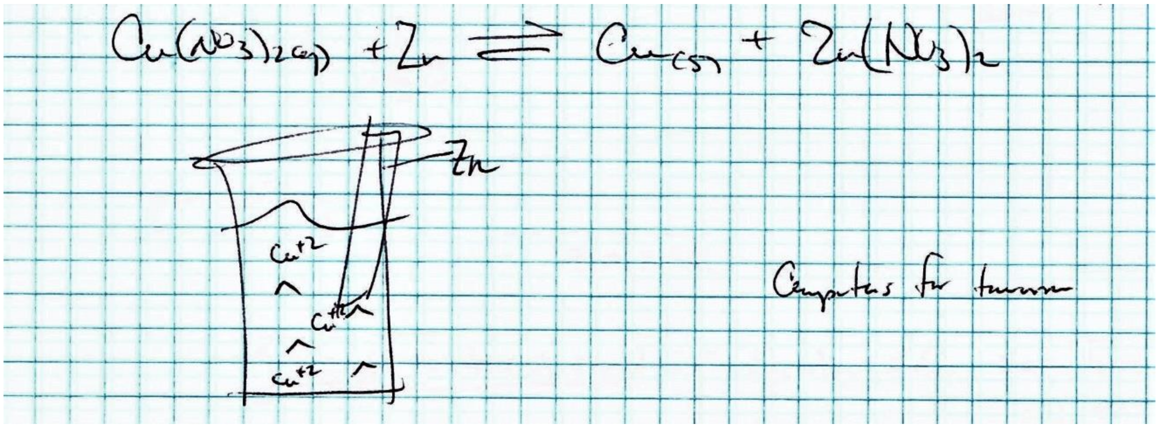


Figure 42. Symbolic and particulate representations of an electrochemical reaction (Neon, notes, Apr. 10)

Belief interviews. Carbon had experience teaching in her country, and this was her first semester in our chemistry department. The TBI profile shown in Table 5 revealed that Carbon held teacher-centered beliefs about the instruction of her students. The beliefs were demonstrated in the way that Carbon monitored her students and expected that the students would engage her for clarity. Carbon wanted to provide an experience for her students that contained all the information and skills they would need to be successful in the class. “I mean, I want to see them, whether they are on the right track or not. Are they getting this? Or are they just giving the results only?” (Carbon, TBI, 13 Feb.). Carbon was not only interested in her student results, “some are not doing anything I mean they are not asking, but still I go through their table and see whether they are doing their part here or not” (Carbon, TBI, 13 Feb.). She wanted her students to understand the experiment independently:

> If they have some confusion before they start the lab, they should email me, or like ask what time I am available for them to help them out. So that, they have a general idea that this is going to happen in the lab. (Carbon, TBI, 13 Feb.)

She appeared frustrated with the student level of engagement, “they should participate more in asking questions or giving the reasons by themselves.

Table 5. Initial Teacher Beliefs Profile for Carbon, February 13, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional	Responsive
1 – maximize student learning	***	*****		
2 – help students learn	***	****		
3- students understand		*****	**	
4 – decide to teach	****	***	**	
6 – learn science best	*	*	**	**
7- learning is occurring	****	*		*
8- other comments		***		*

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI was briefly summarized in the first column. An * represents a response, either a sentence or phrase, indicating their teacher beliefs. GTA’s beliefs were teacher-centered, when most responses were categorized as traditional and instructive, or student-centered, when the majority were responsive and reformed.

Instead of just, okay, I have to do this question" (Carbon, TBI, 13 Feb.). As a teacher, it was apparent she wanted her students to comprehend the conceptual questions relating the experience in the lab to the material presented in lecture. And she had difficulty with one student that continued to ask for the correct answer – she wanted me to help.

> One of my students in lab is, I think he doesn't want to learn anything, but just finish the work and go. And he asks me questions all the time, like what the chemical formula for this is, or what is this, what is this, what is this, what is this, in that case, how can I help him? (Carbon, TBI, 13 Feb.)

Although Carbon knew she wanted her students to understand and the breadth of responses on her profile was evidence that Carbon had started to have ideas about a learning environment that moved beyond the traditional teacher-centered beliefs.

Carbon continued to work through her difficulties during the semester and further developed her beliefs about teaching. The final interview with Carbon focused more on developing knowledge and positive emotions associated with transitional teaching beliefs. "I ask key questions related to that. So, if they are answering, if they are willing to answer, then I think that; yes, now they are making the correlation, which I am giving them" (Carbon, TBI, 12 Apr.). She explained if you can use that theoretical knowledge and see the experiment.

> If they can see that, yes it happens or no it doesn't happen; then that will make the students learn faster. Because what they have read, if they can apply in their life, then that will make the learning process more effective. (Carbon, TBI, 12 Apr.)

Ultimately, she decided that “learning science is, it should be like, first of all, they should have the passion for the science” (Carbon, TBI, 12 Apr.). The beliefs she stated were transitional, Table 6 is the TBI profile.

Table 6. Final Teacher Beliefs Profile for Carbon, April 12, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional	Responsive
1– maximize student learning	*	***** *		
2 – your role		**	**	
3- students understand	*	*	****	
6- learning occurring			**	
7 – learn science best			**	*
8			***	*

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI was briefly summarized in the first column. An * represents a response, either a sentence or phrase, indicating their teacher beliefs. GTA’s beliefs were teacher-centered, when most responses were categorized as traditional and instructive, or student-centered, when the majority were responsive and reformed.

Summary. Carbon was one of only two participants that completed the TBI twice, once at the start of the workshops and again after the completion of the workshops in April. Carbon's belief profile indicated that her beliefs about teaching science shifted toward a more student-centered belief system from teacher-centered to transitional. Question number five was not included in the interview profile (Table 6) because the researcher elected not to ask about switching topics. In the final interview profile (Table 5.2) question, number four that dealt with deciding what to teach was not asked. Two questions, one and six, had answers categorized the same both before and after the workshop, instructive and transitional respectfully. The remainder of the items became more student-centered than in Carbon's initial interview. The most substantial shift in question seven which went from a traditional to transitional answer, showing Carbon reached a more sophisticated understanding of knowing how learning occurred in her classroom. The overall profile shift was from teacher-centered, instructive beliefs, to transitional beliefs, acknowledging the affective filters that impact learning in a student-centered classroom.

While Carbon maintained teacher-centered practices for the entire semester, after participating in the workshops, her beliefs about science teaching were more student-centered (Tables 5.1 and 5.2) in each lesson, Carbon received her highest scores in the categories of propositional knowledge and student-teacher relationships, with RTOP scores that increased as the semester progressed, Figure 5.1. The lowest category for Carbon was lesson design and implementation, which decreased from initial to final observation. The results from the TBI indicated a shift in teacher beliefs from instructive to transitional. Carbon admitted to using her strength of Connectedness to build relationships with her students and found value in the information provided during the workshop with Dr. Neon.

Bromine

At the start of Spring 2017, Bromine introduced himself to his fellow GTA's saying that he "likes to share ideas" (Frick, Jan. 23). During his interview he provided a brief history of his academic experience and explained he had earned his Bachelor of Science degree in 2006 from a university in Bangladesh. Bromine continued to work with chemistry in industry. "I came here in like, you know 2016, June. Now, I am working here as a GTA and doing my master's, this is my second semester" (Bromine, TBI, Apr. 20). Bromine taught three introductory laboratory courses, two sections of introductory chemistry laboratory and one physical science laboratory, the courses were the same as he had the previous semester. Bromine worked for two different laboratory coordinators, Dr. Krypton coordinated the introductory chemistry laboratories, in which Bromine's average student evaluation score for the previous semester was 3.1 out of 5. Dr. Argon coordinated the physical science laboratory in which Bromine had an average student evaluation score of 4.4 out of 5. Bromine was observed twice and attended all six of the workshops including the completed Clifton Strength Finder Assessment (CSFA) and was asked to reflect on misconceptions and strengths. At the end of the semester, after completing all the workshops, I interviewed Bromine using the Teachers Beliefs Interview (TBI) protocol.

Classroom observation. The classroom observations, for Bromine, were conducted while he was teaching one of the sections of introductory chemistry. Figure 43 shows the RTOP for Bromine's class at the start and end of the semester. Bromine began his introductory chemistry lesson, as Dr. Krypton had instructed, on molar ratios using the dehydration of hydrated salts by giving his students a quiz. He officially, "begins class by passing back papers. As he is doing this there seems to be a moderate amount of student-student talk" (Reid, Feb. 18). "Lecture starts with a PP, all the quizzes turned in, examples of a hydrate and steps through the PP slides" (Frick, Feb. 8).

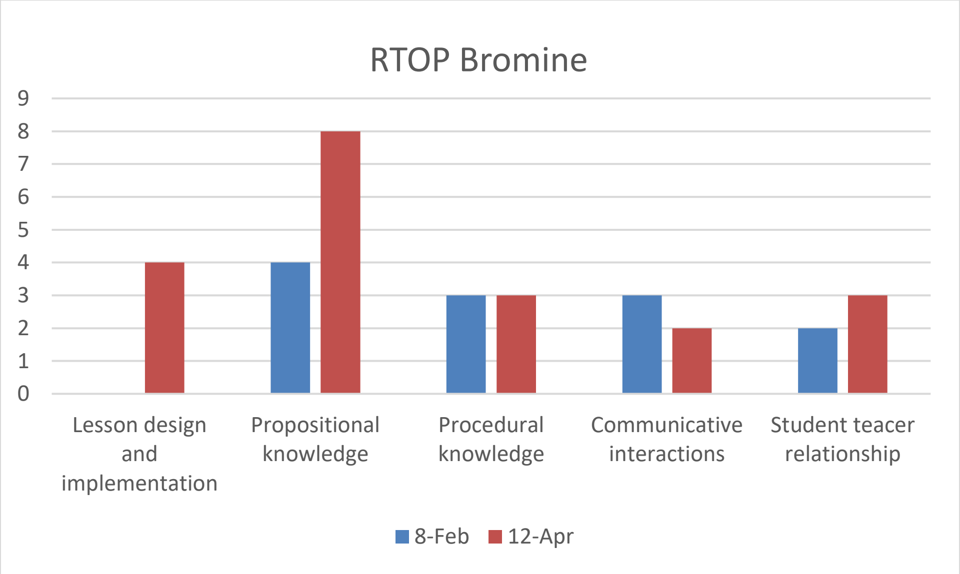


Figure 43. Pre and post RTOP scores for Bromine

"The lesson is Experiment 6: Hydrates. He uses a PP presentation and Reads Slides to discuss/describe what a hydrate is next slide has an example" (Reid, Feb. 18). As he continued through the presentations Bromine explained, when you heat the sample:

> Water is given off as steam. To determine the amount experimentally, we can find out using mathematics. You weigh the sample before and after, you have the mass of water, when you subtract the final value from the initial. To calculate the percent water, you will divide your mass of water by your total original sample and multiply times 100. You will calculate the theoretical value; your experiment will give experimental value. (Frick, Feb. 8)

He asked the students if they had questions and waited less than five seconds before with:

> no prompting, the GTA moves on when students don't say anything. As he presents, he primarily looks at the screen and not at students. This could be a sign of not being completely comfortable teaching or with content. Therefore, I can't tell the level of content knowledge. The PP includes slides with protocol/procedures and he reads those to the students. (Reid, Feb. 18)

Reid believed that Bromine was reading the information from the slides, and found little evidence to support that Bromine understood the information he presented.

Bromine finished the introduction, he "explained they needed three heating's and walked to the back of the room showing where solutions would be discarded" (Frick, Feb. 8). The first section of the RTOP is the Lesson Design and Implementation (LDI), focused on student engagement with the content and respecting student prior knowledge. The in-class observations showed that Bromine focused on the content provided by the laboratory coordinator during his briefing, resulting in no points earned as shown in

Figure 43. “The PP also includes instruments being used such as a scale and waste disposal – did not use the white board” (Reid, Feb. 18). Although Bromine appeared to only be doing what was asked of him by the coordinator, he could find ways to increase the engagement of his students while presenting the laboratory experiment.

As the “experiment begins the GTA assigns unknowns to each group and has them write it down in the lab manual. He explicitly tells them to do this” (Reid, Feb. 18). As the students begin to assemble the experiment, the “GTA is helping students’ setup and lightning burners. Students are having difficulty locating Bunsen burners and ring stands” (Frick, Feb. 8). Bromine continued to work with each group, “as the last setup was lit, he told two groups to work together because one of the burners was not working. GTA seems to be in a hurry and starting to appear stressed as he takes on more responsibility” (Frick, Feb. 8). After the first hour, when students started to collect data, Bromine started working at the front desk provided for instructors. “Students asking each other, how did you set up the problem? The GTA goes to the front lab bench and explains to the students working how the calculations are done” (Frick, Feb. 8). The scores Bromine received in both propositional and procedural content (Figure 43, blue) were based on the fundamental concepts presented while the experiment was completed. Although propositional knowledge was the category in which Bromine received his highest score, Reid (Feb. 18) noted that “he wasn’t clear” with the fundamental concepts of the subject and the coherent ties between conceptual understandings.

As some students had completed the assignment, “students working on calculations are becoming frustrated” (Frick, Feb. 8), as other students completed the experiment and left the laboratory. The “GTA is checking lab notebooks to see if people are finding their theoretical value and questions them when not correct. Students explain to each other how to find the mass of water” (Frick, Feb. 8). The interactions initiated by Bromine “walking around and assisting students” (Reid, Feb. 18) resulted in the points awarded to Bromine for classroom culture, which contains the last two sections of the RTOP, Communicative Interactions and Student Teacher Relationships, in blue on Figure 43. After completing their work “students say this is horribly annoying and tedious” (Frick, Feb. 8), indicating the students feelings relating to their learning experience.

> The student is confused again – now ready to ask the GTA for help. Did you do your calculation? Now, the student must determine how many water molecules were contained within the formula unit of salt. The student likes the step by step guide. (Frick, Feb. 8).

Several students felt that the GTA had told them opposite ways of completing the calculations and felt that they “did it all wrong. What we had in the first place before he told us no, we messed up…The students are stressed about not being able to complete the lab correctly, GTA is confused- tells them different things: sometimes experimental error happens, do not worry, use this, write this in another place” (Frick, Feb. 8). Although he tried to help students with questions by providing correct answers the atmosphere, he established appeared un-engaging, “GTA is standing off to the side with his arms crossed” (Frick, Feb. 8) Which alone would not necessarily seem intimidating except:

> GTA checks the students works as they turn it in with no incident asking the first two male students of a group. The female group member went up and engaged in conversation with the GTA that ended with her saying, I am not explaining myself to you. (Frick, Feb. 8)

The work on student interactions continued as the GTA asked even the last group if they understood, they simply replied, yes before leaving the classroom.

Although the interrater validation for the RTOP was not able to be completed with the final observation of Bromines introductory chemistry class, due to video and audio issues, I reported my scores for Bromine, which were only slightly higher than the initial RTOP, shown in red on Figure 43.

Similar to the first observation, “as the students enter the GTA hands them a quiz, students are in good spirits talking and laughing” (Frick, RTOP, Apr. 13). Bromine scored higher in the areas of LDI, up slightly from zero initially, both times he used the slides provided and this time he emphasized the experiment and worked to build understanding. The other area Bromine improved in was propositional content knowledge. “GTA reads through the slides. Students are looking at slides, not taking notes” (Frick, RTOP, Apr. 13). The lesson was an investigation of the logarithmic representation of hydronium ions in water which make the pH scale. Bromine “asked about pH and common properties of acids and bases, no hands went up instead a few students at the front of the class provided answers to the questions" (Frick, RTOP, Apr. 13). Students were asked to work with partners to "test a large variety of solutions, with pH paper and with a pH probe. Measuring a variety gives students a range of pHs to work through" (Frick, RTOP, Apr.13). This lesson design encouraged students to explore the concrete examples to connect more abstract ideas, "-log[H+] written in lab manual, p=power(-log) and H is the hydronium ion concentration" (Frick, RTOP, Apr. 13).

The remaining three areas, procedural knowledge, communicative interactions, and student-teacher relationships, of the RTOP, had scores that remained relatively stable, and low. As the experiment began:

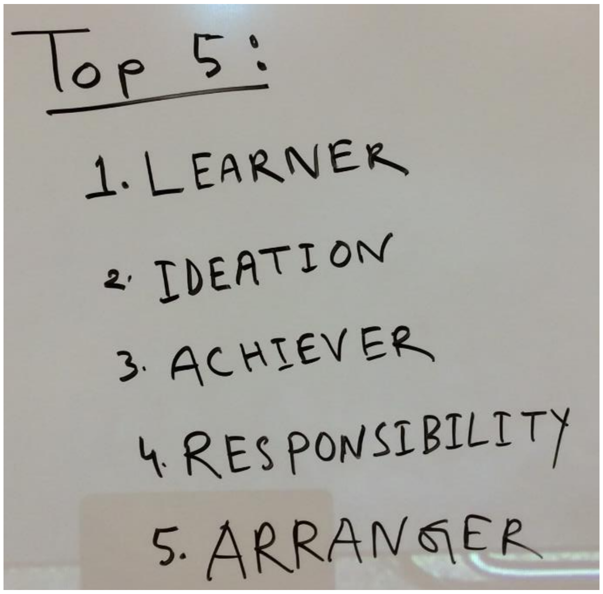
> Bromine was walking around the lab. GTA stops to work at one hood with students, when a person from the other side of the room yells, 'instructor'. GTA moves on to working at from bench with students and onto bench in front of me. Asks student 'what are you doing?' She placed the indicator paper in each tube. Bromine told her to pour it out and start again. She returns, and he takes a drop from each solution and places it on the paper. The same student has yelled instructor again two times while he was working with this group of students. He moves onto another group, ignoring the student that yelled instructor. After completing his conversation with that group, (approximately ten minutes from the first time the student yelled) GTA walks to back bench, where the yelling student is playing on his phone. (Frick, RTOP, Apr. 13).

Although Bromine interacts with the students, he did not work to probe student understanding, instead he worked to make sure students completed the procedures correctly. He did not acknowledge students when they attempted to engage him and missed opportunities to allow his students to construct a conceptual understanding of their experiment.

As the experiment continued, “students are comfortable in the lab, joking with one another” (Frick, RTOP, Apr. 13). They “are doing well working together to determine how to accomplish lab goals and following others” (Frick, RTOP, Apr.13). The solutions in lab helped students connect science to everyday life. “Students found soda to be more acidic than hydrochloric acid. ‘I don’t drink soda anyway’ . The conversation gets louder as students work to answer the questions on the lab report and collect final readings” (Frick, RTOP, Apr. 13). A student came to Bromine for clarification and the “GTA restated what he heard from a student, when affirming statements to Bromine the correct answers were important” (Frick, RTOP, Apr. 13). Bromine struggled to engage students in the learning environment which was the evidence for the RTOP areas in classroom culture as well as procedural content knowledge remaining similar to the scores from earlier in the semester, Figure 43.

Workshops. Bromine remained true to his introduction of himself,as a person that likes to share his ideas, and attended each of the six workshops. The results Bromine reported after completing the Clifton Strengths Finder Assesment (CSFA) revealed that he understood his strengths to be an interesting part of himself, prior to reporting the results to his assesment on Feb. 20, Figure 44. Bromine's dominant talents are in the strategic thinking domain, learner and ideation, and executing domain, achiever, arranger, and responsibility of the Gallup leadership domains. Bromine did not complete the outside observation or the initial interview. When asked:

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? (Discuss your answer and contrast your ideas to what Bodner said. Explain how using your individual talents, as defined by the Clifton Strengths Finder Assessment, can help you better connect ideas in chemistry, so your students' understanding has minimal misconceptions.)



Top 5:

1. LEARNER
2. IDEATION
3. ACHIEVER
4. RESPONSIBILITY
5. ARRANGER

Figure 44. Bromine's reported results from CSFA (Feb. 20)

Bromine provided the following answer:

> I think general chemistry included elementary/basic knowledge about chemistry, but in graduate programs people work with a specific area like organic or inorganic, physical etc. So, people who are working with physical chemistry they may be detached from the fundamental organic/inorganic chemistry. That can be the reason for misconceptions. (Bromine, Mar. 13)

Bromine addressed the primary question asked in both question one and two from Workshop Four; however, Bromine did not use ideas from the Bodner article or his talents to provide evidence for his assertations about the formation or elimination of student misconceptions.

Bromine had the following responses to the questions posed by Dr. Neon at the end of the semester.

- What did you think was useful?

  Strategies are very useful.

- What would help you become a more effective GTA?

  Experience and training

- What is one thing that you plan to try to improve your teaching?

  More communicative than before.

- What do you think is your best quality as a teacher?

> I enjoy teaching and sharing information with my students. (Bromine, Apr. 10)

After, participating in the workshops, Bromine indicated that more training would assist him in becoming a better GTA. The reflections provided by Bromine revealed very general concepts about teaching. He concluded his interview, "I liked all the workshop, I learned many things from there, how to teach and strategy actually. Explanation of the strategy of how to teach. I like teaching strategy" (Bromine, TBI, Apr. 20).

Beliefs interview. Bromine and I had a difficult time setting a time to meet for our Teacher Beliefs Interview (TBI) when we met it was about twenty minutes before he had a laboratory scheduled to teach. I was able to complete a history of his educational experiences. During the conversation with Bromine, I changed the wording of the first two questions. Instead of asking about how to maximize student learning I asked, "you are excited about it; how do you get them excited?" (Frick, TBI, Apr. 20). The second question was supposed to focus on describing his role as a laboratory instructor, and I asked, "how do you help them learn?" (Frick, TBI, Apr. 20), the results from Bromine's TBI are summarized in his profile, Table 7.

Bromine asked for clarity on question seven related to how knowing students had learned. I explained, "how do you know when they learned it? Like, when it is all done, how can you be, like, I know that my students learned titration" (Frick, TBI, Apr. 20). I was able to ask him about the workshops; however, I was not able to ask him about the CSA results or application of his talents in teaching, due to his class starting.

Table 7. Final Teacher Beliefs Profile for Bromine, April 20, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional	Responsive
1 – maximize student learning		*	**	
2 – help students learn	***	**		
3- students understand	*	**		
4 – decide to teach	***			
5 – new topic		*		*
6 – learn science best		*	**	
7- learning is occurring	*	*		

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI was briefly summarized in the first column. An * represents a response, either a sentence or phrase, indicating their teacher beliefs. GTA's beliefs were teacher-centered, when most responses were categorized as traditional and instructive, or student-centered, when the majority were responsive and reformed.

Our interview started with a history of his educational experience in Bangladesh and discussed his previous teaching experience. He had been a private tutor. He noted differences in the education here compared to in his country.

> In the whole class, you are using a lot of modern technology and you are using, what do I say, a lot of modern instrument technology, in my country you do not. There are not so much modern instrument. They are using traditional instrument to learn about chemistry and about science. I found this kind of difference between my country and your country. (Bromine, TBI, Apr. 20)

Not only were the differences he noted in the use of instrumentation; however, Bromine was not accustomed to science being a requirement for nonscience majors. Students in both the classes he taught could apply this laboratory to satisfy the science requirement for their undergraduate degrees.

> I got many non-science students, like from commerce background, like marketing, accounting. They have no good understanding about science and many of them don't like science. And chemistry is disappointing for them, but in my country, when you take commerce or arts, you have no need to involve in science related subject. Like, they have common science subject, but they have no need to especially know about chemistry physics. Like, they have no need to focus on individual physics, chemistry, or biology. They only know the general knowledge about science, but they have no need to do a chemistry experiment, lab experiment. (Bromine, TBI, Apr. 20)

Although not a part of the TBI, the information Bromine provided about his perceived differences in education was something he saw as impactful to his performance as a GTA.

Bromine held teaching beliefs that were mostly instructive or traditional in nature indicating a teacher-centered instructional orientation as shown in Table 6. He explained how he felt about teaching labs in the following statement:

> I feel great, because lab is a practical teaching experience. You involve the student practically. you can teach and learn both learn from practical experiment. You are observing what you learn, what you learn theoretically this is practically and doing experiment. So, this is great. This is great. I am excited to learn, to teach in lab. (Bromine, TBI, Apr. 20)

The students in his classroom try to understand, "sometimes they do wrong answer, then I make them understand what is actually is happening" (Bromine, TBI, Apr. 20). He goes on from this traditional stand point to explain "that way I teach them, and I demonstrate" (Bromine, TBI Apr. 20), in a more instructive orientation. "I ask them questions… Then I find that they have understood the experiment. From asking question, from grading the lab report" (Bromine, TBI, Apr. 20) he ensured understanding by providing information. He noted questioning from himself and students as an important aspect of teaching.

> They ask me questions, I give answer of this question and if they have curiosity, I fulfill their curiosity by providing information and what is that they need. Actually, there was also prelab lecture and in this prelab lecture I give an initial lecture, and, in this lecture, they ask me question and I give them answer of this question. And when the experiment start, I go to the middle table and I walk around the lab and

> try to find if they have any curiosity, if they have any question. Actually, by that way I try to teach. (Bromine, TBI, Apr. 20)

Most of Bromine's comments were instructive in nature; however, some of his answers indicated that he might be moving toward a student-centered teaching belief system. "What do you understand? Can anyone understand, what do you understand, in this step of the experiment. Then they explain me, okay. From their explanation I can understand that they understand every step of the experiment" (Bromine, TBI, Apr. 20). In this way Bromine can respond to the needs of the learners in his classroom. Similarly, transitional understandings were shown when he indicated a belief that students affective domain impacted their ability to learn.

> I feel they are excited about the experiment and when I let them understand what is happening in the experiment, they become, 'oh this is great, I learn,' but I see this practically, and it is exciting. Actually, by that I feel, they feel is exciting - I think. (Bromine, TBI, Apr.20)

Importantly, Bromine believed his students learned science best, "when they become curious. Okay, when they ask me more questions. I like to hear questions from my student" (Bromine, TBI, Apr. 20).

Silicon

Silicon had a year of experience as a GTA; he started the master's program after completing his chemistry bachelor's at a university in Nigeria. He taught nine months of senior-level chemistry in Nigeria after completing his bachelor's degree, as required in his country. He instructed General Chemistry I laboratory in Fall 2016 and received a teacher evaluation score of 3.8/5.0, from his students. He stated in the introductory workshop that he "loved teaching" (Frick, notes, Jan. 23). Silicon taught two sections of General Chemistry I Laboratory, for Dr. Helium, and one section of physical science, for Dr. Argon, in Spring 2017. Silicon had taught Chemistry for Consumers for Dr. Krypton, in Fall 2016, so there was a small change to his instructional responsibilities. Silicon had little change in his teaching evaluation scores which averaged 3.7/5.0 for General Chemistry One in Spring 2017.

Classroom observation. There were two observations of Silicon teaching; one on February 9, 2017 and another on April 13, 2017. The video recording from the second observation, which the other researcher could not attend, had no sound. Unfortunately that meant only my notes could be used to form the RTOP score as Reid was not able to attend the second observation in person. The RTOP results for the end of the semester were similar to those at the start of the semester, as seen in Figure 45. Silicon attended each of the workshops and did not complete the CSFA (Clifton Strength Finders Assessment). I was not able to set a meeting time with Silicon at the start of the semester; therefore, I performed his only Teacher Beliefs Interview (TBI) following his final observation on April 13.

As the class began Silicon was "writing course / daily notes on the board, lesson: Spectroscopy" (Reid, RTOP, Feb. 9), Figure 46. "As the GTA is writing on the board student in class are chatting with each other" (Frick, RTOP, Feb. 9). He "announces observers and 'rallies' students to begin class" (Reid, RTOP, Feb. 9).

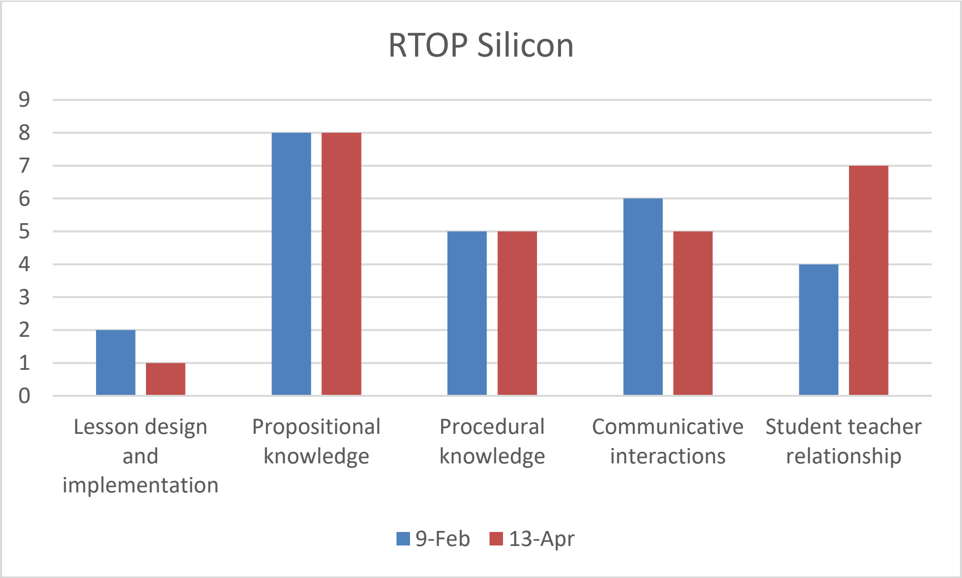
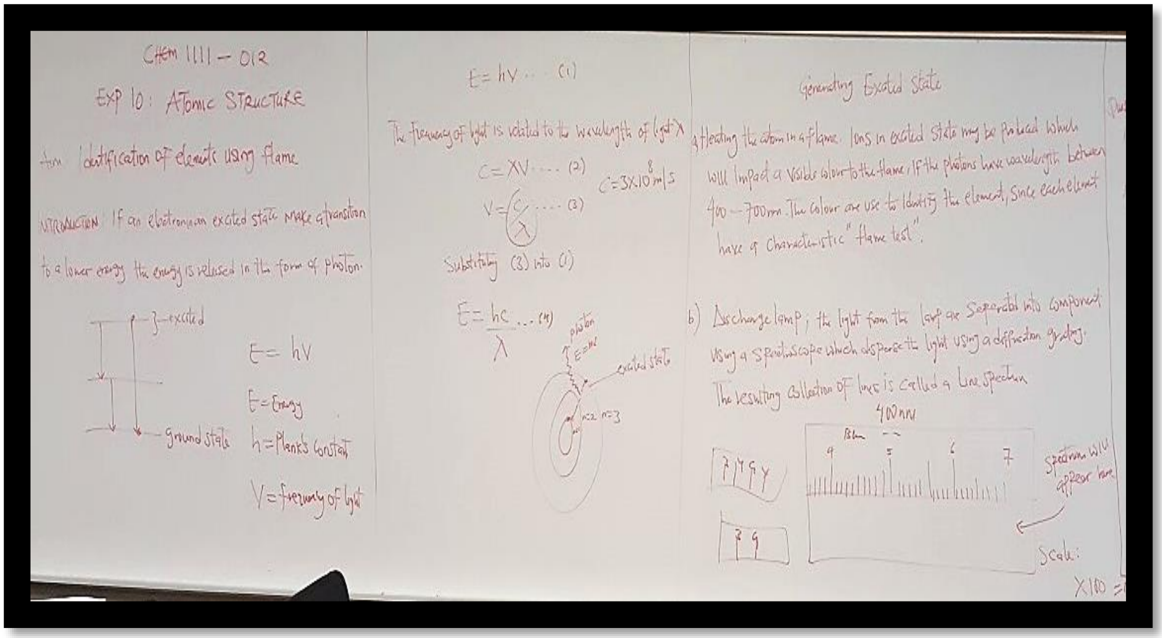


Figure 45. Silicon's initial and final RTOP scores in each of the five RTOP categories.

Silicon was "talking about atomic structure" (Frick, RTOP, Feb. 9) and "explaining the concept of electron excitement – using the drawings on the board and physical movement" (Reid, RTOP, Feb. 9). As he talked, "the GTA walked around the room turning on the lamps and showing the light" (Frick, RTOP, Feb.9). He explained the "concept of excited state electrons and the relationship to color change" (Reid, RTOP, Feb. 9), an "electron from higher energy to lower energy in the form of a photon. He showed the students where the example is written on the board" (Frick, RTOP, Feb. 9). Although the formulas were provided in the lab manuals, Silicon was "breaking down the formulas E=ʎʋ and E = hc/ʎ"

(Reid, RTOP, Feb. 9) where “c is the speed of light – he gives the students the number on the board. He showed them the replacement of one variable for an equation – solving for specific variables. Students were taking notes” (Frick, RTOP, Feb. 9).



CHEM 1111 – 012

EXP 10: ATOMIC STRUCTURE

Aim Identification of elements using flame

INTRODUCTION If an electron in an excited state make a transition to a lower energy the energy is released in the form of photon.

$E = h\nu$

E = Energy

h = Plank's Constant

ν = frequency of light

$E = h\nu \cdots (1)$

The frequency of light is related to the wavelength of light λ

$c = \lambda\nu \cdots (2)$ $c = 3\times10^{8}$ m/s

$\nu = \frac{c}{\lambda} \cdots (3)$

Substituting (3) into (1)

$E = \frac{hc}{\lambda} \cdots (4)$

Generating Excited State

a) Heating the atom in a flame. Ions in excited state may be produced which will impart a visible colour to the flame, if the photons have wavelength between 400 – 700nm. The colour are use to identify the element, since each element have a characteristic "flame test".

b) Discharge lamp; the light from the lamp are separated into component using a spectroscope which disperse the light using a diffraction grating. The resulting collection of lines is called a Line spectrum

Figure 46. Silicon initial notes for class on Atomic Structure.

After the brief introduction, Silicon went on to demonstrate the experiment, using the lab to guide a mini-lecture – content/concepts – protocol - corrections (Reid, RTOP, Feb. 9). Silicon moved to the hood, showing each labeled spray bottle and explained to use those to determine an unknown by matching the color. Students turn toward GTA as he started the Bunsen burner. He demonstrated how to spray the bottle to create the flame changing color. The other part of the lab was the discharge lamps. As he held up a square piece of blue glass in front of the spectrophotometer Silicon explained, “just label lines and look through this, some are missing; some disappear” (Frick, RTOP, Feb. 9).

After walking students through each part to the experiment, Silicon explained, “when given the value for a wavelength you need to calculate frequency” (Frick, RTOP, Feb. 9). The GTA asked, “what do you think the relationship is between these two?” (Reid, RTOP, Feb. 9). He demonstrated good wait time and a student answered. The instructor acknowledged and agreed with the students answer before providing further explanation. He assured students that, “there are examples in the lab manual” (Frick, RTOP, Feb. 9). As Silicon finished the presentation, he restated the inverse relationship between wavelength and frequency before telling the students, “okay, we can start. Make sure; you put your goggles on” (Frick, RTOP, Feb.9).

During the lab, Silicon was “walking around assisting/answering questions. He noted when students were discussing problem and came to assist if needed. Silicon was and had students working together to solve calculations before beginning the lab (Reid, RTOP, Feb. 9). The interactions Silicon participated in engaged students in thinking about the meaning related to the calculations they performed in class. One student questioned the GTA about how to get an answer, Silicon pointed to the board and went to assist another student that raised their hand. The first student was still confused, so another student helped her through the calculation (Frick, RTOP, Feb. 9). Although Silicon attempted to be available for his students, he did not necessarily provide information that helped them understand the experiment or data. An hour after the lab started, one group was still working on calculations, some were comparing answers, and several students were trying to help others" (Frick, RTOP, Feb. 9). The data collection did not take students long to complete.

After being in the lab for an hour and twenty minutes, most students completed data collection. The first student turned in their paper, and the GTA returned last week's lab (Frick, RTOP, Feb. 9). Silicon continued to assist students with understanding; he explained things using the whiteboard as a reference. He asked students to think of the difference between colors for lithium chloride and lithium sulfate (Reid, RTOP, Feb. 9). Although the labs were meant to be completed with partners, several people worked independently in the lab with very little interaction (Frick, RTOP, Feb. 9). Silicon was constantly moving back and forth between three workstations where students were and as the class continued there was still lots of student/teacher interaction (Reid, RTOP, Feb. 9). The last two groups finished before reaching the two-hour mark, with both groups finishing at the same time (Frick, RTOP, Feb. 9).

I observed Silicon for the second time on April 13, 2017. As shown in Figure 45, Silicon had very little change in his RTOP scores in most areas. The most significant change was in the category of Student-Teacher Relationships, which increased by four points. Silicon appeared more patient with students and more willing to let students interpret their evidence while acting as a resource person.

The experiment started much like the first had with Silicon writing on the whiteboard explain the relationship between pressure and volume for gases. Silicon lets his students know that this is the last experiment for the semester, and we will be measuring pressure. GTA talked about inverse proportionality and asked, “what happens if pressure decreases?” (Frick, RTOP, Apr. 13). The classroom atmosphere was more interactive than during the previous visit. Students at the first bench were listening and engaging by making eye contact. The GTA spent the first twenty-five minutes of the class explaining the basics of Kinetic Molecular theory. He talked through all the stuff that he wrote on the whiteboard, which not only related the pressure and volume of gases but also detailed the Ideal Gas Law including moles of gas and temperature in his description. The students completed the data collection and analysis of this lab within an hour of Silicon completing his briefing.

As students conducted the experiment, there was confusion about the meaning of the data they collected. Silicon walked to each bench to tell the students how to use the instrument to collect data (Frick, RTOP, Apr. 13). The students started strong collecting data and discussing classes; they were taking next semester. At the start of calculations, they begin to have difficulty. While Silicon is working with one of the front groups on calculations, another student has had her hand raised with a question for a couple of minutes. Several students are confused and not understanding what to do. Silicon noted the confusion and pointed to the board saying, “just use this formula, you are looking for innate pressure” (Frick, RTOP, Apr. 13). Silicon spoke quietly even when at the front of the room. He told the students which numbers from the data they collected to put into the formula $P_1V_1=P_2V_2$. Silicon asked, “what do you observe about values of volume and pressure? are they related?” (Frick, RTOP, Apr. 13). The students continued the discussion amongst themselves about how to correctly do the math and complete the calculations. After letting them struggle for five minutes, “GTA asks, so does it increase or decrease. How do you put into words? Worked to rephrase, so that student said half” (Frick, RTOP, Apr. 13). Silicon explained the mathematical relationship. As the class concluded the comfort level students had in approaching Silicon with questions was demonstrated by someone asking for clarification to the work on the whiteboard.

Workshops. Silicon attended each of the six workshops. In the first workshop, Silicon let us know that he enjoyed teaching. Silicon did not complete the Clifton Strengths Finder Assessment (CSFA), although he was given the book and in attendance for the guest speaker. He was asked to explain using his knowledge of potential student misconceptions rather than his CSFA results. He completed both reflective in-class assignments. When asked in the fourth workshop:

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? Discuss your answer and contrast your ideas to what Bodner said. Explain how using your knowledge of potential student misconceptions can help you better connect ideas in chemistry, so your students’ understanding has minimal misconceptions. (Frick, notes, Mar. 13)

Silicon answered, “by giving a detailed explanation, stating the objectives of each experiment and showing connection between the practical and theory” (Silicon, Mar. 13).

Silicon had the following responses to the questions posed by Dr. Neon during the sixth workshop at the end of the semester.

- What did you think was useful?

    -How to present an ideal – Getting to know the students (knowing their names, ability) – It was an eye opener on how to relate to each student – Understanding that each individual have different level of understanding

- What would help you become a more effective GTA?

    -Make briefing notes before the lab – Understanding the whole concept of each experiment – Communicate effectively and efficiently – Make more pictorial representation about changes made at the molecular level.

- What is one thing that you plan to try to improve your teaching?

    By trying to ask them questions after the briefing to make sure they understand the concept of the experiment.

- What do you think is your best quality as a teacher?
    - Simplifying complex idea to simple and real-life observation. Attending to student needs individually. (Silicon, Apr. 10)

Beliefs interview. Silicon was not able to complete an interview at the beginning of the semester; however, at the end of the semester, I was able to interview him after his final class. We completed the Teacher Beliefs Interview (TBI) on April 13, 2017. Silicon talked about his educational experience in Nigeria and how different it was to teach at this university.

> It's kind of like a little bit more comfortable here to teach. It is kind of like easier, compared to, like you know, we came from a developing country, so most of those things, you only read in the books. You do not have to like see them physically, so that was - coming here was like a real eye-opener. You could actually see something. As little as they have. Right so, I can remember like back in high school, if we were to run an experiment, you have to queue up (laughter). You have to wait for someone to finish, but, like here, everybody has his own to play with. (Silicon, TBI, Apr. 13)

Somethings that we might take for granted as students from developed nations, Silicon noticed and was thankful, "when I come in here like everyone writing on the board - like in my country we use chalk" (Silicon, TBI, Apr. 13).

The TBI was intended to monitor change in beliefs; we have no initial interview for comparison; however, the post-TBI indicated a teacher-centered belief, Table 8, with the majority of statements being traditional. He started to move from beliefs of merely telling students information to having them connect concepts is an example of instructive beliefs. Silicon showed breadth in his understanding with some student-centered ideas about learning science best and maximizing student learning that focused on understanding the student's conceptual representations. Silicon's his beliefs about teaching were centered mostly around what he could tell the students.

Silicon's traditional rating came from his beliefs about the transmission of content. "I try to let them understand the concept of what we are doing. Like you are coming to the class, you put on the title on the board. So, you need to tell them" (Silicon, TBI, Apr. 13). He wanted to give the students all the information they could ever need. "The aim of this experiment is to investigate the relationship between the pressure and volume of a gas, so, which means, if you increase the volume the pressure decreases" (Silicon, TBI, Apr. 13).

Table 8. Final Teacher Beliefs Profile for Silicon, April 13, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional
1 – maximize learning	****	**	
2 – your role	**	****	*
3- students understand	*	***	
4 – decide to teach	***		
5 – new activity	**		
6 – learn science best	**	*	**
7- learning is occurring			**

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI was briefly summarized in the first column. A * represents a response, either a sentence or phrase, indicating their teacher beliefs. GTA's beliefs were teacher-centered when most responses were categorized as traditional and instructive, or student-centered, when the majority were responsive and reformed.

Silicon found different ways to express this understanding.

> So, I think that is like one of the important even if you cannot say it correctly, but you have an idea of okay, this is what we do. If we increase the pressure, the volume comes down. If you increase the volume, the pressure comes down. (Silicon, TBI, Apr. 13)

Silicon worked to implement the topics presented during experiments as precisely as possible. His role was to "communicate like if you increase the pressure what happened to the volume? They can have an 'oh yeah' the volume is going to increase" (Silicon, TBI, Apr. 13). He wanted his students to be able to respond to "someone if they were to meet them in the street and ask them, 'well what did you do in class today?', they could say oh this is what we did" (Silicon, TBI, Apr. 13). He believed it necessary to make everything explicit to students:

> Okay, like you don't want to overwhelm them with too many information especially where they don't' really need too. Like so, I just try to like simplify the idea, like okay this is what is going on. Okay, today we are just studying the relationship between the pressure and the volume. So, I give them some worked examples, and how to calculate, if you are given the pressure and volume then you have to look for the other one. So, you just kind of like, on your own before coming to class you need to like simplify the whole - the complex information provided in the manual. So that way, when they come to class, they don't have a

> problem with trying to like break down the information. So, you have to like break it down for them – yeah. (Silicon, TBI, Apr. 13)

Silicon transitioned from one topic to another based on his belief of the theoretical material that was most important.

> To determine the state of the gas, we need to study four variables pressure, the volume, and the temperature, and the number of moles, right? So, like, if I am to move from Boyle's law to the Ideal Gas Law, right, I am going to tell them, like okay right now, we keep two constants. So, moving from Boyle's law to Ideal Gas Law that means, we have to incorporate the temperature. So that way, we are just going to keep one constant. So, in the one we were working on the board, we said those values, they are not completely independent of each other, but they depend on each other. So, right now we are keeping two constants, then we are kind of moving those around. So, in some other instances, we might move three around, while we keep one constant. So, that is going to give us another look. Since they know gas has four variables, so you might move the volume and the temperature around, so that is going to give you Charles's law, right. So, it is kind of easier that way, to just take it from that level because they have the main background, they are looking for in gas stage they need four variables, so you can move from two to three and all that. (Silicon, TBI, Apr. 13)

Even his beliefs about learning science best started with traditional views, “think it is by observation. Observation, because we tend to learn more by what we see” (Silicon, TBI, Apr. 13). He believed in finding alternative ways to help students envision theory.

> Relating it to a real world, experiment like you are the size of the classroom. You have like maybe a hundred gas molecules in here; then by the time you decrease the size to half, the greater, collision is going to increases. (Silicon, TBI, Apr. 13)

Although still, teacher-centered Silicon held several instructional beliefs about teaching chemistry. He wanted students to make connections on their own after he had given them all the information.

> They might tell you yeah, we studied Boyle's law, but they might not be able to, define what Boyle’s law means, but they have an idea. Like, Boyle’s Law states this is the volume. So at least, if you ask them, you know they have an idea of like the relationship between the pressure and the volume. (Silicon, TBI, Apr. 13)

Silicon believed, “my role starts from before the class. So, like I need to prepare myself - you go over the notes, you think, you have your own notes, you make your own notes before the class” (Silicon, TBI, Apr. 13). “We try to like look at easier examples that will make them understand it easily. Then when you come to the class, you explain to them” (Silicon, TBI, Apr. 13). He gives the students a little more authority in their learning with beliefs about the importance of their perspective, “I just try to like help them as much as possible, by trying to push them to try and think of the answer by themselves, or if they need a little help" (Silicon, TBI, Apr. 13).

> I am not going to tell them the answer directly. So, some of the students they ask me. So, okay I told them to understand the state of the gas you need to, we need four variables which are pressure, volume, temperature, and the number of moles. So, I said okay we kept two constant, so you try to think which two. (Silicon, TBI, Apr. 13)

He wanted the learning to occur as smoothly as possible and believed he achieved this by providing all the information.

Although Silicon started by saying students learned science best through observation, he talked himself into a more transitional belief.

> I think the best way to learn science is by actually doing it yourself. So, it tends to stick, because we, you can easily forget whatever, like what you do with your hand it is going to take a long time before you forget; better than what someone tells you. (Silicon, TBI, Apr. 13)

He identified transitional points of view when discussing student learning in-class.

> Like sometimes you don't know by observation, yeah, because sometimes you just, there are some student that are like oh, they are not getting it. They kind of feel frustrated, but once you move closer to a particular student or group of

> students, by the time you are overlooking at the student - oh I got it. Yeah this, they tell you more about what they are doing. (Silicon, TBI, Apr. 13)

Silicon thought the workshop “opened some aspect that we’re not really paying attention to, like trying to know the name of the student, trying to get familiarized with them, trying to see, trying to let them see you as a friend” (Silicon, TBI, Apr. 13).

Hydrogen

Hydrogen was the most senior master’s student to participate in the study; this was her final semester. She had started here two years ago after completing her first 16 years of education earning her chemistry bachelors’ degree in Bangladesh. Her previous teaching experience was as an undergraduate teaching assistant, where she helped prepare slides, put together lab reports and grades. Hydrogen was unique, and an accidental control case, in that she was not in attendance for any of the workshops; and as such, she had no artifacts for analysis. Hydrogen taught one section of General Chemistry Two and received a teaching evaluation score of 3.6/5.0 from her students. We were not able to connect for a Teacher Beliefs Interview (TBI) until the end of the semester, after her final observation.

Classroom observations. The initial Reformed Teaching Observation Protocol (RTOP) data collection took place on February 13, 2017, where Reid and I were both in attendance. I conducted the final RTOP alone on April 10, 2017. Reid scored the RTOP from the video, after which we discussed and came to agreements on any differences and completed a final combined RTOP with interrater reliability. The final scores earned by

Hydrogen are shown in Figure 47. The change in scores for Hydrogen seen in Figure 5.10, reflected an increase in propositional knowledge and a decrease in both areas related to classroom culture, communicative interactions and student-teacher relationships.

Hydrogen had an approach that was different from all the other participants. Hydrogen did not present information to the students, as the students entered, she was not writing on the board. It was difficult for us to know as observers that the experiment involved the topics of solutions and solubility of various solids.

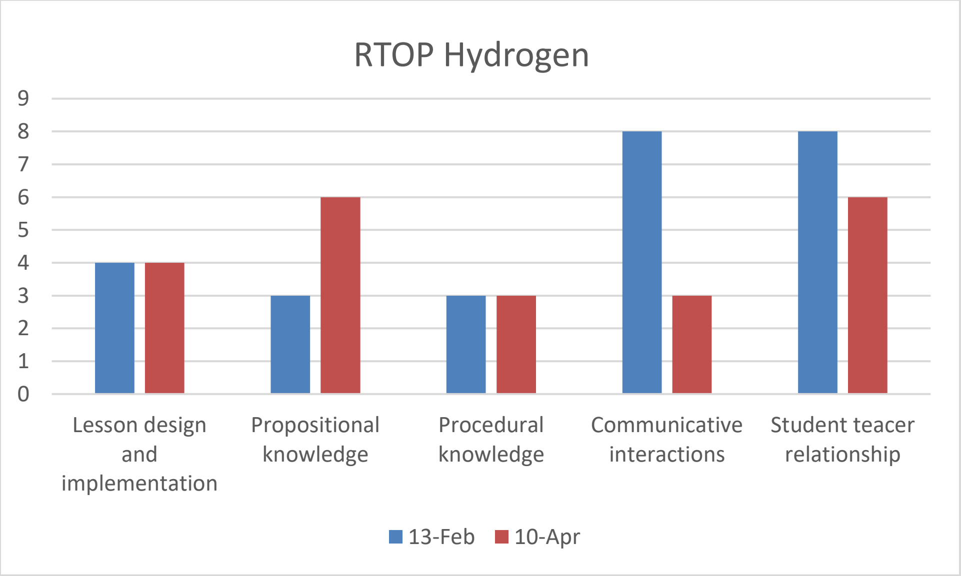


Figure 47. Final and initial RTOP scores for Hydrogen

The students came in and began talking about their experiment while the GTA handed out the papers from the previous week. She gave the students feedback regarding the lab report she handed back (Frick, RTOP, Feb. 13). The students were reading the lab manual and after returning some of the papers, the GTA asked the class, “what does solubility mean?” (Reid, RTOP, Feb. 13). The class was chatty, and it was difficult to hear Hydrogen or the student responses. She asked another question, “how much dissolved?” (Frick, RTOP, Feb. 13). Hydrogen told her students that solute was how much dissolved, which was what they would be testing. Although she had not finished the briefing, students continued to set up the experiment, lighting Bunsen burners, Hydrogen encouraged the students to “continue to set things up” (Frick, RTOP, Feb. 13) while she looked through the binder Dr. Helium had provided. She was quietly explaining procedures and assigning numbers to every group (Reid, RTOP, Feb. 13). Hydrogen finished her briefing in less than ten minutes, showing students where to dump waste, she walked to the back of the lab, and explained that she would assign different weights of solute to each of eight groups. Hydrogen received higher scores in communicative interactions were higher than her other scores because her students worked to understand what they were supposed to accomplish by asking each other. I am not certain that this was a behavior that was facilitated by Hydrogen or the students’ desire to complete the experiment quickly. Hydrogen did exhibit behaviors that encouraged her students to interact with each other and work together as lab partners to determine the results of their experiment.

After twenty minutes and a few questions, the experiment began with Hydrogen asking students if they had any further questions and demonstrating techniques, filter paper folding, and funnel. And as the class progressed, Hydrogen provided information for students and continued passing out more papers (Reid, RTOP, Feb. 13). She let the students know they needed to “report class data in front. And, the lab is very long; so you can turn it in next week” (Frick, RTOP, Feb. 13). Hydrogen walked around the class asking students if they are doing good. She reminded students to be precise in their measurements “two decimals for the mass and one decimal for temperature” (Frick, RTOP, Feb. 13).

As Hydrogen walked around the lab Reid (RTOP, Feb. 13) noticed that she was not wearing proper footwear; she had on slippers that did not cover the top of foot. The students did not comment, and Hydrogen was not noted addressing any safety issues in the lab, other than cleaning up broken glass. About two hours into the lab a student broke a graduated cylinder, by dropping it on the floor. She waited several minutes before alerting Hydrogen. Although not wearing proper shoes the GTA did get gloves before picking up the broken glass (Frick, RTOP, Feb. 13).

Hydrogen assisted students throughout the class time; she worked with small groups instead of addressing the entire class. She explained waste disposal to each of the pairs individually and spent the majority of her time on one side of the room (Reid, RTOP, Feb. 13). Hydrogen provided groups the atomic masses and appeared to work with students on calculations. For one group, she walked to her desk and got a calculator to tell the students how to convert to grams from moles. She explained that solubility is measured in grams per liter and moles per liter for sodium chloride. After checking the binder Hydrogen showed the student an example calculation. As students continued their experiment the

GTA was looking through the binder and watching. Her students were weighing, mixing, stirring and heating as she went to each bench, explaining that there was a correction. At the hour and a half mark, Hydrogen reminds students to “write number seven on the board, when calculations are complete” (Frick, RTOP, Feb. 13). Hydrogen demonstrated how to properly load the centrifuge, and there was a steady ting of stir rods against test tubes. As a student worked to complete her calculations the GTA and student argued over how to set-up the calculation, cross-multiplying (Reid, RTOP, Feb. 13). Hydrogen continued to reference the binder after working with a bench. At the two-hour mark, Hydrogen referenced the notebook to ensure the information she provided to her students was correct. Fifteen minutes later:

> We have forty-five minutes left, are you close? ‘No’ by most of the students. So, what are we going to do? All of the information for the first row of the datasheet is filled, done with sodium and lead? Pair five and six? Group five apparently has no data for any section. So, the class was told to use seven points. (Frick, RTOP, Feb. 13)

Although, Hydrogen tried to provide all the information to her students and continued to monitor progress with fifteen minutes left there were “five groups still working on completing” (Frick, RTOP, Feb. 13). Hydrogen let them know “it’s time to finish up on the lab, even if all the data has not been completed. Any questions about the graph?” (Frick, RTOP, Feb. 13) she asked, but students were still reading, computing, and a couple still had ring stands out. Hydrogen provided information to the students as they needed the material throughout the class.

Figure 47 showed that Hydrogen had some small changes in her RTOP scores between February and April. The second observation occurred on April 10, 2017, in the same General Chemistry Two Laboratory. The increase was in the area of propositional knowledge. Hydrogen demonstrated a solid understanding of the topic of this lesson, electrochemical cells. In the area of classroom culture, the communicative interactions dropped, meaning that the students were not as engaged in conversations with one another as they had been previously. The RTOP score for student-teacher relationships also dropped. We observed no opportunities for students to generate ways of interpreting the evidence for Hydrogen. She changed tactics, slightly, during the second observation and used the whiteboard, although briefly.

The instructor was talking at the front of the class while students were sitting at lab benches, entering the class, standing, or prepping work station (Reid, RTOP, Apr. 10). She started by asking, “what kind of cells are these?” (Frick, RTOP, Apr. 10). One student at front lab bench seems to be engaged in conversation with the GTA when she asked about oxidation and reduction. Seven minutes after class started, the prelab briefing was over while students looked around for the lab supplies. Hydrogen was in front of the class looking through the binder (Frick, RTOP, Apr. 10). The students spent the next ten minutes reviewing their lab manuals, trying to determine how to proceed. Hydrogen did not explain the laboratory procedures in her briefing, just the reactions the student would need to write.

Twenty minutes into class the majority of students were talking between each other to determine how to set up the cell. The students were asked in their lab manual to draw a diagram of the physical apparatus. Students approached the GTA with a problem, the voltmeter was not reading at all. It provided a reading of zero both times. Hydrogen told them to "make sure the wires are connected properly" (Frick, RTOP, Apr. 10). The voltmeter was supposed to read zero initially, as the students had not yet connected the cells with a salt bridge. The students continued to move forward with the experiment, and you could hear the murmur of student interactions mixed with laughter from the front lab bench where GTA worked with students one group of students. Near me, students set up the cell and let it run for a little while before taking readings. One group member said, "well isn't it Le Chatelier that said if you take some out of that it will shift the rate of reaction?" (Frick, RTOP, Apr. 10). As the students worked on a new cell and waited for the reaction to run, the GTA asked to see their reports. She told them to "be sure to put the reaction on the sheet along with the solubility for each part of the experiment" (Frick, RTOP, Apr. 10). When Hydrogen moved to the next bench a student confessed that, "I was a little confused" (Reid, RTOP, Apr. 10), the instructor seemed to ignore the student and walked away. As the first hour ended, the group in front of me talked about electron flow, while another group, lamented not paying attention during lecture. Again, the students were talking with one another and explaining the process, without any input from Hydrogen, even when they admitted to being confused.

Hydrogen checked in with the class as a whole "doing good? Any questions?" (Frick, RTOP, Apr. 10). Most were doing well, just waiting on results. The GTA continued to primarily work with one group until an hour and a half after they started the first group complete the lab and turned it in. Others begin to ask questions of the GTA, and the students are getting excited to leave. Several students were working with goggles on their forehead or around their neck instead of on their eyes. Twenty minutes later, two groups were still working on collecting data for analysis, the GTA and I were the only ones still wearing goggles, as Reid had just left. As the last groups finished up an hour early, Hydrogen did not ask them questions about the experiment as she had during the first observation. Instead, the GTA was checking benches and helping clean the area, while groups finished up calculations (Frick, RTOP, Apr. 10).

Beliefs interview. Hydrogen and I met only once for an interview, directly following her last classroom observation on April 10, 2017. She was confident in her answers and spent little time elaborating. When I asked her question 5, “how do you decide when to switch topics?” Hydrogen responded that she had never switched topics because she only taught chemistry labs. We were not sure how to code the answer, so I did not include the question in Table 9 Hydrogen held beliefs that were teacher-centered and traditional. Hydrogen’s instructive beliefs included thoughts about her students’ perspective. She believed her role was “to walk around and just to see what they are doing every time” (Hydrogen, TBI, Apr. 10). She knew when her students were not understanding “by their face, they have an expression that they are not getting things” (Hydrogen, TBI, Apr. 10). She also thought her students learned science best, “of course, by doing hands-on things” (Hydrogen, TBI, Apr. 10).

Although her initial responses were coded instructive, the follow-up questions revealed Hydrogen's demonstrated her traditional ideas

Table 9. Final Teacher Beliefs Profile for Hydrogen, April 10, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive
1 – maximize learning	**	
2 – your role	*	*
3- students understand	*	*
4 – decide to teach	*	
6 – learn science best	***	*
7- learning is occurring	*	

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI was briefly summarized in the first column. A * represents a response, either a sentence or phrase, indicating their teacher beliefs. GTA's beliefs were teacher-centered when most responses were categorized as traditional and instructive, or student-centered, when the majority were responsive and reformed.

in communicating her thoughts for how to adapt the laboratory:

> Yeah, like today's lab, so, we had to take like cathode and anode, we had to fix that, but it was not specified. Just to increase the volume, but it was not specified how much we need to increase. So, like we used $CuSO_4$, so it was 1 M, and you were just to increase the concentration, but it was not saying exactly what should be the final concentration. (Hydrogen, TBI, Apr. 10)

The traditional teaching beliefs Hydrogen held kept her from allowing the students to experiment with changing the concentrations by various amounts. Rather than letting the students explore the concept on their own, as the curriculum intended, “I just ask them to do it for 1M and 0.1M” (Hydrogen, TBI, Apr. 10). “I like to provide them as much as I know, and I like to make things clear and transparent” (Hydrogen, TBI, Apr. 10), in this way Hydrogen hoped to maximize her students’ learning.

Sodium

Sodium was in his third year of the Molecular Biosciences Ph.D. program. Sodium attained his master’s degree in biology from a university in the southeastern United States after receiving his biotechnical engineering undergraduate degree in India. During the introductions, Sodium let us know that he had been a graduate teaching assistant (GTA) for six years. Although he had experience teaching introductory courses in biology, his current research was with a chemistry professor and was asked to teach introductory chemistry labs. He had just started teaching the laboratory course Chemistry for Consumers in Fall of 2016. The laboratory coordinator was Dr. Krypton. He had a teaching evaluation score of 4.0/5.0. He taught the same class in Spring of 2017, receiving a similar evaluation score 4.1/5.0 from his students.

Classroom Observations. We observed Sodium’s first class on February 6, 2017. Sodium’s final observation took place on April 17, 2017. Figure 48 has initial and final scores from the Reformed Teaching Observational Protocol (RTOP) assigned to the practices observed during his instruction. Reid and I were in attendance for both laboratory classes, and our field notes were referenced to attain the behaviors represented by the RTOP. The Chemistry for Consumers Laboratory lab coordinator distributed PowerPoint (PP) slides to use in the briefings, which Sodium referenced during both observations. Sodium scored highest in the categories of student-teacher relationships and propositional knowledge, achieving both high scores during the initial observation. The greatest changes from initial to the final meeting were in the groups of student-teacher relationships and lesson design and implementation which both decreased during the second observation.

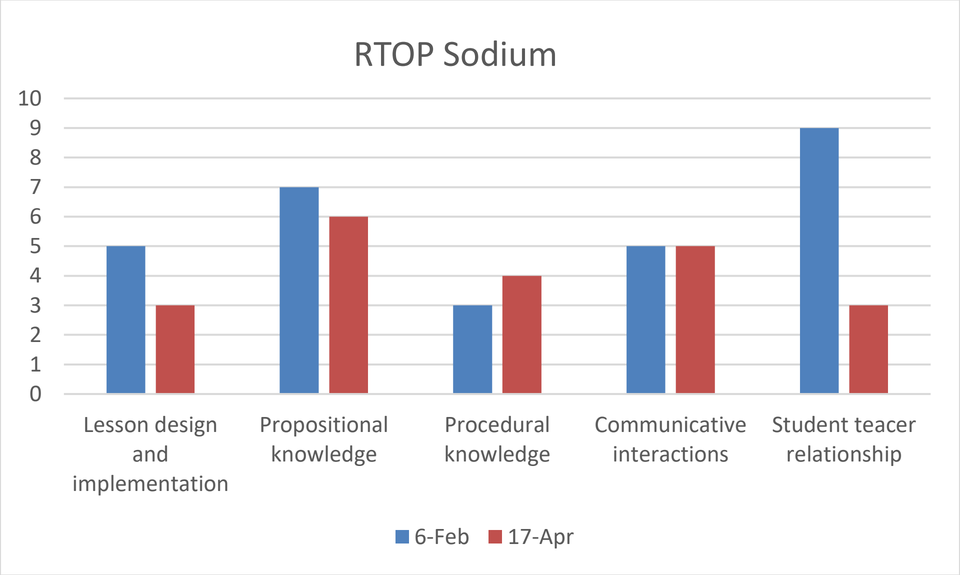


Figure 48. Final and initial RTOP scores for Sodium

The topics Sodium highlighted during the first observation included laboratory equipment and density. As the first class began, Sodium had all the students remove everything from their lab drawers. He asked questions such as: “which is a beaker? is there anything you don’t know? everyone knows a watch glass? A funnel?” (Frick, notes, Feb. 6). As the students went through their drawers, he continued to explain the uses of other equipment and asked each group to set up a Bunsen burner telling them, “please, do not turn it on” (Frick, notes, Feb. 6). Sodium walked to each lab bench checking to ensure each pair had correctly set-up the equipment. After Sodium completed his rounds, he returned to the front of the class holding up a graduated cylinder. The GTA asked, “what is this used for?” A student answered, “measuring.” He responded looking around the class, “what else, does anyone know what a meniscus is?” (Frick, notes, Feb. 6). He scrolled through the PP to a slide with a picture of a graduated cylinder, he zoomed in to easily see the top and bottom of the meniscus. Sodium continued asking students for the volume reading and the units associated with the measurement.

He demonstrated his knowledge of the topics related to the experiment as he moved quickly from the questions about equipment to asking the students how to measure density. He encouraged students to give loud responses. Sodium informed his students, “This will be the easiest lab of the semester; I expect you to know these things” (Reid, RTOP, Feb. 6). He explained that in this lab they would be calculating the density of both liquids and solids. The students set up the experiment and he assigned unknowns to pairs of students. He continued to ask questions about what other measurement they would need and how to measure the mass of liquids. Students answered that you could tare the scale with the graduated cylinder. Sodium demonstrated how to do this; although, the lab manual said to take the weight of the graduated cylinder and subtract the mass from the total weight. In this instance, Sodium allowed the student to guide the development of experimental procedures. As groups continued to collect data Sodium monitored his students reminding them to be careful when reading the meniscus and to be sure to include the correct units. He told his students to “show your math – you need to be accurate in your data collection; otherwise, you will lose points” (Frick, notes, Feb. 6). Students continued to work quietly and as some completed their calculations. The GTA asked, “What do your numbers look like? Are they close to the ones on the board?” Ethanol – 0.789g/mL Ethyl Acetate – 1.09 g/mL “Be sure your numbers are very close. If your numbers are way off, I would advise you to redo the experiment” (Frick, notes, Feb. 6). Sodium gave the students the opportunity to make their own decisions about their measurements.

Sodium returned to using the PowerPoint (PP) slides as he explained the calculations and significant figures. In the back of the room, I had a difficult time hearing what the GTA said. He told the students that irregular objects can be measured with water displacement, as discovered by Archimedes. He continued through the slides that explained to the students how to use a graduated cylinder, a scale, water, and ten pennies to determine the density of the pennies. The students pointed out that the lab manual said to use twenty pennies. Sodium initially responded, “do twenty if that is what the lab manuals says.” After observing one group of students taking measurements and talking with another group students, he said “that’s too many – use ten” (Frick, notes, Feb. 6). He once again listened to his students as he continued the lesson. Sodium reminded students to be very careful when taking measurements, and that they needed to be accurate. He walked around the class monitoring student progress and telling them to be careful when dropping the pennies into the graduated cylinder. He placed the density of copper on the board, 8.96g/mL. The students completed the last of their data collection and calculations, while Sodium returned to the front of the class to review his binder. I overheard students were talking with one another. “The last question asks if the penny is pure copper, what do you think?” The GTA was at the front reading, and there was very little interaction between and among students. The GTA asked a student about density: “Is it close or way off? 7.2, 7.8, 7.5, 7.4 If I tell you to calculate the percent copper, how much? I am not going to tell you that” (Frick, notes, Feb. 6).

Reid (RTOP, Feb. 6) noted that Sodium did not leave much wait time for students to respond. As several students finished with data collection, Sodium reminded them to put away their Bunsen burners and make sure to take inventory of their drawers. He did not notice the students looking quizzically at the pieces of glassware spread before them. Sodium did take note of a group of students that had not completed their measurements for the volume of pennies. Sodium helped the students by placing water in their graduated cylinder and having them write down the volume reading. He put the pennies into the cylinder and had the student read and record the final volume. In this way, he ensured his students stayed on task and as they finished their calculations Sodium replaced the chairs at the lab tables.

The second observation of Sodium took place on April 17, 2017. The topic covered during the lesson was polymers. As shown in Figure 48, Sodium maintained similar scores in both propositional and procedural categories of the content knowledge area from the RTOP and in the catagory of communicative interactions, from the classroom environment area. The differences were most prominent in the way Sodium interacted with his students, the patience and work to enhance student investigation seen in February had decreased as Sodium provided answers to his students. He presented information from the PowerPoint slides as before; however, because he saw little reason for his students to understand the molecular structure of polymers, he provided only the parts of the lesson he felt his student would need. The differences in the area of lesson design and implementation were attributed to the use of PP slides as an introduction rather than a way to continuously engage the students in connecting the slides to their actions.

The students walked into Sodium's class, and the PP slide with polymers stayed up while students completed their quiz. He asked the students about proteins and spent about ten minutes to explain the link between what they studied last week and what the student would complete this week. He told the students about each polymer and explained that they would be making three different polymers in today's experiment. As he continued talking, students took out equipment and began working to complete the investigation.

Sodium watched the students work for a while, after telling them the exact procedures to set up the exploration. He went to the front to describe the four-unit structure of the polymers. Sodium said, "I don't expect you to know this, but it is in the book. See", holding up the lab manual. "It does not explain it well, and I do not think it is needed" (Frick, RTOP, Apr. 17). Sodium proceeded to tell the students what they needed to write for their answers to specific questions in the lab report.

Sodium continued to monitor his students as he walked and paced in the front of the room. Sodium would answer questions when the students asked.

Student: "Do we need more of this?"

GTA: "What's this? I don't know what this is."

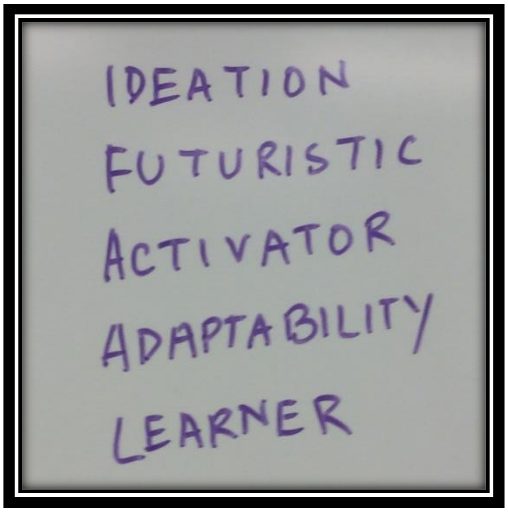
Student: "You need to be nicer. It is our last day."

GTA: [chuckled] "I am always nice to you." (Reid, RTOP, Apr. 17)

The students placed some of the slightly slimy-looking polymers, that they had fun playing with, in the sink. Sodium told them that this was a fun experiment they could do at home, as Borax was a detergent. He explained that students needed to write descriptions and the answers "should be your personal opinion" (Frick, RTOP, Apr. 17). The classroom had general ease to it, as students continued to joke with Sodium while he described how to make slime on the whiteboard.

As some of the students packed up, Sodium wrote on the board some of the characteristics that students should be looking for in their polymers. He told them to be sure to write the name on each of the samples. When compared to the first lab, Sodium asked fewer questions during the second lab and displayed less curiosity about student responses. Although it was apparent Sodium still had a good relationship with his students, he did not work to engage them throughout the experiment resulting in the lower RTOP score for student-teacher relationships.

Workshop participation. Sodium attended four of the six workshops; he missed the fourth and fifth. He did receive the book and completed his Clifton Strength Finders Assessments (CSFA), Figure 49.



IDEATION
FUTURISTIC
ACTIVATOR
ADAPTABILITY
LEARNER

Figure 49. Sodium CSFA results (Sodium, Feb. 20)

Sodium was not new to teaching, only new to the chemistry department, and during the workshop, he shared some of the various experiences he had in different departments. Sodium did not complete an observation of a peer and was the only graduate student to join the Wiki, which had been created for the reflections. Sodium was not in class to complete the misconceptions reflection questions. He did complete the final reflection in class.

End of class reflection:

- What did you think was useful?

  Underlying the fact that general chemistry can be tricky, even for experts. I am a researcher primarily, and little techniques on how to teach and keep students engaged were helpful.

- What would help you become a more effective GTA?

  Have more patience with students.

- What is one thing that you plan to try to improve your teaching?

  Having more interactions about real-life examples and how it connects to the lab experiments.

- What do you think is your best quality as a teacher?
  I am passionate about passing on information to young students. (Sodium, Apr. 10)

Beliefs Interview. He agreed to complete his initial Teaching Beliefs Interview (TBI), directly before we observed his class, on February 6, 2017. Table 10 showed that even after just one workshop, Sodium had a broad belief structure.

Table 10. Initial Teacher Beliefs Profile for Sodium, February 6, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional	Responsive
1 – maximize student learning		**	**	
2 – your role	**	***	*	
3- students understand	*	**	**	
4 – decide to teach	**	**	**	
5 – new activity	*	*	*	
6 – learn science best	*	**	***	
7- students enjoy				**
8- other comments	**	**	****	**

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI is briefly summarized in the first column. An * represents a GTA response, either a sentence or phrase, indicating their teacher beliefs. GTA's beliefs were teacher-centered when most responses were categorized as traditional and instructive, or student-centered, when the majority were responsive and reformed.

Sodium was comfortable examining his beliefs about teaching; as he answered questions about how to integrate his ideas about good teaching practices. Sodium's replies became more student-centered as the interview progressed. Sodium's responses were mostly transitional. This indicated that Sodium was in the process of adopting student-centered beliefs although his initial reactions to the questions were of a traditional teacher-centered nature.

Sodium talked easily about his educational experiences, as a student and a teacher; however, he did not smoothly flow into thinking about his impact in the courses he taught. When I asked him how to maximize student learning as a laboratory instructor, Sodium replied:

> Well the lab I teach there is literally no way you can maximize it, cause that's probably the ceiling. I feel like for an intro chem lab; I don't think there is a way. Really, unless yeah, I don't know about the exact like the method of teaching. That might be different. (Sodium, TBI, Feb. 6)

I encouraged him to pull on his experience as a student to think about possible things he used successfully in the lab that he might have shared as an instructor. Sodium admitted, “I like to interact with students, like all the time. I make them comfortable with me so they can always ask me anything, some teachers are not like that they are very formal” (Sodium, TBI, Feb. 6). In this statement, Sodium talked about his transitional idea of interacting with students and followed it with instructive ideas. “I am also formal, but at the same time I try to also give them the impression that I am always available, and you can talk to me” (Sodium, TBI, Feb. 6). Similarly, when I asked about his role as an instructor, Sodium started with teacher-centered beliefs.

> What's your role? Alright so, it's about like, for me; I would say that it's a bridge between the lecture and the lab. So, it is something. Whatever you learn in the lecture there's big big term. That's simplified in the lab, and they actually get to know it in a hands-on way. (Sodium, TBI, Feb. 6)

When we moved onto talking about student understanding, Sodium had difficulties interpreting the actions of his students. He held the transitional belief that in his classes, “you can always feel. Like there are a group of students, you know who, which group is doing well after a few labs” (Sodium, TBI, Feb. 6). At the same time, he held traditional beliefs about struggling students.

> I don't know, but there are some students like that, and that is what my experience has been for all the six years I have been a TA. It's just, some groups I would say, I don't know percentages vary I guess, they just don't. They come here, they are disinterested, no matter how well you tell them to do stuff, no matter how easy you make them, they are just not interested. (Sodium, TBI, Feb. 6)

As Sodium continued to answer questions about his beliefs with his transitional statements such as, “I feel like some people just love it. They want that connection between real life and what they are studying. So, it makes a huge difference” (Sodium, TBI, Feb. 6). Sodium began to share some of his thoughts related to the density experiment; he taught on the same day:

> I just feel this is an unnecessary lab, which can be coupled to something, which is, like next week; I think we are doing the bleach experiment. They have to compare bleach, different brands. So there also, they measure densities. I think that was one of the parts. Measuring the density and then go on and measure the other characteristics. So, maybe it can be coupled to a lab, not exactly the bleach experiment but coupled to something else.

The ideas Sodium started to share here encouraged me to ask the next question in a slightly different manner.

> Lithium: I am thinking it needs to be more of a grassroots type of effort. Like maybe grad students need to ask, what do our students enjoy? The professors are not always seeing labs to know what's going on in them.

> Sodium: I used to give an exercise in the biology classes about writing, write an essay about genomes. Something like that or write an essay about vaccines. And I would not just take the essay. I said well I am going to read those, but what I really want to do is have a class discussion. So, it's going to be like pros and cons just go for the pros first, go for the cons first, then I will explain what’s going on -what, where you are wrong and where you need to change. So, what I did was at the end of the lab, for one of the labs that ends early, I had like a15-20-minute block just for that part. I think they loved it; I think they actually got to know. Oh well, they say it causes mutation, but they have no idea what mutation is, so I guess. *laughter. (TBI, Feb. 6)

In this section, Sodium demonstrated his responsive teacher beliefs in working to engage students as developed understandings with open discourse between one another. As Sodium continued describing multiple ways for student-centered instruction, I spotted the use of one of his dominant CSFA talents of Ideation during the interview.

> Sodium: Yeah, it's not about the simplicity it's about making it interesting that's what matters. Even if you make it a little challenging, that's not bad, but maybe you can challenge their critical thinking and maybe make a little puzzle out of it who knows?
>
> Lithium: You have a lot of really good ideas. (TBI, Feb. 6)

Sodium engaged his talents to be more responsive to his students, building on his strength as an educator by creating designs that could enhance student engagement. Sodium's final thoughts regarding teaching and learning revolved around onboarding GTAs.

> Sodium: They can probably put you in a like an assistant TA kind of thing, like where they can just observe for a semester, what's going on; because especially someone coming from an international country. For me, it wasn't that a problem, my language was really good from the beginning, but for others, I can see that it might be a huge problem. Not only being a different culture and the system is different it's the communication gap that's also a problem.
>
> Lithium: The spoken language?

> Sodium: Especially when I see the chemistry department, it's just a personal opinion. It's just that needs to be improved, no matter what.
>
> Lithium: How do you, do you have any ideas on doing this?
>
> Sodium: Well I feel like, instead of just throwing them into a lab in their first semester they can, well you can't really do anything to improve their language. It's not a language class, but maybe they can sit in for their first semester, and observe how labs are taught out here, how you interact with people. They see that they get to a better idea. They get more confident, and then they apply it the next semester. (TBI, Feb. 6)

Although, Sodium did not follow up with a post-interview he already had some feedback regarding the GTA professional development. “As long as you give them advice, I guess they will probably – cause, one thing I got from talking to them was, they want to improve. It's not that they don't want to be better” (Sodium, RTOP, Feb. 6).

Iodine

Iodine had completed his entire educational career in the same state that housed our current university. Iodine completed his Bachelor of Science degree in chemistry from the same department in which we worked as GTA’s. Iodine started teaching Consumer Chemistry courses in Spring of 2013. He explained that although he took many classes from the department when Iodine began teaching it was in a class, he had not completed as an undergraduate. He felt that he, “picked up on it pretty quick” (Iodine, TBI, Apr. 14). In the Fall semester of 2016, Iodine taught only general chemistry, the average score on his teaching evaluations was 4.8/5.0. He worked toward completing his Ph.D. in Molecular Bioscience at the time of the interview. In the Spring semester of 2017, we observed Iodine teaching physical science. The coordinator for the physical science course was Dr. Argon. He was seen initially on February 13, 2017, and again on April 10, 2017. I interviewed Iodine, using the Teaching Beliefs Inventory (TBI) on April 17, 2017. The student evaluation score Iodine earned for teaching the course we observed was 4.0/5.0.

Classroom observations. While teaching Topics of Physical Science, Iodine taught a broad range of concepts, during the initial observation he discussed theories related to Kinetic Molecular Theory, while the final observation included an overview of geological samples. As shown in Figure 50, the scores from the Reformed Teaching Observation Protocol (RTOP), Iodine demonstrated his best practices, and we observed growth within the area of propositional content knowledge. Although initially earning one of his lowest scores for lesson design and implementation, Iodine exhibited growth in this area. The classroom culture enacted by Iodine changed very little during the semester, as he maintained his highest scores in the category of student-teacher relationships.

The first observation was of a laboratory in which students would complete a variety of experiments related to the movement of particles. Iodine started his class by very quickly reviewing lab topics and safety (Reid, RTOP, Feb. 13). He explained kinetic theory by telling the students that, “we are discussing atoms and molecules, with no charge. Originally, the kinetic theory started with the examination of gases" (Frick, notes, Feb. 13).

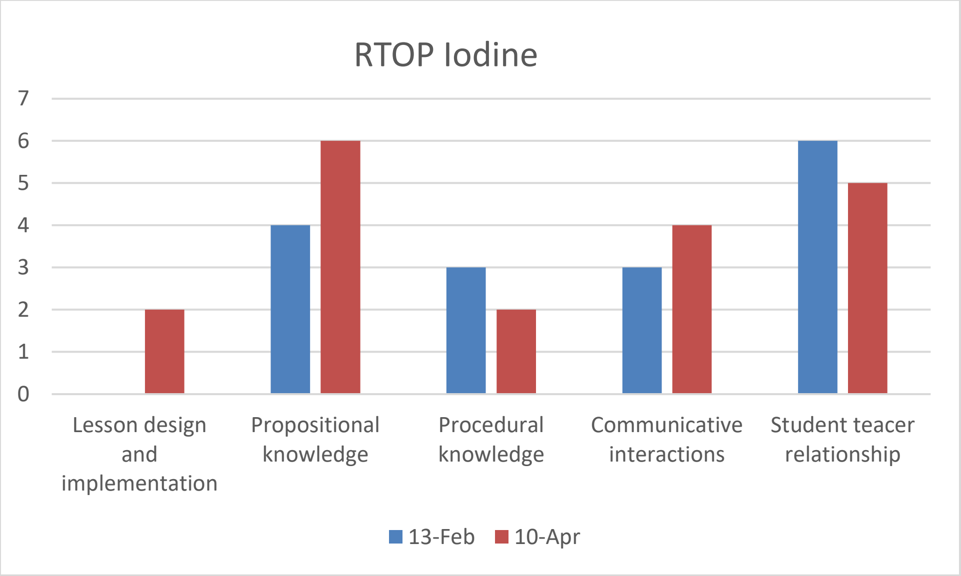


Figure 50. Initial and Final RTOP scores for Iodine

He continued talking about gases and used the example of smelling perfume to explain the diffusion of molecules. He went on to explain how heating can "speed up a reaction" (Frick, notes, Feb. 13). He discussed phase change by saying:

> You are applying heat, which applies energy. You need more and more energy to change the state. As it gets hotter and hotter, it will change to a liquid, overcoming the bonds that hold the solid together. Continue to the next phase

> change; you need more energy, add more heat, until it starts becoming a gas (Frick, notes, Feb. 13)

As Iodine stood at the front of the class, he paged through the binder and appeared to read before continuing with the instructions. He told the students that they would have to make observations both when hot and after cooling the sample for 15 minutes. He also told the students they would need to determine the melting point of an unknown, explaining that it would be one of three different compounds. Iodine showed students how to load the capillary tube and explained that to determine the melting point the students would have to "use the thermometer with the stopper and wait for the powder to turn from white to clear" (Frick, notes, Feb. 13). The final experiment of the day required students to place four drops of potassium permanganate into hot and cold water to observe the differences in rates of diffusion. Iodine explained all the processes necessary to complete the lab report within the first 15 minutes of class.

When a student asked about goggles, Iodine replied, "you will not need goggles for this week; however, you must have them next week" (Frick, notes, Feb. 13). Iodine then came and talked to me about the fact that students did not have to have goggles for this lab; even though they were heating water and using chemicals, he expressed concern for their safety. Iodine moved from the front of the room to "walking around assisting students" (Reid, RTOP, Feb. 13) as the class progressed. Reid noted that Iodine "had not asked any questions as he wrote the waste procedures on the whiteboard. There has been very little student talk so far and only within pairs" (Reid, RTOP, Feb. 13).

Thirty minutes into class, Iodine continued to walk amongst the students listening to their discussion. Some students were still reading, but most were setting up their experiment. They attached a balloon to the side arm of an Erlenmeyer flask with water inside. As the flask was heated the balloon expanded. While Iodine was walking, “he went to assist and explain when a group struggled with the set-up. The GTA set up the experiment for them” (Reid, RTOP, Feb. 13). By the forty-five-minute mark, most students were moving forward to determine the melting points. Most questions directed to the GTA were ones of validation where the student asked, “am I doing this right?” (Frick, notes, Feb. 13). By the time the first hour passed, students turned in their reports as Iodine reminded “bring your goggles next week” (Frick, notes, Feb. 13). One group continued to work after all the other departed, Iodine worked to help them complete their report by filling their capillary tube and explaining the way to determine melting point.

Our second observation was of the last lab of the semester for Iodine’s class. He started by reminding students that their make-up lab was due, before continuing the explanation of the geology experiment. He explained that students would work in pairs to identify differences between rocks, minerals, and fossils. The data students would need to collect included color, luster, hardness, magnetism, specific gravity, and streak. Iodine explained that with streak tests the students would have to provide the color of the streak. He described how to determine specific gravity, by seeing if the object would float or sink in water. In total, he spent five minutes explaining the procedures before walking around handing out a kit to each pair of students. He told students to start with minerals.

Students had a grid of minerals; they had to test their samples and correctly place each one on the grid. Iodine let them know they would have their grade before leaving the lab.

Students worked in pairs quietly discussing among themselves. Iodine sat at the front of the class until a couple of students would have him come and check their answers. He explained to several students how to identify luster, hardness, and streak. Iodine appeared to be pacing, as he walked around the room with his arms crossed. The first group completed their assignment about fifteen minutes after Iodine handed out the kits. As he checked their work, he looked at each item and marked those that were incorrect. Iodine told the students after he completed the grading, “you may go” (Frick, RTOP, Apr. 10). He reminded students to “make sure both names are on the sheet you turn in to me” (Frick, RTOP, Apr. 10). After the first pair of students left the room the energy level of the other students increased; they asked more questions and talked more amongst themselves. If students asked a question Iodine provided an answer. When students asked questions such as: “What is hardness?” or “what is streak?” Iodine provided definitions of hardness and streak. He also answered questions that did not have straight forward answers:

Student: “Are these two the same? They are both shiny?”

Iodine: Picks up the samples and says, “I would say this one is different.”

Student: “What is the point of this?”

Iodine: “To gain more knowledge and be able to identify minerals.” (Reid, RTOP, Apr. 10)

In general, as the students left the class, they seemed happy to have the laboratory completed as they discussed their courses for the next semester.

Workshop participation. Iodine introduced himself in the first class and explained that he had worked with Dr. Neon as a graduate teaching assistant (GTA) the previous year. He attended four of the six workshops. He was not in attendance for the second workshop; however, Iodine did stop in to see Dr. Neon and get a copy of the book. Although Iodine was in attendance for the third workshop, he did not report his results for the Clifton Strengths Finder Assessments (CSFA). Iodine was present for the fourth workshop in which we worked in a small group together. He did not attend the fifth workshop, but he was able to provide his responses to Dr. Neon’s final questions. He also shared some of his opinions about the workshop during our interview.

In the fourth workshop, after working through our misconceptions on some of the chemistry topics and discussing how to alleviate misunderstandings, Iodine was asked to respond to the following question:

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? Discuss your answer and contrast your ideas to what Bodner said. Explain how using your knowledge of potential student

> misconceptions can help you better connect ideas in chemistry, so your students' understanding has minimal misconceptions. (Frick, notes, Mar. 13)

His response was:

> General chemistry covers such a large field; it is hard to remember a little bit about a lot. Usually, by this time, the graduate student is good or proficient in their field of study and have to reteach themselves about other fields. (Iodine, Mar. 13)

Although Iodine answered the initial question asked, he did not explain how knowing about potential misconceptions would be beneficial for teaching. Earlier in the day Iodine and I had been in a group together, we were both teaching a lab for Dr. Argon. While in groups discussing the exits students took in our labs:

> GTAs tended to focus on what was wrong with student learning…I attempted to refocus the discussion on the positive interactions with students. Only one of the others in my group had any ideas on how to potentially engage students. Iodine's idea was to be at the whiteboard and allow students to provide information for him to work the problem. (Frick, notes, Mar. 13)

Iodine reflected on the workshops twice, once in class and again during our discussion at the conclusion of the final interview. At the end of class reflection:

- What did you think was useful?

I found the diagram of student learning (unchanged beliefs, new beliefs, etc.) was useful for understanding the students.

- What would help you become a more effective GTA?

  If I would do the experiment first, that would make me a better GTA.

- What is one thing that you plan to try to improve your teaching?

  I'm going to attempt to perform the experiment beforehand.

- What do you think is your best quality as a teacher?

  My best quality as a teacher is English being my first language (Iodine, Apr. 10)

In the interview, I asked him what he thought was beneficial about the workshop. Iodine replied:

> A lot of it was interesting, and it kind of helped me understand how the students actually thought. I think the biggest thing that I actually took away from it was when she was doing roses around the petal or petals around the rose game. Where, she was just saying the same thing, and that actually kind of opened up my eyes to seeing how, well, you can't just repeat yourself. You have to break it down. So, they understand how it actually works. I thought that was the most, to me that stuck out the most. (Iodine, TBI, Apr. 14)

I found it interesting that Iodine could sight, in detail, lessons from the workshop he appreciated. When I asked Iodine if he had any feedback for the department that could benefit GTAs he replied:

> I mean the workshop was good. I didn't feel like I really needed to go to it as much; just because I had been doing these labs for a while, but again, some of it was kind of interesting. But for new people I do agree it was, I bet it was beneficial, I haven't talked to anyone else because again, it did open up my eyes to some part of it. But yeah, it's, I tried to go to them as much as I could. But, a lot of the times I felt like I was kind of twiddling my thumbs, a little bit. (Iodine, TBI, Apr. 14)

Although Iodine thought completing the labs ahead of time would help his students, he felt the workshop was redundant because he had taught before.

Beliefs Interview. Iodine completed one interview. Iodine held beliefs that were teacher-centered. Most of Iodine's statements were traditional as shown in Table 11. The teacher-centered beliefs Iodine held were consistent with him being the authority in the laboratory. He believed his role was to "make sure they don't kill themselves" (Iodine, TBI, Apr. 17). I asked:

> Anything else?
>
> Iodine: To give them a brief overview, I figure most the time's labs are supposed to sink up to lecture. So, they're going to have a rough understanding. I feel the labs are just to kind of get a visual representation of it. So, I usually assume that they

> have a rough knowledge of it, but they're still going to struggle with it. And, I am just there to help make sure again they don't hurt themselves, or anything like that, while they are performing the experiment. (TBI, Apr. 17)

Table 11. Final Teacher Beliefs Profile for Iodine, April 14, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional	Responsive
1 – maximize student learning	*	**		
2 – your role	***	*		
3- students understand	*	*	**	
4 – decide to teach	***		*	
5 – new activity	**			
6 – learn science best	***		*	
7- learning occurred		*	*	*
8- other comments		*		

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI is briefly summarized in the first column. An * represents a GTA response, either a sentence or phrase, indicating their teacher beliefs. GTA's beliefs were teacher-centered when most responses were categorized as traditional and instructive, or student-centered when the majority were responsive and reformed.

He was confident in the belief that he had to supply the information for students. "I will a lot of times go to the whiteboard and start displaying things out so they can see it in person, themselves" (Iodine, TBI, Apr. 14). He expressed his frustration with students coming to lab unprepared, when I asked about moving onto a new activity.

> I try to inform them of times; they can do that. I don't ever see them really doing it, because they are just following the lab procedure to the tee. I especially notice it with teaching general chemistry 2, so I notice it with those guys. They don't read the lab ahead, and they just do it as they are going on. And they could really save time if they actually could start another part of the experiment at the same time. (Iodine, TBI, Apr. 14)

In the observations we noted when students had fallen behind Iodine completed some of the set-up for them. He controlled the pacing and as far as deciding what to teach:

> I mainly go by like the briefing notes on things they need to be brushed up on. I usually don't figure out what they need to know until they're about halfway through the experiment. That's when I'll go to the board and start writing stuff up there as well. I mean there are things that I feel are pretty common practice in the actual lab, things that we do a lot, that I kind of show them. (Iodine, TBI, Apr. 14)

When I asked how his students learned science best, he replied. “Right now, it just feels like all they are doing is memorizing. They memorize the formula. So, they know how to input the numbers to get to the answer they need” (Iodine, Apr. 14). He provided a safe environment and all the information his students would need to finish their experiment. He did not have authority to change the way his students currently learned science.

Iodine occasionally demonstrated beliefs that were transitional, as he started to think about student understanding. He knew understanding occurred when, “people actually start asking questions that seem reasonable towards the problem" (Iodine, TBI, Apr. 14). He also found value in listening to his students when deciding what to teach, "once I get two or three people asking me the exact same question is when I, kind of stop everybody and, show them on the board" (Iodine, TBI, Apr. 14). In this way, Iodine used his student's perspective as a guide for his traditional teaching method. He thought that it was not until upper-level classes that student understanding could occur. "It's just when you start having that light bulb moment when you are really kind of like, oh, that's why it actually works this way" (Iodine, TBI, Apr. 14). Interestingly, when he described student understanding, Iodine said:

> I will do an example, and they essentially give me the same answer, as the example. So, I don't really see it so much, but there are just a few students. While, I watch their progress, and I'll actually see that, oh, they're starting to get it. (Iodine, TBI, Apr. 14)

Iodine had one student-centered belief; he could tell when students understood if "they start teaching people around them" (Iodine, TBI, Apr. 14).

Fluorine

Fluorine introduced himself in the first workshop and said jokingly, "my son is the youngest freshman at the university. He is four" (Frick, notes, Jan.23). Fluorine attended each of the six workshops and completed his teacher beliefs interview (TBI) during finals week, May 5, 2017. He had teaching experience before starting as a master’s student in physical chemistry at our university in 2012. Fluorine completed a bachelor’s and master’s degree before being a college lecturer in Nepal for five years. Fluorine described teaching in his country:

> The syllabus is already fixed. So, they have already prepared it. So, we are not allowed to change it, because when the students are asked questions on the exam, they will ask from that curriculum. So, what we do is, we prepare our own notes. That's a convenience of mine. So, just like preparing the notes before you go to the class, but yeah, not allowed to design the course or whatever. I cannot look at a book, teacher especially. Students don't like, because they think like, this teacher doesn't know anything. *laughter* So, you have to have everything to remind them. Just like you have chalk and board, that's what, yeah. It is very hard; it used to be very hard when you first time you enter into the classroom, like that feeling. (Fluorine, TBI, May 5)

Fluorine worked as a graduate teaching assistant (GTA) at two universities in the United States of America. He completed his master’s in 2013, at our university and joined a Ph.D. program at a university in the southwestern United States, before returning to our university in the Fall semester of 2016. Fluorine was pursuing a Ph. D in the Computational Science program at the time of the study. In Fall 2016, Fluorine taught two laboratory classes for Dr. Krypton, both were consumer chemistry, and one physical science laboratory for Dr. Argon. Fluorine had an average teaching evaluation of 3.7/5.0 for Fall 2016. In Spring 2017, he continued to teach one section of consumer chemistry and taught one section of general chemistry two for Dr. Helium. We observed Fluorine teaching general chemistry two on February 17, 2017, and again on April 17. 2017. Fluorine's teaching evaluation score for Spring 2017 in his general chemistry two laboratory was 4.5/5.0.

Classroom observations. In both observations, Fluorine worked with his students during his laboratory classes, and it was apparent the students believed him to be the authority in the room. The initial observation on February 17, 2017, included topics related to solubility, while the second observation took place three months later on April 17, 2017 dealt with electrochemistry. He did not tell students the answer he wanted them to write, in either observation; instead, Fluorine asked the students for their ideas about the chemistry concepts at the beginning of class. He expected students to use evidence from their experiment to answer the questions during the laboratory class. Fluorine exhibited behaviors during the second observation that increased his scores in many areas of the reformed teaching observational protocol (RTOP), the most prominent changes were in the area of lesson design and implementation, as well as prepositional content knowledge, Figure 51.

As Fluorine began his lesson on solubility, he first let the student know, "this experiment is long, not hard, but a lot of work" (Reid, RTOP, Feb. 17). The official title of the laboratory was written on the whiteboard, "solubility of ionic solids and gases in water – NaCl, $PbCl_2$, and CO_2" (Frick, RTOP, Feb. 17). Fluorine started with several questions:

> What's a solid? What is solubility? How would you define solubility? What do you understand about solute? What about the maximum amount of solute in the solvent? Why are we doing this experiment at different temperatures? So, does temperature impact solubility? What about concentration? (Reid, RTOP, Feb. 17)

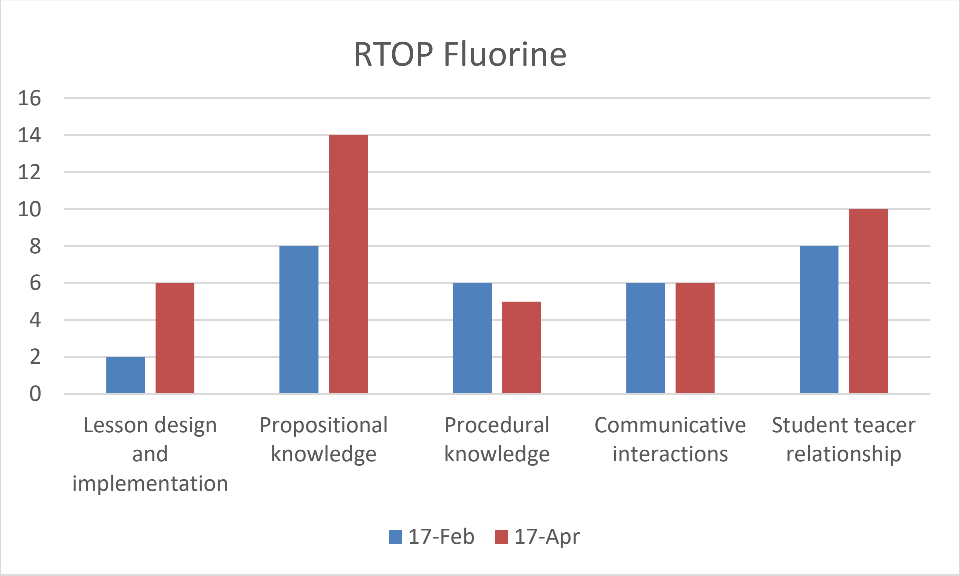


Figure 51. Fluorine's Initial and Final RTOP scores

Although the students replied with nods to the last couple questions, Fluorine told them, "you need to figure it out. If you have any questions, I am always here" (Frick, RTOP, Feb. 17). Fluorine finished his briefing, within fifteen minutes of the class starting, which included safety and waste disposal, and an introduction to the experiment.

Fluorine walked around the class while he assigned groups different temperatures for taking the measurements for the solubility of sodium chloride or lead chloride. At this point, most students worked independently, setting up hot baths and finding the appropriate chemicals they would need. Fluorine reminded them, "you are not provided lead chloride. You have to make your own" (Frick, RTOP, Feb. 17). As Fluorine walked around the room, a student called out his initials, a nickname, to get his attention.

> Student: Sodium chloride is supposed to dissolve, why do I need a strainer. Theoretically, it will all dissolve.
>
> Fluorine: You can only dissolve a certain amount.
>
> Student: I am pretty sure two grams is going to dissolve.
>
> Fluorine: We will see. You have got to be able to change your mind with evidence. I am man enough to admit when I am wrong. (Frick, RTOP, Feb. 17)

About an hour into the lab, the students begin to use the centrifuge, and Fluorine takes a moment to show students how to load and run the equipment. The students were starting to notice the time and decided collaboration was their best course of action. "We will move forward more quickly if we are both completing tasks" (Frick, RTOP, Feb. 17), a student said to her partner.

Within the next hour, the grid Fluorine had placed on the board for the solubility of sodium chloride was complete. Fluorine asked the students to look at the data and think about which would be expected to be more soluble, lead chloride or sodium chloride. As the students looked at the data, one noticed their data and asked Fluorine: "Do you know why our data is so much different?" (Frick, RTOP, Feb. 17). Fluorine encouraged the group to examine their calculations. He took the opportunity to introduce the idea of an outlying data points and told the students they could remove the outliers from their graphs. After some discussion about the difference between solvent and solute, he encouraged students to continue working.

Students moved on to the last part of the three-part experiment, the solubility of carbon dioxide. Fluorine helped by working with the students to write the equation for the reaction of carbonic acid on the whiteboard. With twenty minutes left in the class, students were working collaboratively to find answers. They were still confused about the questions asked in the lab report and Fluorine worked with students at each bench. The final numbers for the solubility of lead chloride were placed on the whiteboard, with only five minutes left before the end of class, and the students felt pressured to finish their calculations. Fluorine addressed the entire class, "some students are still collecting data for carbon dioxide solubility, finish your data collection and turn in the report next week. Use the good data when you plot the graphs" (Frick, RTOP, Feb. 17). Fluorine allowed student feedback to dictate when the assignment was due, showing patience and an understanding of student perspective.

Fluorine continued to accept feedback from his students during the second observation, as he discussed electrochemistry. "The GTA used the real-world example of batteries to explain the electrochemical cell. He continued to explain the oxidation-reduction process using Bohr's model of an atom" (Reid, RTOP, Apr. 14). As he wrote on the board, he described the process that created a current in batteries. He explained that the chemical reactions and electron flow produced the energy needed to run our phones. He used examples of sodium and chlorine to gauge student understanding of electrons. Fluorine asked students how to arrange the electrons around the atoms. He encouraged the students to provide answers by rephrasing the questions. "It's a halogen, how many electrons?" (Frick, RTOP, Apr. 14) The students entered the conversation by answering questions.

Fluorine continued to explain the idea of electrochemical cells. He told the students that the flow of electrons carried a charge, which cannot be seen and must be measured with a voltmeter. He wrote the chemical equation for the reaction of copper in a solution of copper sulfate. Fluorine asked the students if there would be a flow of electrons. The students did not think so because the example was of just one electrode. He continued asking questions, about what would happen if we changed the concentration. "Does it matter?" (Frick, RTOP, Apr. 14) Although several students immediately replied, yes, Fluorine said, "I do not want an answer right now. Let me know what after thinking about it and walking through what it looks like" (Frick, RTOP, Apr. 14).

After talking about each section of the cell, Fluorine asked what would happen if we supplied a current to the cell. He discussed the process of electroplating using real-world examples of cars and jewelry. “GTA used images from the internet on the projector, as well as the whiteboard to explain the concepts using drawings, equations, and writing” (Reid, RTOP, Apr. 14). Fluorine asked the students to put on their goggles and begin the experiment just over ten minutes from when the class started.

As the experiment continued Fluorine demonstrated his prepositional knowledge by connecting the symbolic representation of chemicals in the written equation to the particulate understanding of electron flow. He worked to assist students in the knowledge of concepts fundamental to interpreting the meaning of the readings on their voltmeters.

> GTA walked around the class and spoke with students as he passed. He addressed the entire class, “be sure to clean your test tubes.” The students at the bench nearest me talked about the experiment and the metals present in the cell. As the GTA walked by, the student asked, “do you think it bonded?” He pointed to the metal. “This is copper. What do you write?” The student replied, “atoms to ions.” The GTA walked toward another group. (Frick, RTOP, Apr.14)

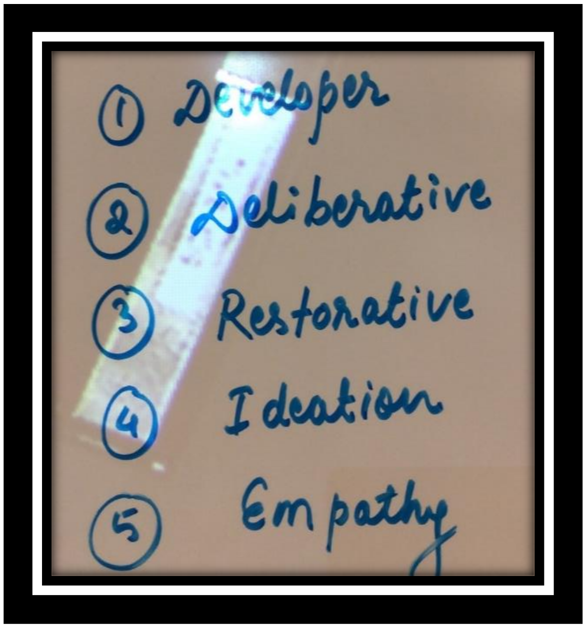
He helped students individually or in pairs for almost thirty minutes before he brought the class back together.

> Based on student questions and comments, the GTA went to the whiteboard and discussed various chemical equations, spectator ions, and net ionic equations. Then he went further and explained using the image that was projected on the screen. (Reid, RTOP, Apr. 14)

Fluorine allowed the students to dictate the pacing of the experiments; he encouraged students to think about which combination of concentrations would produce the highest voltage. Students exhibited ease in answering his questions and in asking him questions, even if that meant shouting his initials from the other side of the lab

Fluorine encouraged students to struggle with the data to gain an understanding of the process. He worked with one group for about ten minutes, helping them set up the experiment and collect readings. Just before Fluorine walked away from the bench, the student Fluorine talked with the most had excitedly high-fived him, apparently happy to have clarity on his experiment. Fluorine continued to guide his student through the last moments of class. When the first group approached with their completed lab reports, Fluorine asked them about the previous question. He listened as they explained that it had asked about the anode and the cathode. With ten minutes left and most groups wrapping up a student asked Fluorine for an answer. He told her, "I am not going to give the answer, but lead you to the answer" (Reid, RTOP, Apr. 14). After waiting another five minutes, Fluorine encouraged her to "'just relax and think about what happened.' She did and explained each step to Fluorine. When she finished the GTA simply said 'so' and smiled. She exclaimed, 'oh it's opposite'" (Frick, RTOP, Apr. 14).

Workshop. Fluorine attended all six workshops. He completed the two in-class reflections and the Clifton Strengths Finders Assessment (CSFA). Fluorine reported the results, shown in Figure 52, during the third workshop.



① Developer
② Deliberative
③ Restorative
④ Ideation
⑤ Empathy

Figure 52. Fluorine’s top five talent themes (Fluorine, Feb. 20).

When I asked Fluorine about the results during our interview, he apologized for not reading the book. Fluorine recalled:

> I took the assessment. I don't remember like, what were those points, but I took the assessment. And, yes, those points were likely. I believe that yeah. I went through. I am like what does each word like they give you signature and what does that mean. (Fluorine, TBI, May 5)

Fluorine thought the results from his CSFA likely described his actions and though the points were valid. He was not able to recall the strengths he reported or the meaning behind the talent themes.

In the fourth workshop, Fluorine was asked:

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? Discuss your answer and contrast your ideas to what Bodner said. Explain how using your knowledge of potential student misconceptions can help you better connect ideas in chemistry, so your students' understanding has minimal misconceptions. (Frick, notes, Mar. 13)

Fluorine answered, "they generally skip understanding the basic chemistry and engage themselves with advanced knowledge in their field of interest" (Fluorine, Mar. 13). Fluorine addressed the initial question; however, did not offer any ideas on how to reduce student misconceptions. After attending each workshop Fluorine offered the following reflection:

- What did you think was useful?

  The class encouraged us to figure out many hidden problems and misconceptions related to the teaching. It encouraged us to think from the student perspective as well.

- What would help you become a more effective GTA?

  More compassion and the ability to convey the chemical problem in such a way that even the layman can understand.

- What is one thing that you plan to try to improve your teaching?

> Try to prepare myself more in terms of making the experimental concept easy to students.

- What do you think is your best quality as a teacher?

> I speak slowly and try to provide them with the big picture of the problem, which will help them understand what they are doing. (Fluorine, Apr. 10)

I asked Fluorine during our interview what he thought about the workshops with Dr. Neon. He replied:

> Nice, something is like the misconception and the test… That was really interesting, and that really strike me. The thing is like, I know, it looks like really easy question, simple question **laughter**, right? And, it happens to the student as well. And, the same thing I observed next day; next lab, when I was in the, probably you notice that you were there for that, in my class, when I was doing … the solubility class. They (Fluorine's students) have a concept like, if you have a certain variety it can dissolve, almost everything, right. And that's what he was saying - I get this really less amount, and I said, "What do you think?" And he said, "it should dissolve." That's what the concept is, even, I think. So, there are a lot of misconceptions, about the very basic phenomenon. So, see that was a really nice, sincerely. That was a very good part like I learned I need to think about misconceptions. And it is very important like if you can help a student to come up

> with a good, I mean like correcting a misconception, even one misconception - that is really a lot. (Fluorine, TBI, May 5)

Fluorine was correct; I did note the interaction in my observation. He was already adapting his teaching practices, after the information from the first workshop. One of Fluorine's students had asked him a question, prior to completing the solubility experiments. The student believed all the solid salt would dissolve. Fluorine asked the student, why he thought the solid would dissolve, he said it was because he was adding such as small amount to the water. Fluorine encouraged him to complete the experiment and find out. Fluorine and his student constructed their understanding of how much salt would dissolve, by measuring the amount added and together determined that the solution became saturated faster than they originally expected. Fluorine thought the workshop had helped his instructional practices. His higher scores on the RTOP and student evaluations after the professional development indicated that the changes had impacted his identity as a GTA.

Before concluding the interview, I asked Fluorine if he had any further thoughts related to the workshops or if he would want to attend workshops in the following semesters. He thought the workshops were particularly important for new GTAs and recalled his experience from another university.

> So, during the fall they have a one week, it is like five days. So, you have a gen chem one and gen chem two. So, gen chem two you have like five GTAs or like seven eight GTAs, here, ten GTAs, that were divided in the two different classes,

> and they will do all the experiments. They do themselves, and that was really helpful. And then, you don't need to go and ask anybody, and they will not be confused during the experiment…At least we can do with some introduction session… I want to say, if it is possible sometime like, the coordinator of gen chem one, gen chem two and also the consumer chemistry, they can tell the GTA; not like giving them just two hours briefing maybe, at least for the first time, like, otherwise, after that they know, it is the same thing, repeating and repeating so, but at least for the new GTA. It'll be good. (Fluorine, TBI, May 5)

Beliefs Interview. The actions Fluorine took in teaching his labs were aligned with the beliefs he held about teaching and learning. Fluorine and I discussed his educational experiences and beliefs about teaching and learning at the conclusion of the semester of Spring 2017. Fluorine was my last participant to interview and we had the longest conversation. The interview indicated that Fluorine had a broad range of teaching beliefs, as shown in Table 12.

The majority of Fluorine’s statements indicated that he had transitional beliefs. He appeared to be developing a deeper understanding of his potential in the role of being a teacher. The focus of his statements indicated that Fluorine adapted his conceptions based on the information provided to him during the workshops. Fluorine’s responses showed his move toward a student-centered belief profile. In responding to the very first question on how to maximize student learning he traveled quickly through the teacher-centered concepts toward student-centered ideas.

He explained, “I try to give them a very basic thing, and then relate it to the experiment directly. Not going all around the like theory part, like okay, you need these things” (Fluorine, TBI, May 5).

Table 12. Final Teacher Beliefs Profile for Fluorine, May 5, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional	Responsive	Reform-based
1 – maximize student learning	*	*	*****	*****	
2 – your role		**	*		
3- students understand			***	*	
4 – decide to teach	**	***			
5 – new activity	*		***		
6 – learn science best		*	*		*
7- learning occurred		*	**	**	

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI is briefly summarized in the first column. An * represents a GTA response, either a sentence or phrase, indicating their teacher beliefs. GTA’s beliefs were teacher-centered when most responses were categorized as traditional and instructive or student-centered when the majority were responsive and reformed.

Fluorine transitioned by explaining what he wanted from his students:

> At least you should come up with some clue. I don't, I mean, I don't want you to have a right clue, you can come up with a wrong clue as well, but at least come up with something, and then I will talk to you. (Fluorine, TBI. May 5)

Fluorine demonstrated the student-centered nature of his beliefs about maximizing student learning in the lab once they started working on the experiment:

> They start finding the answers themselves, but what they now start doing is, if I ask them: “Why do you think so?”, and they say because I think like this. So, at least they start coming up with something. Something, even if that is wrong. And then they say something, then I say something, and I can ask them still from that part. “So, remember, or like imagine, if this is like this, what you are saying, then what about this?” So that will, yeah, that will help them too. And then finally, when they get answers, some of the student really happy. Like: “Did you get it? No?”, and then: “Okay, go on, think about it, think about it.” And then, they start like jumping: “Yes, yes.” Yeah, it is like that. (Fluorine, TBI, May 5)

Fluorine’s beliefs related to his role in the laboratory, deciding what to teach, and how to move to a new topic, were teacher-centered or transitional.

Fluorine described his role as:

> A moderator, like you, I mean you are a bridge in between the confusion and the, they have a confusion, and they have a textbook, but sometimes they get like, they cannot connect. So, I can help them to connect with the idea, yeah. And give them the right way, so that they can, okay yeah, this is the right way to think about these things. (Fluorine, TBI, May 5)

Although he started with transitional thoughts of being a moderator, Fluorine moved to the teacher-centered statements about knowledge transfer. His thoughts about deciding what to teach also demonstrated a teacher-centered belief system.

> First thing is, I will go over the briefing notes that the coordinator has already prepared. So, that's the best point to start with, because those points are probably

> based on their experience; and then so, those are the very important things and so I will never skip those parts. And then now, I will think that how to make those points or those concepts more simpler and simpler, so that they can learn. That's so; I would just like make some briefing of the briefing notes. Like so what is this, what is this, and where are they coming, and what is the today's experiment purpose, and how we connect these things. You need to know these terms. (Fluorine, TBI, May 5)

In preparing for teaching, Fluorine focused on information the students would need to have provided for them based on the information from the laboratory coordinators.

Alternatively, when Fluorine was asked about how science was best learned, he demonstrated transitional beliefs, before indicating that he had developed a student-centered understanding of learning science best. The transitional statement focused on student feelings:

> So, the best thing they can learn about science is the motivation. If you do not have that, they are not going to enjoy, because you have a lot of things to deal with, like electrons. You have to first remember the elements name, a lot of elements. What is this? Sodium. What is this? Potassium. What is it in the block? So that's the motivation. (Fluorine, TBI, May 5)

Florine asked about how the education system worked in the United States of America, trying to get an understanding of the background of his students. After I explained the science requirements of the state, he described his student-centered beliefs:

> Those who know, those who have already taken the science from the very beginning, so probably they're smart, like a lot, and those who are not, then they don't like science. Because you see like, there are [*sic*] a lot of gaps. You come into the undergrad, like first year, like gen chem, it's like, it starts with the mole concept, right? And that's not an easy concept. **laughter** Right? It's not an easy concept. So, if somebody has taken like a few courses in high school, then it is a lot of gap in between, and that is why they think like, no, I cannot do it. This is, I just want to pass it and leave it. I will take another major or something like that. That also, when especially it used to happen in my country also, like for - after the high school there was a big gap. Like you only deal with simple algebra up to class ten and then you just directly goes to the like here, calculus two or something like that, not even a one, it is like a two. Everything pushed together, yeah. So, science you, during the high school, you learn about how to prepare. I mean like synthesize simple compounds, very simple compounds, like Urea and all those things, and lab prepares enough oxygen, carbon dioxide. The very basic things, but now when you go to the intermediate, first year, you cannot like even finish reading your book throughout the year. It is a way big syllabus, and you just get lost. (Fluorine, TBI, May 5)

Fluorine indicated that he understood his students' perspective, acknowledging the ability to comprehend material relied on their feelings toward the content and the previous knowledge they have before coming to the class. For students to learn science best

Fluorine believed he needed to understand the perspective of his students before providing an explanation.

Chlorine

Chlorine was in the third year of the Computational Science Ph.D. program in Spring 2017. Chlorine completed his early education in Vietnam where he attended a magnet high-school. He moved to the United States where he completed several classes at a local community college before enrolling at our university in 2010 to complete his bachelor's degree. He began teaching as a graduate teaching assistant (GTA) in chemistry laboratory classes in 2014. In the Fall semester of 2016, Chlorine taught a general chemistry one laboratory course and earned an average of 4.2/5. Chlorine reported to Dr. Helium again in the Spring semester of 2017 and he taught the same course. We observed Chlorine twice, once on February 15, 2017 when he taught students how to synthesize and calculate the percent composition of magnesium oxide. Chlorine introduced students to the gas laws during the final observation on April 17, 2017. Chlorine's student evaluation scores for Spring 2017 were 4.3/5. Chlorine attended four out of the six workshops. He was one of two participants that completed the teacher's beliefs inventory (TBI) twice. He met with me for the first interview on February 16, 2017. We completed the final interview after Chlorine taught on April 17.

Classroom observations. Chlorine taught different topics during each observation – he appeared comfortable with the students and provided step-by-step procedures for each lab in addition to those provided in the lab manual. In the first observation Chlorine provided the information his students needed to correctly complete the experiment and during the second observation Chlorine's promoted a stronger connection between real-world concepts and the fundamental chemistry knowledge. Chlorine scored higher in the reformed-teaching observational protocol (RTOP) categories of propositional knowledge and communicative interactions, Figure 5.16.

Chlorine started his lesson with the title for the experiment written on the whiteboard, "Experiment 6: Synthesis and percent composition of magnesium oxide" (Reid, RTOP, Feb. 15). He stood in the front of the room and apologized for not being in the lab last week. He quickly transitioned into discussing the experiment for the week. Chlorine wrote the chemical reactions on the whiteboard while he explained: "The process to produce a new product – reaction" (Frick, notes, Feb.15). He mapped out the chemical process of magnesium turning to magnesium oxide or magnesium nitride when burned in the air and explained how they would calculate the percent composition.

Chlorine "asked questions and waited from zero to two seconds before continuing with a mini-lecture of how to use the molar mass of water to determine the moles of water" (Reid, RTOP, Feb. 15). Chlorine asked students if they had talked about present composition in lecture. He asked students for the mass of water, what they knew about molar mass, and how many moles of hydrogen compared to oxygen. "The GTA kept his back to the table by the door; they may not be able to see what he is writing" (Reid, RTOP, Feb. 15). As he concluded discussing calculations, Chlorine stated, “very easy right?” (Frick, notes, Feb. 15).

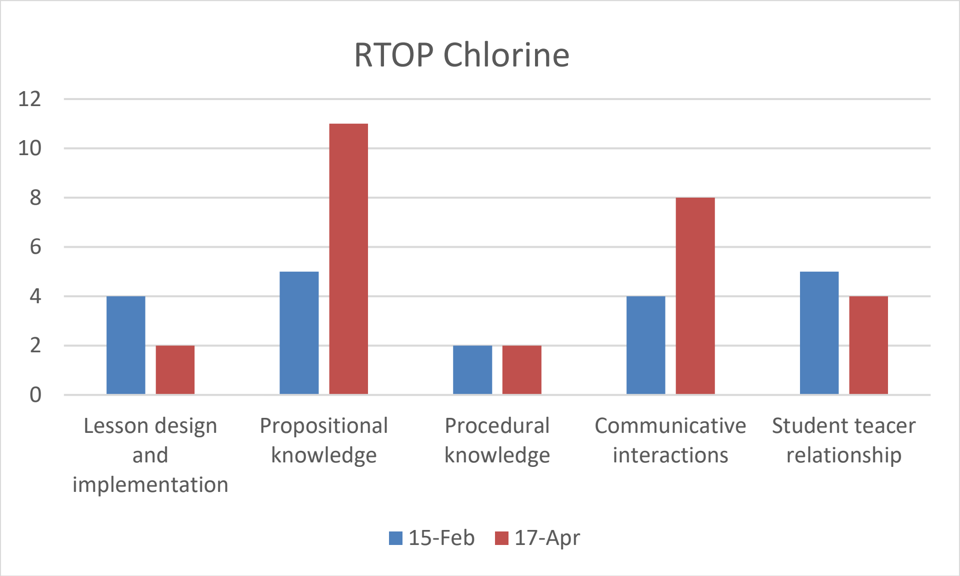


Figure 53. RTOP scores for Chlorine in each category before and after the workshops.

Chlorine next demonstrated how to use the crucible tongs and encouraged the students to practice. He explained that when the magnesium started to glow the students would also need to place the cover on the crucible using the tongs. Chlorine “stopped to answer student questions and used lots of hand gestures” (Reid, RTOP, Feb. 15). He talked students through the next steps of cooling the sample and told them to “put in enough water to cover everything. Replace the cover and heat for another three to five minutes. Is that clear? If you are ready get started” (Frick, notes, Feb. 15).

As the students began to set up their equipment, Chlorine walked around the lab answering questions and helping groups. Chlorine reminded the students to make sure their crucibles were clean and demonstrated an intense flame with the Bunsen burner.

After a group started, Chlorine approached and told them they needed the crucible closer to the flame and showed them how to adjust the fire. He announced to the entire class to check with him before they started heating their samples. Chlorine emphasized that students were misunderstanding why the crucible needed to be clean and heated to a constant mass before starting, “so, follow and read the book” (Frick, notes, Feb. 15). He worked with groups and had students explain what they had done. Chlorine encouraged students to read the next section as they waited for the heating to be complete.

Once the students had their crucibles heated to constant masses, they moved onto the reaction of magnesium to magnesium oxide. Chlorine encouraged students to not worry about the calculations and focus on the experiment as they had two trials to collect. Chlorine leaned comfortably on the bench as he interacted with the students. When a student in the front of the class asked a question, Chlorine used the whiteboard to facilitate his communication. When several groups of students had collected data, Chlorine gathered his students for “another formal presentation on calculating the mass of magnesium oxide” (Reid, RTOP, Feb. 15). With less than an hour left in class, Chlorine told students they did not need to collect two trials because everyone would not have enough time. Chlorine sat at the front while students wrapped up their calculations. He reminded students to use units and explained how to calculate percent yield. Chlorine validated students’ answers when they asked if something was correct. He “promoted a conceptual understanding by saying ‘the idea here is’ and asking questions to help students construct knowledge. ‘Look at this to see an example’” (Reid, RTOP, Feb. 15).

Chlorine referenced the lab manual and showed students where they could find an example.

Chlorine continued to assist students in constructing knowledge during the second lesson we observed on April 12, 2017. The "Experiment 9: Ideal gas law and Boyle's law. What is the gas law talking about? I am sure you have talked about this in lecture. You have covered some of the gas laws" (Reid, RTOP, Apr. 12). Chlorine waited for six seconds before continuing on by answering himself. He talked about the equation for the ideal gas law, PV =nRT, He explained that today the gas they would use was air and reminded them to think about very small particles. Chlorine asked several questions: "What is one mole? What is the molar mass? Avogadro's number?" (Frick, RTOP, Apr. 12). Students did not respond so he told them that the "n" in the equation was the number of moles. With no interaction from the students, Chlorine used the whiteboard to explain the concept of the mole. After that he asked about the T in the equation, a student responded, stating that T was temperature. Chlorine then moved onto asking: "'What is pressure?' After waiting five seconds, he used a balloon to explain the concept of pressure when students could not provide an answer" (Reid, RTOP, Apr. 12). Chlorine defined pressure as "force per unit surface. What is the standard unit? Torr, Pascal" (Frick, RTOP, Apr. 12). Chlorine took the lesson a step further, as he explained that the unit of force was Newton and the unit of the surface was m^2 which he used to describe the standard unit of measuring pressure a Pascal, which is equal to one Newton per squared meter.

After giving his students the definition of pressure, Chlorine encouraged them not to be:

> Freaked out by the equation. In today's experiment, we will be talking about Boyle's law. We are working with the same number of moles and temperature. So, take out n and T, the other is a constant. Now, determine the relationship between PV -inversely proportional. (Frick, RTOP, Apr. 12)

Chlorine went on to describe the Lab Quest and how to collect pressure at different volumes using an attached syringe. He told students, "when attaching, be gentle" (Frick, RTOP, Apr. 12). The careful attention Chlorine gave to connecting detailed explanations to the experiment contributed to the improved score in propositional knowledge seen in Figure 5.16.

As the students collected data for the experiment, the GTA walked around assisting each table. I overheard Chlorine asking students about the number they had for the reading. Once they replied he said, "okay move on, you have to do it, not me" (Frick, RTOP, Apr. 12). Chlorine encouraged the students to take their own readings when they offered him the Lab Quest. For the next twenty minutes, the GTA monitored student progress and reminded them to take careful note of their interpretations. Students were talking among themselves, and there were lots of murmurs between partners as they moved from 5.0 mL of air to 10.0 mL of air and looked at the differences in pressure.

Chlorine walked to each bench and encouraged students to finish the lab report in the next fifteen minutes. He wanted to have time to review the study guide for the final they would take the following week. Chlorine explained the purpose of the lab was to determine the relationship between pressure and volume. He pointed to the whiteboard and illustrated "PV, pressure times volume, should be constant because nRT is the same. Is that clear?" (Frick, RTOP, Apr. 12) Chlorine asked the students questions as he walked away from the front of the room. The students worked quietly on the calculations while Chlorine corrected them. Occasionally, telling them to redo calculations and reminding students to answer the question that was being asked on the report sheet, as he walked around the classroom. Chlorine did not give students the answer rather he had them look at their data to provide evidence. Chlorine "asked 'is that clear?' a lot over the next twenty minutes, as he walked around answering student questions" (Frick, RTOP, Apr. 12). He promoted student interaction by not giving them direct answers allowing them to build concepts with their peers while acting to make corrections when necessary.

He gained the students' attention by asking, "Guys is everything okay? Is it okay if we work the last problem together? It comes straight from Boyle's law" (Frick, RTOP, Apr. 12). Chlorine encouraged the students not to be distracted by the extra information, $P_1V_1=P_2V_2$. "He compared $P_1V_1=P_2V_2$ with $C_1V_1=C_2V_2$ possibly to help students relate knowledge back to things they already know" (Reid, RTOP, Apr. 15). Chlorine knew something neither his students or Reid were aware of, because of his education in physical chemistry (PChem), Chlorine understood a more complex relationship between pressure and concentration. In our initial interview, he explained his feelings "when I took it, I loved PChem" (Chlorine, TBI, Feb. 16). Chlorine reminded students that this is a comparison of before and after, as they continued to work on their lab reports. Chlorine gave the students fifteen more minutes to complete their work before he moved on with the exam review. Several groups of students finished in the next five minutes, less than half the class stayed for the exam review.

Workshops. Chlorine attended the first three workshops. During the third workshop, when Dr. Neon attempted to engage GTAs in the game of petals around the rose, she noted Chlorine had already checked out of trying to find an answer. He attended the second workshop when the books were handed out but did not complete the CSFA. When I asked about CSFA, he said he did not take the test but looked at the results with Cobalt.

> You know that because I don't know how to say this, but if I consider become an instructor in the future, yes, the answer is definitely yes. I just need to finish, and then I go to work, yeah, but I understand my responsibility. Whenever you come here because when you come to the class you teaching; you're in charge, but not only are you in charge, you are doing your responsibility. (Chlorine, TBI, Apr. 17)

Chlorine attended only the last workshop after that, where he completed the following answers to the questions presented by Dr. Neon:

- What did you think was useful?

> The useful thing of these workshops is to provide us the analysis of different situations of being a student or instructor. That helps us to recognize what student or instructor needs.

- What would help you become a more effective GTA?

  Understanding more about students, what they want, what they need, who they are, and finding a better way to instruct them.

- What is one thing that you plan to try to improve your teaching?

  I think I need to improve my communication style and become a more dynamic person.

- What do you think is your best quality as a teacher?
  My best quality as a teacher is my knowledge in chemistry and knowing how to share that knowledge to students in such a way they can understand easily. (Chlorine, Apr. 10)

Chlorine provided further feedback when I asked about the workshops in our final interview:

> For me that was, that's okay because it’s kind of, I don't know, maybe it benefit for you. For me and the other guys, but for me not very much because I am not in the education. But I mean, it's good because I can understand how different instructor and student look like. Yeah, I think it is good though because we need to sit down and talk like that, communicate with the people around here. It's good yes, it's good. (Chlorine, TBI, Apr. 13)

I followed up asking him about the readings and letting him know it was okay to say he had not read. Chlorine said, “I am sorry to say no because sometimes I skip some to go to some meetings too and I forget too. So, sorry to say that” (Chlorine, TBI, Apr. 13). Although Chlorine appeared to understand the context of the workshops, he did not feel as if the workshops helped him to accomplish his goals as a graduate student. Chlorine focused on finishing his research and did not believe the information provided in the readings would improve his ability to complete his goals – unless his goal was to be an educational researcher. Chlorine was motivated to complete his studies and teaching was a responsibility he already understood. He believed that getting together with other GTAs was a benefit the workshops provided.

Belief interviews. Chlorine was one of two participants that met with me to complete the teacher’s belief interview (TBI) twice. Chlorine completed first interview on February 16, 2017, and his final meeting on April 13, 2017. The first interview indicated that Chlorine’s beliefs were mostly teacher-centered instructive, and the second interview showed similar belief patterns with a slight shift toward transitional from instructive. During the second interview, I did not ask questions four and five, leaving an incomplete beliefs profile for comparison.

The belief profile created for Chlorine after the first interview, Table 13, showed the instructive/transitional nature of his beliefs about teaching and learning. Chlorine’s nicely summarized his beliefs when he answered the second question. I asked: “How do you describe your role as a laboratory instructor?” (Frick, TBI, Feb. 16). Chlorine replied:

> You came to see me, right? Normally I try to be their friend and I can. Instructors are someone who should do instruction. So, you just give them the idea give them

> the vision and then go ask them to do whatever you want them to do. (Chlorine, TBI, Feb. 16)

Table 13. Initial Teacher Beliefs Profile for Chlorine, February 16, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional
1 – maximize student learning		**	***
2 – your role	*	**	**
3- students understand		***	**
4 – decide to teach	*	****	**
5 – new activity	***		
6 – learn science best		**	**
7- learning occurred		***	**

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI is briefly summarized in the first column. An * represents a GTA response, either a sentence or phrase, indicating their teacher beliefs. GTA's beliefs were teacher-centered when most responses were categorized as traditional and instructive or student-centered when the majority were responsive and reformed.

Chlorine seemed to have some dissonance between the instructive beliefs, which required students to be monitored, and the need to be their friend. When he explained his goals for teaching Chlorine believed that:

> You rearrange the schedule because every day we work on a different schedule and that's it. I try to be flexible that way how I am doing, yeah. Sometimes I solve for the whole class, or sometimes I just solve for someone's group. (Chlorine, TBI, Feb. 16)

The nature of his belief shifted when he examined the student perspective, even though he knew each week covered different amounts of information Chlorine recognized:

> Student in class they are different, they have different background, different level and sometimes some group just went on for 45mins, and they are finished, and they don't want to stand over there to wait. So, if they have a few questions, you can focus and explain for them. And if not, why let them wait until when everyone ready, and I move on at one time. (Chlorine, TBI, Feb. 16)

Chlorine believed he could tell when learning occurred:

> Very easy because the way they work through that part. Of course, I am keeping my eyes on them, so if they do everything correctly set up this way and follow that way. So, and they talk, they speak, because sometimes I stop them and ask them. So, what's the value, they explain to me, and I know that they are good. So, and that's it. Lucky in class most of them, they did very well. (Chlorine, TBI, Feb. 16)

Chlorine's initial statements were instructive, in that he had to check on students written work. He concluded with transitional remarks revolving around student answers and feelings toward the chemistry.

I completed the second interview after the second observation and subsequent final exam review. Chlorine's answers to the questions during the second TBI created a similar profile, Table 14. When I compared each question, although his answers during the second interview were more concise, Chlorine indicated a transitional belief structure in two areas that had previously been instructive. While the shift would not typically show a changing belief pattern, it seemed that Chlorine related to the student perspective about chemistry through a personal lens. Chlorine talked about how he gained their viewpoint:

> They come here they are thinking about appling for medical school or biochemist or chemistry something like that, and then they just quit at the first semester. So horrible, yeah, I have my own brother. My only brother, when he came here 2011, he choose chemistry as a major, like me; but right now he switched. And, he has already switched to the business department.
>
> Frick: Did he say why?
>
> Yes, of course, I knew; because he got a B in chemistry two. It not really bad but, the way he was, he didn't like chemistry anymore. I understand. (Chlorine, TBI, Apr. 13)

Chlorine observed the frustration students had when learning chemistry. Although he maintained teacher-centered beliefs, Chlorine said, "I don't blame them very much. They are not silly. They are not idiots, but they just don't understand the problem" (Chlorine, TBI, Apr. 13). He believed that for students learning occurred when "I give them you know, a chance to learn. For the lecture what they didn't know, but the idea they took freshman, they need something easy, but we need to understand they are just new" (Chlorine, TBI, Apr. 13). Chlorine believed that students needed basic foundational knowledge and he acknowledges their feelings as being relevant toward learning. Chlorine knew they required time:

> Because when you show them how to do their interpretive formula, but they don't know how to do their summation, their plus and minus and multiplication and divide. So, how can they do it? So, they are not idiots. They just don't know it. (Chlorine, TBI, Apr. 13)

Table 14. Final Teacher Beliefs Profile for Chlorine, April 13, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional
1 – maximize student learning		***	***
2 – your role	*		**
3- students understand	***	****	
6 – learn science best		*	***
7- learning occurred		**	*

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI is briefly summarized in the first column. An * represents a GTA response, either a sentence or phrase, indicating their teacher beliefs. GTA's beliefs were teacher-centered when most responses were categorized as traditional and instructive or student-centered when the majority were responsive and reformed.

Chlorine acknowledges the student perspective from the affective domain multiple times.

I asked Chlorine about his role and asked him to describe the expectations he had for himself when he entered the classroom as an instructor. He said:

> Expectations of myself, yeah, I just want to be the responsible guy, to give all the information to them, like the requirement. And then I can help them feel better in this industry, and yeah, because I was a student. I am still a student right now, but I feel how difficult the student face. (Chlorine, TBI, Apr. 13)

The transitional beliefs Chlorine stated were supported with traditional beliefs about providing information to the students.

> Gen chem two I figured out for me, watching them today, it is a difficult class to teach. The reason is because they require you more, they assume you know something. So, they just move on, but I figure out many times student skip, forget from gen chem one. And, when I said something like I say the sulfuric acid, they don't know how to write the name down, so how can you keep saying? You have to stop, and you have to explain to them how it looks like, and of course, that is not your job. It is something you didn't expect to cover that day, but you have to spend thirty minutes to spend, even more than that. So, you see very frustrating for instructor teaching at a higher level. (Chlorine, TBI, Apr. 13)

As a result of the semester, Chlorine identified areas of frustration for instructors, as well as students, although he did not feel he needed further development as a teacher because he was not studying education. He did have advice for the department about how to train future GTA's, although he had no problems. Chlorine provided feedback:

> Some friends, that for the first year they teach they don't feel we should because sometimes they don't have no, any class to train them. Sometimes, you know, they come from the other schools from here. So, they don't know how the lab looks like. So, and they sometimes, you know during their, we just took even some new advice or something like that. And of course, right now I am okay because I already have some years working. But the first time for them to learn, they don't

> know how to use the device, or they don't know how to use, so how can they teach a class, you know. So, I think they should have some training sessions before they, of course not for me, apply for the new one. You cannot apply to the old one because they don't want to hear the old story, yes. So, you make sure if you have a new instructor, you make sure they know how it looks like; if not, you should train them. Don't make them surprised, and cause sometimes some my friends, they came to ask me how to do this one, and how to run the lab, what is a here, what is that mean, what should we do, what should we do, what should I do, something like that. And I think that should be the thing the coordinator should do something. Everything very nice around here. We have a very nice place right here. (Chlorine, TBI, Apr. 13)

Cobalt

Cobalt started his graduate career at our university in 2007. He began teaching as a GTA at that time. Cobalt completed his master's before moving forward to work in the Computational Science Ph. D program. He was working to complete his dissertation and hoped that this semester of study would be his last. In the Fall semester of 2016 Cobalt taught two laboratory sections of general chemistry one; his teaching evaluation score was 4.1/5.0. In the Spring semester of 2017, Cobalt taught a physical science laboratory class for Dr. Argon and an introduction to general chemistry one laboratory for Dr. Krypton. We observed Cobalt once, while he taught the introduction to general chemistry two laboratory on February 16, 2017. Cobalt attended every workshop except for the last one.

The laboratory classes he taught for the semester ended early and Cobalt returned to India for the summer; therefore, he was not present to complete a final observation or interview. Cobalt had a teaching evaluation score of 4.5/5.0 for the class we observed.

Classroom observation. We observed Cobalt while he taught students how to synthesize alum. The students start the laboratory with a quiz. Cobalt started the lab with the last slide of the provided PowerPoint visible on the screen. The slide told the students which experiment they would be getting ready for the following week. Cobalt seemed at ease in the laboratory, which was reflected in the scores he received in the area of student-teacher relationships. Figure 54 shows the scores Cobalt earned on the Reformed Teaching Observational Protocol (RTOP); propositional knowledge was the second highest score he received.

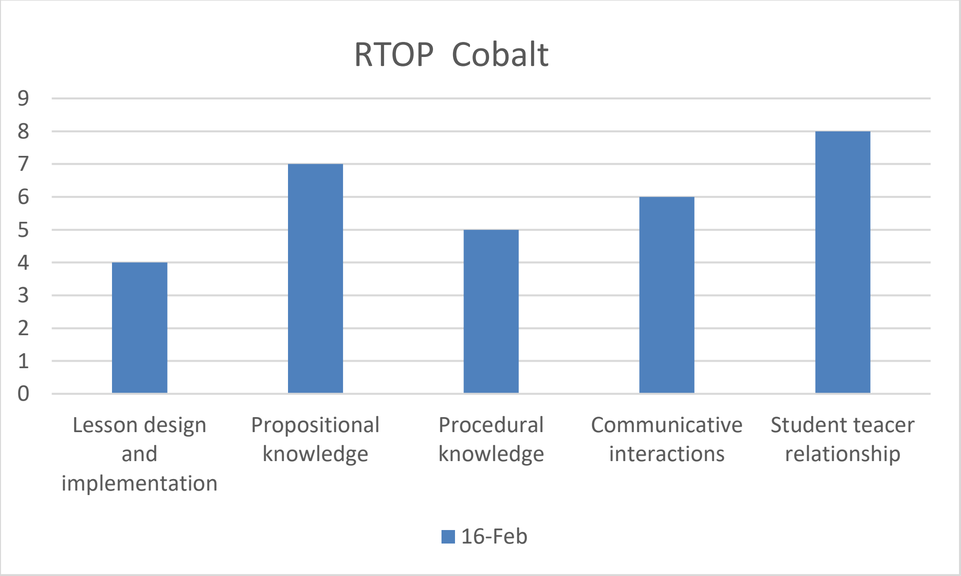


Figure 54. Initial RTOP scores for Cobalt in each category (February 16, 2017).

Cobalt demonstrated both propositional knowledge and procedural knowledge as he started the class by asking students: “Okay, what are we doing today?” (Reid, RTOP, Feb. 16). After five seconds, he flipped back in the slides and asked students how this related to last week’s lab. He took ten minutes to talk the students through safety and demonstrated how to use the vacuum pump. Cobalt “asked a lot of questions and as the lab began, he assisted students through demonstrations, explanations, and questioning” (Reid, RTOP. Feb. 16). When students asked questions about setting up, Cobalt would help them, by explaining how to hook up the hose. As time went by and the lab was approximately halfway through, Cobalt completed the setup for students still having problems.

As the first hour passed, Cobalt continued walking among the students asking them: “Is it working? What happened?” (Frick, RTOP, Feb.16). If he noticed someone, he would call them by name, “Alex, use a stir rod” (Frick, RTOP, Feb. 16). As Cobalt continued to monitor student progress, one pair of students had difficulty answering the questions, based on the evidence they had collected. One student asked, “do you know what our problem is?” Cobalt smiled and said, “yes” (Frick, RTOP, Feb. 16). He explained to the student, who rephrased what he understood to the GTA. After a brief dialogue with the student, Cobalt turned to address the entire class. He let them know they could start working on calculations. The students did not know how to complete the calculations, so Cobalt gave them an example. He asked students “what goes here and are you sure” (Frick, RTOP, Feb.

16), as he continued to work the problem, he had students provide each piece of information he needed.

Cobalt would not just supply an answer to his students. When a student had a question about converting grams to moles, Cobalt replied, “I don’t know, you have to figure it out” (Reid, RTOP, Feb. 16). The students talked amongst themselves about calculations, as Cobalt continued helping students complete the experiment by scrapping beakers. A student said, “I’m confused” (Frick, RTOP, Feb. 16). Cobalt asked to see her calculations he explained, “you’re not doing percent” (Frick, RTOP, Feb. 16). The student seemed to understand and erased what she had as she asked another question. Cobalt started to give her an example and noticed, “oh, your lab partner was here last week, she can help” (Frick, RTOP, Feb. 16). He did not wait for a response as he walked away. After about five minutes he came back, and the lab partner looked confused. He showed her where she had completed the work on last week’s lab report. She said, “oh yeah” (Frick, RTOP, Feb. 16). He let her work with her partner for a few minutes, while other groups were turning in their reports. Before the lab ended, he went back to the student, took her paper, and walked her through the calculations. As the students completed their calculations, Cobalt waited patiently in the front of the room for them to turn in their reports. Cobalt’s high score in student-teacher interactions was due to the work he facilitated between students and the patience he showed in giving them time to reach their understanding.

Workshop participation. Cobalt introduced himself in the workshop as a person that loves teaching. Cobalt said, “I try to teach my students that chemistry is easy. I try to make them comfortable" (Frick, notes, Jan. 23). He attended all the workshops, except the last. He also completed the Clifton Strengths Finders Assessment (CSFA) and reported his talent themes in the third workshop as shown in Figure 55.

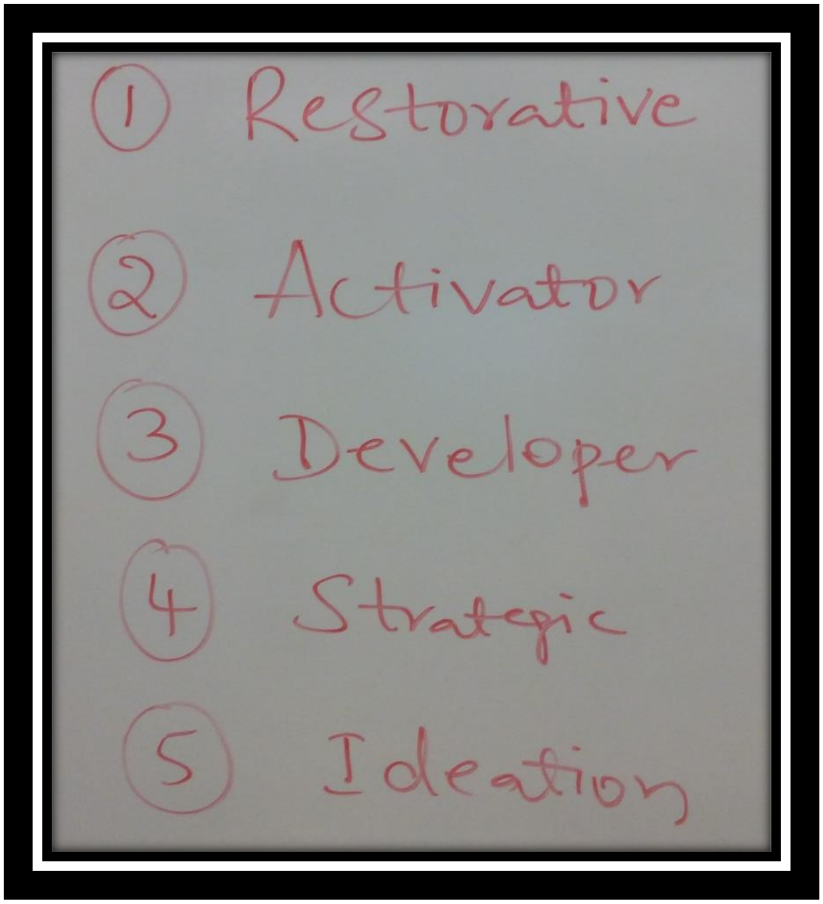
In the fourth workshop, Cobalt was asked to answer the reflection question that involved the CSFA results.

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? (Discuss your answer and contrast your ideas to what Bodner said. Explain how using your individual talents, as defined by the Clifton Strengths Finder Assessment, can help you better connect ideas in chemistry, so your students' understanding has minimal misconceptions.)

Cobalt answered:

> The misconceptions are because of learning the same stuff in different ways. During the process of learning, we connect with our previous ideas. Different books explaining things in different ways is also a problem. (Cobalt, Mar. 13)

Cobalt did not address the explanation portion of the question which asked him how he could use his CSFA to minimize student understanding. Cobalt did have an answer that contributed misconceptions to difficulties in learning the knowledge, similar to how Bodner (1991) explained the potential for GTA misconceptions. Cobalt completed his semester early and left the university; I was not able to obtain his reflections or comments regarding the workshops.



① Restorative
② Activator
③ Developer
④ Strategic
⑤ Ideation

Figure 55. Reported results from Cobalt's CSFA (Cobalt, Feb. 20)

Teaching beliefs. I interviewed Cobalt after the first workshop and the teacher beliefs interview (TBI) profile showed Cobalt had beliefs that were from diverse perspectives of teaching and learning. The majority of responses from Cobalt were coded as transitional beliefs. Even though Cobalt held student-centered beliefs, his overall profile revealed that most of his views were teacher-centered, Table 15. The transitional nature of Cobalt's beliefs were captured well in the way he described his role as a GTA.

Table 15. Initial Teacher Beliefs Profile for Cobalt, February 17, 2017

Question # (Addy &Blanchard, 2010)	Traditional	Instructive	Transitional	Responsive
1 – maximize student learning	**			
2 – your role	*		***	
3- students understand		*	*	*
4 – decide to teach	*	*	**	
5 – new activity			*	
6 – learn science best		*		
7- learning occurred		**		

Note. The questions and method for obtaining the code (*) can be found in Chapter Three. Each Question # from the TBI is briefly summarized in the first column. An * represents a GTA response, either a sentence or phrase, indicating their teacher beliefs. GTA's beliefs were teacher-centered when most responses were categorized as traditional and instructive or student-centered when the majority were responsive and reformed.

After the traditional stress on the importance of safety, Cobalt's felt his role was to:

> Use my strengths to learn. Actually, after coming to lab, they should feel that: "Okay, we understood the concept." Because before coming to the lab, so they like some students, they read the experiment. But they feel like: "Oh no, I didn't get it." But, after you do the experiment, they have to feel that: "Wow, oh yeah, I got it. I understood the concept." So that's what I like to see. (Cobalt, TBI, Feb. 17)

Cobalt wanted to understand the student perspective he wanted to know "what questions they have, and then I try to change my teaching style according to like their questions" (Cobalt, TBI, Feb. 17). He wanted the students to connect each aspect of their experiments. So, when I asked about transitioning from one topic to the next, Cobalt said, "most of the time, I try to correlate. I find a link between those two things and how can we use this information here" (Cobalt, TBI, Feb. 17).

The student-centered nature of Cobalt's beliefs was not noticeable in the traditional response he gave when asked about ways to maximize student learning. The first thing Cobalt mentioned was:

> Sometimes, I see that lecture class and labs are not going at the same time… In that case, I try to explain. I usually ask them, like: "Do you know this stuff?" If they say no, then I try to explain that first. (Cobalt, TBI, Feb.17)

He wanted the students to have fully formed ideas about the experiment before coming to the laboratory class. He placed the responsibility of learning science on the student interpretation of the investigation.

> I feel like, if they know concepts before coming to the lab, most of the students need to read lab; but I don't see a lot of them doing that. Whoever reads the experiment before coming, I saw like they're performing better than the one who is not reading. (Cobalt, TBI, Feb. 17)

He could tell learning was occurring by reading the lab manual because: “They (the students) perform well on the quiz if they did it. And also, when I am talking, like when I am giving the briefing, I try to ask questions and whoever read the experiment, they try to answer” (Cobalt, TBI, Feb.17). Student engagement was as important to Cobalt as getting the correct answer to the question.

Lithium

Lithium started as a graduate student at this university in Fall 2011. She completed her master’s in chemistry in Spring 2016 and was currently working to complete a Ph. D in Mathematics and Science Education. Lithium taught as a learning assistant and worked as a tutor while completing her bachelor’s degree in chemistry at a university in the north midwestern area of the United States. While a GTA, she taught dual enrollment general chemistry one at a local high school and was on a writing fellowship in Fall 2016. Since she was not teaching a laboratory course she received no student evaluation scores for comparison. Lithium taught two courses, physical science for Dr. Argon, and introduction to chemistry two for Dr. Krypton. Reid observed Lithium once on March 1, 2017. Watson rated the observation from a video, and they completed the interrater combined ratings for the reformed teacher observational protocol (RTOP) for the Topics of Physical Science laboratory class. Lithium received 4.3/5 on her student evaluations for the class observed. Lithium attended each of the six workshops and completed each in-class assignment. Lithium did not complete the teacher beliefs interview (TBI).

Classroom observation. The RTOP scores Lithium received while teaching physical science were not able to be compared to a later observation, as the audio from the video was not audible. Lithium's scores are shown in Figure 56.

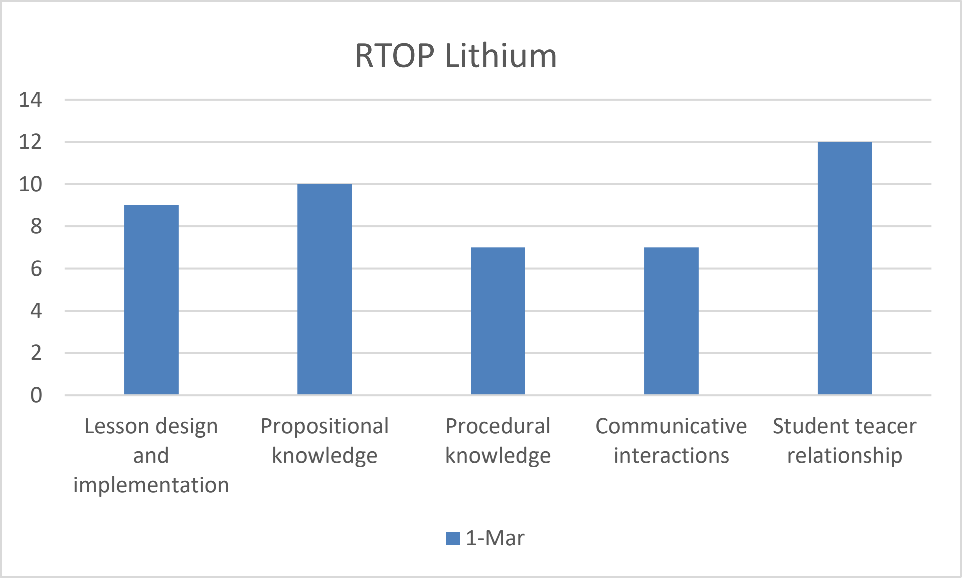


Figure 56. RTOP scores for Lithium at the beginning of the semester.

Lithium earned her highest score in the area of student-teacher relationships, followed by propositional knowledge and lesson design and implementation. Lithium allowed her students to explore their understandings prior to starting the experiment. She also listened to student responses and acted as a resource to her students, while they completed their experiment.

Lithium started her instruction by asking students questions: “Has anyone read the lab? What are we looking at? What are the lemons for?” (Watson, RTOP, Mar.1). “There was no true formal presentation, mostly making sure students knew which lab they were to complete” (Reid, RTOP, Mar. 1). Lithium asked if they had questions before moving onto the next discussion where she reminded students of previous ideas, “we talked about ions last week” (Watson, RTOP, Mar.1). “GTA reviewed the previous weeks material through questioning” (Reid, RTOP, Mar. 1). The questions she asked showed that Lithium had a good grasp on the foundational material presented in the laboratory experiment. She reminded her students of the connection between ions and electrons; that they would explore further while making batteries out of lemons.

The interactions Lithium had with her students demonstrated a strong student teacher relationship, as well as propositional knowledge understanding. While Lithium asked questions, she walked around the room calling students by name (Reid, RTOP, Mar. 1). Lithium continued to walk around the classroom talking with students as they got ready for their experiment (Watson, RTOP, Mar. 1). She walked around helping students and explaining the experiment. Lithium asked questions to help scaffold their understanding and help them progress (Reid, RTOP, Mar.1). Lithium spent a lot of time at one group asking them what they tried, while the students were not really talking to each other (Watson, RTOP, Mar 1). Lithium continued to ask questions of her students: “if red is connected what is that telling us? What is the positive and negative sign telling us? What do we think?” (Watson, RTOP, Mar. 1). She waited for her students to answer, but was pushing them along (Watson, RTOP, Mar. 1). Although there was no formal while-group discussion Lithium explained the reactions that happened inside the lemon, after her students provided their data. She helped them summarize their findings, “so you are basically saying” (Watson, RTOP, Mar. 1). By the end of the class students were explaining concepts to one another, such as “why it doesn’t matter about the size of the lemon” (Reid, RTOP, Mar. 1).

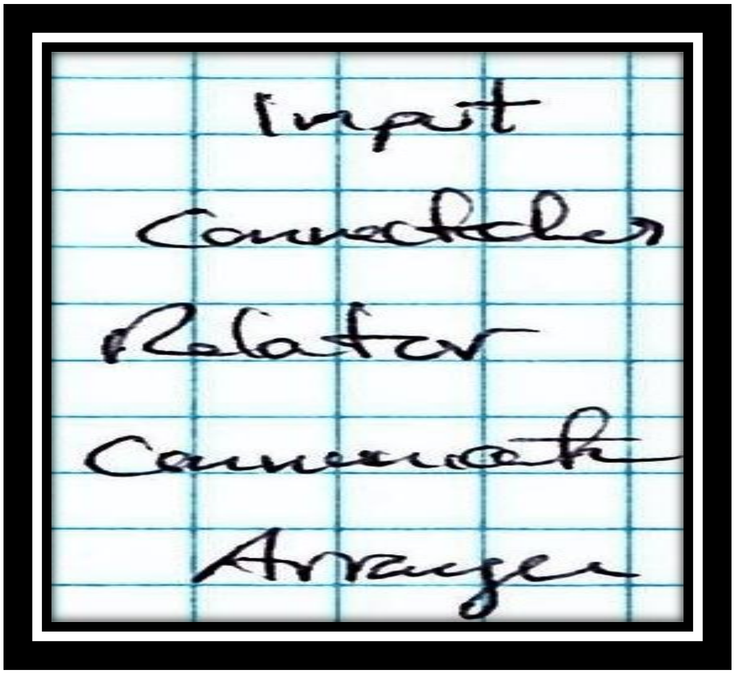
Workshops participation. Lithium attended each of the workshops. She completed both in-class reflections and reported her results from the Clifton Strengths Finders Assessment (CSFA), Figure 57. After reporting her CSFA results in the third workshop, Lithium was asked the following question relating her understandings of misconceptions and strengths:

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? (Discuss your answer and contrast your ideas to what Bodner said. Explain how using your individual talents, as defined by the Clifton Strengths Finder Assessment, can help you better connect ideas in chemistry, so your students’ understanding has minimal misconceptions.)

Lithium responded:

> People have misconceptions for many reasons in chemistry; it could be that the graduate student was not exposed to the ideas. It is most likely that we have falsely accommodated information about particular fields. We will always be learning.

> I can use my talents of input and communication to help my students attain the information they need. I also use relator and connectedness to determine what knowledge gaps my students maintain. (Lithium, Mar. 13)



Input
Connectedness
Relator
Communication
Arranger

Figure 57. Lithium's results from CSFA

Lithium addressed both pieces of the question including accurately explaining how she used her talents while teachings. She continued to participate in the workshops and answered the questions, from Dr. Neon, during the last workshop.

- What did you think was useful?

I thought it was useful to work with other GTAs to find out what my peers are doing or struggling with when teaching their labs. Sometimes the difficulties others have help me to see areas where I can improve.

- What would help you become a more effective GTA?

  I would be a more effective GTA if I really understood why the labs were chosen for each class. It would also help to be provided an opportunity to give feedback to the lab coordinators, about improvements or challenges we face during weekly labs.

- What is one thing that you plan to try to improve your teaching?

  While I am always trying to improve my instruction, this semester I have focused on trying to shut-up. I enjoy talking and students seem to want the answer. It is easier for me to tell rather than ask. So, I am trying to think of questions before going to lab.

- What do you think is your best quality as a teacher?
  I think that my best quality as a teacher is that I enjoy people and chemistry. I like seeing how others understand chemistry content compared to how experts perceive the chemistry content. (Lithium, Apr. 10)

CHAPTER SIX: DISCUSSION AND CONCLUSIONS

It would not be inaccurate to say that my research project started the day a began graduate school; however, the formal research into the role-identity of chemistry graduate teaching assistants for this project took place in the Spring of 2017. The role-identity of graduate students for the Spring semester of 2017 has been examined from multiple perspectives of myself and Dr. Neon in Chapter Four, from the perspective of each participant in Chapter Five. As the focus of my research was on the GTAs and their role-identity, the presentation of the six workshops constructed for the professional development, which were firmly grounded in the reviewed chemistry education literature, were designed to provide a contextual learning environment. The cases provided a format for me to analyze the GTAs' actions, thoughts, and beliefs related to the practice of being a chemistry laboratory instructor. The start of this chapter provides a summary of the entire semester that set the stage for answering the initial research questions. After summarizing the data and answering the research questions, this chapter will conclude with implications for the professional development of chemistry GTAs as science teachers and future research suggestions.

Boundaries

The boundaries of a research project are set with the limitations and delimitations, design factors that impact the internal and external characteristics of the study (Creswell, 2013). Limitations of the research project are the factors beyond the researcher's control. Conversely, delimitations are critical factors related to the design of the project that were set by the decisions of the researcher. In this study, some limitations occurred before and during the study that significantly impacted the intended design presented in my prospectus — the delimitations related to the choices I made in the topics of research and decisions for the methodology. I followed the example of Moustakas (1994) and placed the limitations of my phenomenological in the final chapter, in context with the findings.

This study included several factors that were limitations - contextually, methodologically, and physically. Because of the limited allowed timeframe for completion of a graduate-level research study, and the required time to implement a new course, the professional development could not be done in a required course with an assigned grade, which potentially limited the influence of Dr. Neon. The inability to assign grades also potentially impacted the GTAs willingness to complete the assignments and readings outside of the workshops. GTAs willingness to participate also forced a change from the original intent of the study to have an online reflection component. Methodologically the single phenomenological study is not statistically generalizable outside of the frameworks contained within the research, but maybe transferred to other settings (Cresswell, 2013).

My lens also limited the study as a participant observer in the professional development that would not be accessible to many researchers. Although attempts were made to mitigate researcher bias with instruments that have previously been developed and the use of another independent researcher (Reid & Phelps) I had personal interactions with each of the participants which influence my perspective. The interactions we had as graduate students in the same department included previous interactions such as study groups, taking classes together, going through the professional development (PD) together, and the times during the study where I served as a researcher instead of a peer, including the teacher beliefs interview (TBI) and observations outside of the PD workshops. The communications with other GTAs may have increased the validity and potentially decreased the reliability of this study. The scope of the study was also limited by the availability of participants, as many did not complete one or more of the interviews and observations they had initially agreed to complete. Other factors of this study that might have an impact on the intended potential audience include the extensive volume of data reported and length of the final report.

The delimitations related to this study included the topics of study, the literature reviewed, and the frameworks used to support the data collection and analysis. The external boundaries of the study were set by the questions I chose to ask and the symbolic interactionist theoretical framework. Framing the study within the context of mind, self, and society allowed me to align perspectives from multiple areas of research to provide a foundation for the chosen methodological framework. Similarly, my choice of instrumentation for data collection resulted from the methodological GTA conceptual framework. The use of previously established instruments and frameworks presumably increased the transferability of the results from my study.

Research Problem Review

Undergraduate student retention in science technology engineering and mathematics (STEM) fields of study has been a concern for decades (Strenta et al., 1994; Carnevale et al., 2010). The path to increased retention has focused on the development of curricula and on recent developments in STEM education promoting the development of GTAs (Addy & Blanchard, 2010; Gardner & Jones, 2011). After researching GTAs, Luft et al. (2004) encouraged using the literature base in science education to design impactful professional developments for GTAs.

Gess-Newsome (2015) diagramed the knowledge domains important to be a successful science educator after attending a conference devoted to the examination of researchers' understandings of pedagogical content knowledge (PCK) in science education. Although not a well-researched topic, the development of GTAs as science educators does have a literature base. In examining the PCK of Biology GTAs participating in a lesson study, Lampley (2015) observed different levels of PCK development resulted in different implementations of the lesson. Lampley also noticed that while they participated in the lesson study, the GTAs claimed that they implemented instructional strategies that were not observed. Sandi-Urena et al. (2011) encouraged the use of student-centered instructional strategies as a method for professional development. They found that GTA implementation of student-centered instructional strategies in problem-based chemistry laboratories positively impacted GTA skills in epistemological reflection and metacognition. Bauer et al. (2013) found that GTAs had a difficult time implementing the techniques necessary for student-centered instruction, while Golde and

Dore (2001) found that STEM GTAs often had high self-efficacy for teaching that was not reflected in their instructional practices. Alternatively, DeChenne et al. (2012) correlated GTA teaching self-efficacy and their abilities as instructors.

Golde and Dore (2001) pointed out that teacher training for GTAs in STEM fields was rarely available and when it was available it was often focused on general pedagogical content. Marbach-Ad et al. (2012) found that when GTAs willingly volunteered for a professional development, they received higher student evaluation scores compared to those GTAs that did not participate in the PD. Researchers involved in constructing and evaluating GTA professional developments found several factors to be relevant to the successful implementation (Connolly et al., 2016; Lambert & Tice, 1993; Bieber & Worley, 2006) that included length of time and attitudes toward teaching. Park (2011) included the professional development of GTAs as an essential factor in the stability of graduate programs.

Clifton and Nelson (2010) proposed a model of self-development that promotes the personal growth of talents into strengths. Researchers have continued to refine these 34 talent themes as a way to improve the effectiveness of professionals like teachers, managers and leaders (Rath & Conchie, 2008; Asplund et al., 2009; Louis, 2011; Liesveld et al. 2005). The unique nature of this study allowed me to explore the growth of GTAs who were required to participate in the PD experience while teaching labs in a setting that did not encourage the implementation of a student-centered curriculum.

The use of symbolic interactionism (SI) as a framework allowed me to align research from multiple perspectives to explore the science teaching role-identity of ten chemistry GTAs. The implementation of a six-workshop PD courteously led by Dr. Neon enabled me to explore their GTA beliefs and actions related to their role as chemistry laboratory instructors. GTA identity relates to the expectations and agreements between the individual and society, while their role describes how they translate their conceptual understanding into actions. The conceptual framework provided by Reeves et al. (2016) served as a foundation to evaluate the workshops in this study that were designed to improve the effectiveness of chemistry GTAs.

Review of Methodologies

The Reeves et al. (2016) framework promotes the examination of GTA cognition, teaching practices and student outcomes which align well with mind, self, and society. I used Addy and Blanchard's (2010) modified teaching beliefs inventory to examine GTA cognition through transcribed interviews that were coded by myself and another researcher (Phelps). After ensuring agreement on these codes, I created a teaching beliefs profile to represent the number of responses coded in the five categories: traditional, instructive, transitional, responsive, and reform-oriented. The TBI included two teacher-centered categories (traditional and instructive) and two student-centered categories (responsive and reform-based) with a transitional category between the two sets. The categories on the TBI were very similar to the epistemological development model presented by Baxter Magolda (2004), summarized in Table 1, and highlighted as an indicator of chemistry GTA growth by Sandi-Urena et al. (2011). This made the reformed teaching observation protocol (RTOP) an excellent device to explore GTA practices. The RTOP has twenty-five statements (five in each of five categories) that can be rated from zero (never observed) to four (very descriptive of this teacher). The scores for each GTA were reported in their case (Chapter Five) the five categories were listed on the instrument and in each bar chart in the following order: lesson design and implementation, propositional content knowledge, procedural content knowledge, communicative interactions, and student-teacher relationship. Sawada et al. (2002) performed a factor analysis as part of their RTOP report, the categories loaded into three factors. Researchers found four of the five categories loaded to two factors content (procedural knowledge and propositional knowledge) and classroom culture (communicative interactions and student-teacher relationships) the category of lesson design and implementation loaded as a single factor. The categories of the RTOP also aligned with the professional knowledge domains of teachers related to science educators PCK in Figure 1 (Gess-Newsome, 2015).

Although the GTAs in our study were not asked to implement a reform-based curriculum, they worked as laboratory instructors with a lot of autonomy and minimal supervision. The RTOP allowed the researchers to capture their observations of GTA practices systematically. The practices we observed were related to the behaviors of successful science educators by two researchers. The researchers came together to discuss their observations and created a combined score after agreeing on how to rate the GTA on each statement. Finally, student outcomes related to their opinions of teaching practices implemented by GTAs were taken from the undergraduate student evaluations of their GTAs. Student evaluation data was not as useful as the other measures because the instrument was not available and I did not have access to the details related to the creation and validation of the instrumentation. Marbach-Ad et al. (2011) used student evaluation data as a reporting measure for the successful implementation of a PD. Similarly, I used student evaluations as a way to provide a picture of how GTA beliefs and practices were interpreted by their undergraduate students.

Research Summary

The workshops were a place where the GTAs were encouraged to investigate the concepts related to teaching and learning in an area outside of coursework where they could interact with other chemistry laboratory instructors. The amount of prior experience the participants had varied greatly from Carbon (in her first semester) to Cobalt (a Ph.D. student in his last semester and tenth year as a GTA). The GTAs level of experience did not necessarily predict the developmental outcomes; however, Carbon was the only master's GTA to exhibit signs of epistemological reflection regarding her role as an instructor. The potential factors impacting Carbon will be discussed in detail later in the chapter. Carbon believed the PD had a significant impact on her conceptual understanding of her role as a GTA. No learner comes to the classroom as a blank slate; although Carbon felt that way about her role as a chemistry GTA at the start of the semester. Hydrogen, in her last semester as a master's student exhibited beliefs and behaviors associated with the least sophisticated level of epistemological development. Silicon and Bromine (the other two master's students) were in their first year as master's students and had a similar level of epistemological development as Hydrogen; although they attended all six workshops. The doctoral GTAs also had a variety of experience levels, with Sodium (in his first year as a chemistry GTA with a biology background) to Cobalt (with the most experience in the chemistry department). The level of epistemological development was related to GTA experience, only in so much as the Ph. D. students exhibited a higher level of epistemological sophistication when compared to master's students; however, the number of workshops doctoral students attended related to their epistemological development. The interdisciplinary nature of the doctoral programs at our university meant that only a few of the GTAs had an undergraduate major in chemistry. Participation in the workshops allowed GTAs the opportunity to grow in many ways and, at least for Carbon, she wanted the support to continue - enough to ask if the workshops would continue during her final TBI. At the conclusion of the semester and in subsequent years, Dr. Neon noted that she had more GTAs stop in to ask her questions about the experiments they are teaching or the students they are dealing with, as her office is across the hall from the laboratory classrooms.

The development and implementation of the professional development required considerable time and effort to plan and reflect on lessons in order to assist GTAs at each level of development. Although the GTAs were asked to participate in the workshops regardless of the amount of time they had been GTAs, several doctoral GTAs did not attend all the workshops. It was also challenging to set up interviews with the participants, and I had to remind the GTAs several times to schedule and attend the interviews (TBI). As a result, only two participants were interviewed both at the beginning and the end of the semester. The majority of GTAs were observed twice using the reformed teaching observation protocol (RTOP). Table 16 shows each GTAs participation in the professional development, and the evidence collected for triangulation throughout the semester.

Table 16 Summary of GTAs Results and Participation

SE 2016	Participant	Degree	Initial RTOP	Initial TBI	# WS	SE 2017	Final RTOP	Final TBI
	Hydrogen	M.S.	26		0	3.6	22	Trad
3.8	Silicon	M.S.	25		6	3.7	26	Trad-Inst
3.1	Bromine	M.S.	12		6	2.9	17	Trad-Inst
	Carbon	M.S.	24	Trad-Inst	6	3.6	26	Trans-Inst
4.8	Iodine	Ph.D.	16		4	4.0	19	Trad-Inst
4.0	Sodium	Ph.D.	29	Inst-Trans	4	4.1	21	
4.2	Chlorine	Ph.D.	20	Inst-Trans	4	4.3	27	Inst-Trans
4.1	Cobalt	Ph.D.	30	Trans-Inst	5	4.5		
3.7	Fluorine	Ph.D.	30		6	4.5	41	Trans
	Lithium	Ph.D.	45		6	4.3		

Note. The numbers in the Student Evaluation (SE) columns were scored out of five points on Likert scale responses. The degree column indicates if they were in a master's (M.S.) or doctoral (Ph.D.) program. Reformed Teaching Observation Protocol (RTOP) scores had the potential of being scored 100. The results from the Teacher Beliefs Interview (TBI) indicated the category or categories with the highest number of responses; two groups were listed when respondents answered the remaining questions with another majority response: traditional (Trad), instructional (Inst), Transitional (Trans). The number of workshops (#WS) attended by each participant was potentially 6. The color of the participant's name represents GTA epistemological development level, absolute, transitional, independent, contextual.

Dr. Neon and I adapted the lesson plans between each workshop. We discussed the content and engagement level of GTAs and brainstormed ways to facilitate their conceptual development of knowledge, skills, and practices related to their identity as chemistry laboratory instructors, while GTAs enacted their roles participating in the workshops. To help GTAs recognize their content knowledge, we had them complete the chemistry concept inventory in the first workshop and shared the results during the second workshop. Fluorine found the results of the misconception test to be illuminating, in that sometimes even fundamental ideas were misunderstood. In the third workshop, we played ‘Petals Around the Rose’. This game allowed the GTAs to experience the feeling of frustration many of our students feel in our classes as a way to assist the GTAs in constructing conceptual changes in their understanding. Iodine recalled gaining the insight that saying things louder and slower would not help his students; instead; he had to find other ways to help GTAs. In the same workshop, we discussed talents, which Carbon and Lithium thought were essential aspects in assisting them to be more effective GTAs. As Dr. Neon and I continued to plan workshops, and I started to collect initial observations and interviews of all the participants, we noticed GTA lack of pedagogical development and thought GTAs would benefit from seeing others teaching. In the fourth workshop, we discussed the observations and talked about positive interactions with students that could help them develop accurate conceptual representations. Iodine noted the images of student learning exits used to frame Workshop Four was useful. Bromine thought the information from the fifth workshop was most useful as Dr. Neon provided a handout with tips for questioning, which he thought of as a helpful teaching strategy. In the final workshop, we discussed the difference between experts and novices, which opened Silicon’s eyes to the idea that individuals often have different levels of understanding. Each GTA found at least one thing useful from the workshops and few agreed on the same aspect as being perceived to be most impactful to them.

The level of chemistry GTA epistemological development in general increased as their experience as GTAs increased. The workshops offered GTAs opportunities to reflect on their practices and potentially improve their teaching effectiveness. While the master's students Bromine, Silicon, and Carbon found the workshops to be valuable with respect to many aspects of their identity as GTAs, doctoral students did not necessarily agree, as both Sodium and Chlorine noted that they did not feel the workshops applied to their status as a scientist because they were not primarily teachers. The feelings several doctoral students had related to teaching their labs being something they just had to get done, and the lack of importance influenced Iodine's behavior toward attendance. Cobalt and Sodium did not mention similar feelings about attending the workshops in their interviews; however, it should be noted that neither of them sat for a final interview to discuss their feelings. There was a noticeable absence of GTAs during the fourth and fifth workshops. Iodine and Chlorine did not feel as if the workshops should apply to them, because they had been GTAs for so long. Chlorine explained that he had friends that were chemistry GTAs and had taken classes with them before, so he felt comfortable speaking to me on their behalf as well as his own. Chlorine believed because they were not researching educational issues, like Lithium, the information did not apply to them. The final responses on TBIs, RTOP scores, and student evaluations indicated that GTAs beliefs were more likely to be transitional after completing the workshops if they believed that the professional development were important in their identity as a GTA.

So, how do these cases fit within the symbolic interactionists' theoretical framework, presented and discussed in the first two chapters. The original research questions, shown in Chapter One, pertained to GTAs roles and identities. When GTAs taught, they were enacting their role, which was how they believed laboratory instructors should behave when teaching a class. To represent their mental construct of being a GTA, I asked each participant to explain their role in the laboratory during the teacher beliefs interview (TBI). I also observed their practices during instruction and rated each of them using the reformed teacher observation protocol (RTOP). I wanted a baseline understanding of the role GTAs took in the department, before attending the professional development.

The second question was more complex and brought in the construct of identity. To determine the role-identity of GTAs after the professional development, I reviewed seven of the GTAs' cases and discussed their progress throughout the semester. I discovered the role the GTAs took based on their responses from the TBI and their answers in the final workshop reflection, while identity combined the expectations provided from the workshop and the teaching practices from the RTOP and student evaluations.

The third and fourth questions referred to the professional development and were answered with artifacts from the workshops and responses from post TBIs. To address the third question related to the GTA thoughts about the workshops, I looked at both their workshop participation and their final TBI for a holistic review of the professional development and reviewed any ideas participants had regarding assistance from or practices of the chemistry department. I modified the last question from the one initially proposed, which incorporated multiple on-line reflections, to one in-class reflection. To answer this question, I examined each of the participants Clifton Strength Finders Assessment (CSFA) results and the responses to different reflection questions four participants responded to the CSFA question, while three replied to the original misconceptions question. I also reviewed their final epistemological development level to categorize responses and refine differences based on answers to the questions rather than based on the question asked.

Role

Research Question One: What were graduate students' beliefs about their professional roles as GTAs, specifically their roles as instructors in undergraduate chemistry laboratories?

I reviewed the cases to determine the beliefs GTAs held regarding their roles as laboratory instructors, before the professional development. The graduate students progressed through four stages of epistemological development absolute, transitional, independent, and contextual. Hydrogen did not attend the workshops serving as a sort of control; Cobalt and Sodium only completed the TBI at the start of the semester. Carbon and Chlorine were the two participants that can be evaluated for growth as a result of the workshops, as they completed both an initial and final TBI. The roles GTAs adapted as participants in the workshops and as teachers were used to determine their level of epistemological development. I used evidence from the TBI to support the level of epistemological development for each participant.

The two individuals who had with the most traditional beliefs about their roles as laboratory instructors were Hydrogen and Carbon. Both Hydrogen and Carbon held beliefs and maintained practices that were teacher-centered. The TBI profiles presented in Chapter Five showed that Carbon, in the first semester of her master's program, responded 47% of the time with comments consistent with instructive beliefs; while, Hydrogen, in her last semester of her master's studies, responded with traditional comments 75% of the time. Although Carbon believed her role required her to provide information to students, she was not secure in her methods. She worried that students would not understand her because of her accented English. She tried to give her students all the information they would need to complete the assignment. Carbon wanted to be sure her students were not confused when they finished their lab reports, and she worked examples for them at the front of the class. Hydrogen, on the other hand, expected her students to read the assignment and complete the experiment while she walked around to see what they were doing. Hydrogen's understanding of knowledge was absolute. When asked what she did when her students were not working correctly to complete the lab, she replied, "I haven't seen them" (Hydrogen, TBI, Apr. 10). Hydrogen and Carbon believed knowledge to be in the information provided to the students, either in the process of reading the assignment or by the GTA telling them the information. Carbon and Hydrogen both demonstrated absolute levels of epistemological development with the belief that students learn from the knowledge provided by the instructor and the belief that teachers have a superior understanding that can be passed on to their students.

Chlorine and Sodium exhibited teacher-centered beliefs as well; however, the beliefs profile showed that both doctoral students responded to the questions on the TBI a with a higher percentage of transitional statements when compared to the GTAs at the absolute level of epistemological development. Chlorine and Sodium rformed an initial TBI in February. Sodium's responses to the TBI were 36% transitional and 36% instructional. Sodium was in his second semester as a GTA in the chemistry department; his previous experience had been in a biology department. The only differences he thought of as being relevant when comparing teaching introductory labs in the two departments were the expectations of the laboratory coordinators, although he did not provide details regarding the differences in expectations. Sodium wanted to be the bridge between the lecture and the lab. He felt that the significant terms the lecture professors used could be simplified in the laboratory experience. He thought that students could read the book and hear about the topic during lecture, and still be confused about topics. The experiment provided a hands-on way to show students what is going on with some of the things they learned in the lecture. Sodium felt that in the laboratory course he was easily able to interact with the students. Each class only had twenty students and he thought the setup allowed him to have more personal interactions with his students than would have been possible in a lecture class. Ultimately, he believed his role was to explain the concepts and do a lab each week until all eleven were completed. Chlorine's responses to the TBI were 47% instructional and 38% transitional. Chlorine believed that if he gave his students the vision, then they would do whatever he asked of them. He thought his role was to be the students' friend and help them, as the content was already challenging.

Chlorine wanted to make learning easier for his students by instructing them about the experiment. While Chlorine and Sodium both held beliefs about absolute knowledge, they also exhibited an understanding that the knowledge students held could be different from what was presented by their professors. Both still felt that they needed to provide students with information and believed that they needed to act as either a friend or a bridge to help their students gain knowledge. Chlorine and Sodium portrayed beliefs that placed them at the transitional level of epistemological development. Although they understood knowledge as being a transitional construct; some knowledge was absolute (the theories presented in lecture) while student knowledge was held independently. Their role as laboratory instructors was fulfilled by providing students with the correct knowledge by ensuring they had the information needed to correctly answer the questions in the lab manual.

Of the five participants that completed the TBI before the workshop, Cobalt had the most developed epistemological understandings. Cobalt believed he would be finishing his doctorate by the end of the semester. Cobalt's TBI results were 41% transitional and 29% instructive, indicating that he was transitioning from teacher-centered to student-centered beliefs at the beginning of the semester. He described his role as a laboratory instructor in several ways - first of which was to provide safety. Cobalt felt that students should understand the concept better after completing the experiment. He thought students did not understand the theory behind the laboratory before coming to class and noted that topics presented in lecture and laboratory should align more closely. He believed his role was to help students feel "wowed" after the investigation, because now students understand the concept. Cobalt exhibited epistemological beliefs that placed him at the transitional developmental level. Although Cobalt felt good when his students understood an idea, he thought he could help provide them the information they did not understand from the lecture.

The concept of role varied slightly between GTAs that were master's students and doctoral students. All five master's level participants held teacher-centered beliefs regarding knowing and learning. Carbon and Hydrogen both exhibited absolute epistemological understandings of knowledge and wanted to provide all the information they believed their students needed to complete the experiment successfully. Both of these GTAs also thought it was essential to monitor the progress of their students. Sodium and Chlorine also thought observing their students and providing answers to their questions was an essential part of their role in the laboratory. Sodium and Chlorine had some beliefs that took students feelings about chemistry and the difficulties they faced into account. Cobalt felt strongly about his students' understanding and wanted to assist his students in understanding. He perceived challenges for the students learning that related to the alignment of laboratory and lecture topics.

Role-identity

Research Question Two: What impact did a multi-week professional development training have on GTAs perceptions of their role-identity in the laboratory classrooms?

Role-identity is a multifaceted construct that considers not only the role taken by the GTA but also the way the GTA portrayed the position of a chemistry laboratory instructor. The TBI indicated the beliefs each participant held regarding teaching, and I used those beliefs to determine the level of epistemological development (absolute, transitional, independent, or contextual) for each GTA. I did assigned Lithium to the contextual category; however, it was not based on answers from the TBI but rather on her comparatively high initial score from the reformed teaching observation protocol (RTOP). Lithium had the highest RTOP score of 45 and she demonstrated a desire to continuing refining her teaching practice. The mean initial RTOP score for GTAs was 25.7 (n=10). The scores were a standard deviation below the comparison mean provided by Sawada et al. (2002) for reformed science educators, not GTAs, in the RTOP reference manual with a mean of 51.0 and a standard deviation of 20.9.

The impact of the professional development on role-identity was difficult to determine for most participants because only two GTAs completed both TBIs, and RTOP scores of the same topics could not be compared. Six participants completed the TBI after all six workshops were finished. Bromine and Silicon, the other two master's students that participated in the study, both exhibited absolute understandings of knowledge, as did the doctoral student Iodine. It is safe to say the professional development did not appear to appreciably impact their role-identity. Chlorine's TBI showed some differences, although most of his statements still indicated a teacher-centered beliefs system. Although, Carbon had shown growth to a transitional understanding of knowledge development after attending the workshops. Fluorine was the only GTA to exhibit an independent understanding of knowledge constructions. While his teacher beliefs profile indicated transitional perceptions of science teaching and learning, he held just as many teaching-centered as student-centered beliefs. His RTOP score improved eleven points over the semester and his student evaluation score improved from 3.7 in Fall 2016 to 4.5 in Spring 2017 giving a strong indication that Fluorine's beliefs about teaching practices were impacted by his participation in the workshops. Figure 58 shows the groups of GTAs at four levels of epistemological development.

When I looked through the RTOP data for all of the GTAs it was difficult to see any patterns; however, when the GTAs' RTOP scores were sorted into groups based on their responses to the TBI, several patterns became evident. First, regardless of grouping, chemistry GTAs scored highest in propositional content knowledge and lowest in lesson design and implementation, except for Lithium, indicating a science teaching identity that favors propositional content knowledge over the other knowledge areas foundational for establishing a reform-based learning environment. The other noticeable trend was that each developmental stage had a higher average RTOP score in comparison to the previous developmental group, with similar growth patterns in each area, indicating an alignment of teacher beliefs and teaching practices in each domain. The absolute group, with a mean RTOP of 21.2 (n=9) included Carbon at the beginning of the semester and both RTOPs for Hydrogen, Silicon, Bromine, and Iodine. The transitional group, with a mean RTOP score of 25.5 (n=6), contained Cobalt's first RTOP and Carbon's end of the semester RTOP, along with both RTOP scores for Sodium and Chlorine.

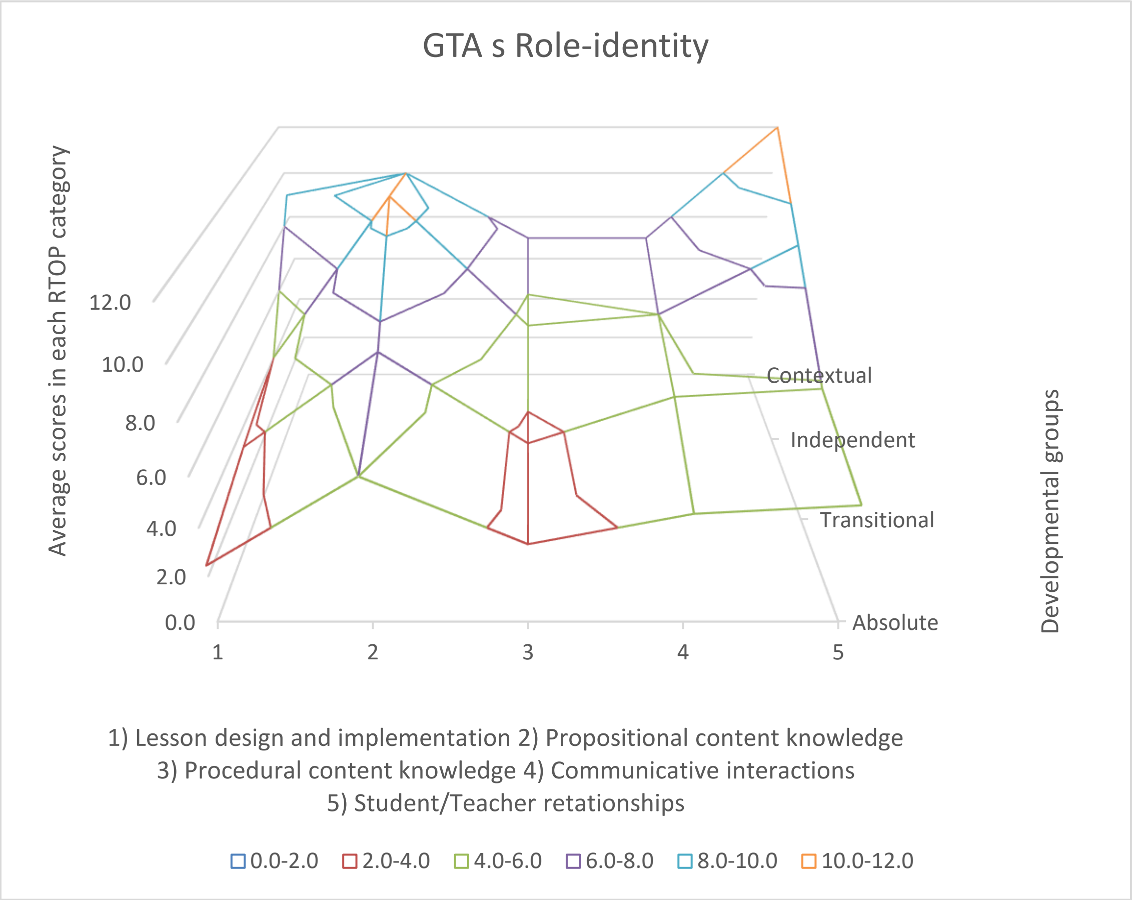


Figure 58**.** Role-identity of GTAs based on epistemological development level from TBI and RTOP averages in each category – absolute (n= 9), transitional (n=6), independent (n=2), contextual (n=1).

The final two developmental groups included one participant each - Fluorine who was categorized independent with both RTOP scores averaging 35.5 and Lithium as contextual with a score for the beginning of the semester of 45. Each epistemological development group had some interesting anomalies from the standard patterns and averages.

In the absolute group, the roles taken by Hydrogen and Carbon regarding their teacher beliefs before the workshop have been deiscussed on page 277; now we will consider, Bromine, Silicon, and Iodine. Like Carbon and Hydrogen, Bromine and Silicon were both master's students. Bromine and Iodine dichotomized chemistry content knowledge into two areas, theoretical and practical (visual).

Bromine enjoyed teaching because the experiments connected the theoretical ideas to physical representation. When asked how Bromine felt about teaching labs, he replied:

> I feel great because the lab is a practical teaching experience. You involve the student practically - you can teach and learn both from practical experiment. You are observing what you learn, what you learn theoretically this is practically in doing the experiment. So, this is great. This is great. I am excited to learn, to teach in the lab. (Bromine, TBI, Apr. 10)

The positive feelings or simple admittance of emotions associated with teaching indicated that Bromine understood learning to be fun and related his learning to teaching. Bromine taught by determining what information students needed to complete their assignment and providing them that information when they were curious.

Bromine's responses were 44% traditional and 36% instructive during his TBI. He played his role by giving a briefing at the start of class and walking around to each group questioning their procedures. Bromine gave an example of the questions he asked when he stepped to each table; he asked students: "What is happening here? What is happening in this lab? What are you doing?" (Bromine, TBI, Apr. 10). If the students did not understand, then he would “make them understand through demonstrating” (Bromine, TBI, Apr. 10). The joy Bromine seemed to feel for teaching did not translate into positive feedback regarding teaching science in a reformed classroom. Bromine had the lowest scores on the RTOPs and the lowest student evaluations of all of the GTAs in this study. According to his final reflection on the workshops, Bromine thought experience and training would make him a better GTA. He considered his best quality as a teacher was his enjoyment for teaching and sharing information with his students. Bromine’s understanding of knowledge was an absolute construct to be transferred to the students as they gained practical experience in the laboratory.

Silicon responses were similar to Bromine during his TBI, with 48% traditional and 34% instructive. Silicon considered providing information to his students to be a primary part of his responsibility as a laboratory instructor. Although Silicon asked questions as part of his role when he gave an example from the lesson on Boyle’s gas law: “If you increase the pressure what happened to the volume?”, he expected the response, “oh yeah the volume is going to decrease” (Silicon, TBI, Apr. 13). Silicon had specific information he wanted his students to know when they finished the experiment - if volume increased pressure would decrease. Silicon tried to push his students to get the correct answer by providing examples and showing them all the critical variables or steps necessary to complete the experiment.

He also tried to observe his students and correct anything they were doing incorrectly. Silicon thought about implementing several things to make himself a better GTA, including understanding the entire concept before going to class, making briefing notes, communicating effectively and efficiently, and making visual representations of molecular level changes. He felt he had improved by trying to ask more questions to the students during the briefing to be sure they understood the concept. Silicon thought his best teaching qualities included the ability to simplify complex information and attending to students' needs as individuals. Silicon scored slightly higher than the other absolute group members with an average RTOP score of 25. Silicon scored higher in the area of propositional content knowledge, which indicated he had implemented reformed techniques that exhibited his understanding of the content.

Iodine was the only doctoral member of the absolute group with 55% traditional and 23% instructive responses on his TBI. Iodine thought teaching lab was like training people at work. He described his role as making sure his students did not kill themselves. Iodine explained that the experiments were supposed to sync up with lecture, and he expected his students to have a rough understanding of theory before coming to his classroom. Iodine believed the investigation was a visual representation of content. Iodine was unique among the absolute group in that his student evaluations score was five-tenths of a point higher than the group mean of 3.5, which would have placed him in the transitional group. Iodine reflected on what would make him a better GTA and planned to complete the experiment himself before the lab each week. Iodine believed his best teaching quality to be having learned English as his first language.

Silicon and Bromine focused on transmitting knowledge to their students, while Iodine thought his role was to train his students. Iodine's portrayal of himself as a trainer rather than a teacher might have impacted the way he was viewed by the students because he felt comfortable in the identity of a trainer. Iodine worked in the laboratory to make sure his student could correctly complete the procedures and conduct the experiment. He did not give students a lot of theoretical information and focused on helping them complete each process. Although Iodine did not exhibit student-centered practices, as reflected by his RTOP scores, students rated him more favorably than other GTAs displaying similar epistemological development. Iodine believed his language ability was his best teaching quality, because he shared a native language with most of his students. Based on the results of this study, there does not seem to be a direct correlation between native language and teaching beliefs or abilites. Two of the GTAs with higher epistemological development did not speak English as a first language. They scored higher on RTOP and student evaluations indicating that not being a native English speaker had little impact on their students perceptions of their abilities to teach chemistry. Silicon had taught in Nigeria for a year before becoming a GTA. Connolly et al. (2016) attributed increased teaching ability for GTAs that had previous experience as high school teachers. Silicon's RTOP score could have been influenced by his teaching experience given that his higher RTOP score was closer to the average of the GTAs in the transitional group.

The transitional group had an interesting mix of GTAs, with Carbon being the only master's student, Cobalt, in his final stages of dissertation work, Sodium, a doctoral student in his first-year teaching as a chemistry GTA, and Chlorine, an experienced chemistry GTA. Chlorine completed both TBIs with very little change in beliefs. While Carbon completed both TBIs and showed epistemological development moving from the absolute group at the start of the semester to transitional after completing the professional development. Cobalt did not have a final RTOP, interview, or reflection; the only evidence of any impact from the workshops was found in his student evaluation scores, which increased from 4.1 to 4.5. The 4.5 score on the student evaluation was similar to GTAs in the independent or contextual groups, giving some indication of growth.

Sodium did not complete a TBI after the workshops either; however, he did finish the in-class reflection. Sodium found the workshops useful because he learned that general chemistry topics could be tricky, even for experts. Sodium transitioned between focusing on his attitude about teaching to thinking about his students' perspectives. Sodium did not feel like he could maximize student learning in the labs he taught, until I reminded him that he was a student as well and had to do something when he taught to help his students understand. Sodium admitted he thought students should feel comfortable enough to ask questions during instruction, and so he focused on creating a stable learning environment for his students where they would feel safe and comfortable asking questions. Sodium explained, "they are a little intimidated at the start so that it can make a huge difference - the way you communicate" (Sodium, TBI, Feb. 16). Sodium thought of himself primarily as a researcher and appreciated the tips on teaching and engaging students. Sodium believed he would be a better teacher if he had more patience with his students and planned to implement more interactions with his students about real-life connections to the experiment. Sodium's RTOP score regarding student-teacher interactions dropped six points over the semester; his comment about needing to have more patience with students demonstrated self-awareness in the context of his classroom.

Sodium was passionate about passing on information and thought this was his best quality as a teacher. Sodium had ideas about how to improve instruction and felt limited by the curriculum provided by the coordinators. Sodium relied on his negative experience as an undergraduate to drive his teaching as he wanted his student to make connections between the theoretical knowledge presented in lecture and the practical experiences in the laboratory. He explained:

> I felt when I was in undergrad that my practical knowledge in the lab especially in certain labs, they did not do a very good job in connecting to the real life and the practical and theoretical knowledge - the bridge was not good. It was like, no bridge. It was like; I didn't know what was going on. (Sodium, TBI, Feb. 16)

Sodium tried to be a bridge for his students so that they did not suffer as he had as an undergraduate; he wanted his students to have a better experience. Sodium previously taught a biology class and allowed the students to write an essay about genomes – he felt students enjoyed the opportunity to connect their understandings to information from class.

> Again, I am not sure how to improve it, but people get really bored of it really easy. It's one of my observations, and it's probably the first two classes they are interested, after that for some reason, they just like phase out and that needs to be improved if the retention has to be improved. (Sodium, TBI, Feb. 16)

Without a post-interview, it was difficult to determine the impact the workshops had on Sodium’s beliefs about teaching and learning. He did not show growth in either his RTOP score or student evaluation scores; it is unlikely he progressed to the independent development level. Sodium mentioned practical and theoretical knowledge relating to science and attempted to connect the two rather than seeing the constructs as having a dichotomous relationship. Sodium did not see researcher and teacher as the same identity, rather two separate roles that he portrayed. He felt his status as a GTA was defined differently depending upon the lab coordinator for the course he taught, although he did not go into detail about the perceived differences.

Chlorine exhibited a predominantly transitional level of epistemological development at the beginning of the semester (traditional 15%, instructive 47%, and transitional 38%) and his TBI at the end of the semester showed a similar distribution of categorical responses, traditional 17%, instructive 43%, and transitional 43%. Chlorine did not exhibit epistemological growth after completing the workshops; the professional development appeared to have minimal impact on Chlorine’s identity as a GTA. Chlorine’s RTOP score for propositional knowledge increased six points over the semester, which indicated he adapted his traditional way of presenting content knowledge to be more student-centered. Although Chlorine showed growth to more student-centered beliefs on two questions Luft and Roehrig (2007) stated that the answers to three questions needed to become more student-centered to truly indicate a changed belief regarding science teaching.

In February, Chlorine talked about his responsibility as a GTA as being friendly and providing information to his students. In April he explained:

> I just want to be the responsible guy to give all the information to them, like the requirement. And then, I can help them feel better in this industry. And yeah,

> because I was a student - I am still a student right now, but I feel how difficult the student's face. (Chlorine, TBI, Apr. 13)

Chlorine understood that the content was challenging; and like Sodium, Chlorine wanted to provide a stable and compassionate environment for his students. Chlorine shared his personal experience related to student retention. He told the story of his little brother. Like Chlorine, his brother had started as a chemistry major, but because he earned a B in one of his introductory classes, he switched to a business major. Chlorine understood why his brother did not like chemistry and worked to help his students have a positive classroom environment, where all the information they needed to understand was provided. Chlorine explained how he believed his students learned chemistry best:

> They have to enjoy it; they have to love science, they have to think it is easy for them to learn. They have to have some available resource like you have to be a good teacher to show them. If you reach them the first days, you just have to be very easy understand. Very easy step by step so, to me the first week and the second week are very important. Later they have it. So, the first half is the important half. (Chlorine, TBI, Feb. 13)

Chlorine thought “being a GTA was a very good opportunity for everyone, because you have the chance to talk to everyone, to transfer your experience to younger friends” (Chlorine, TBI, Feb. 13). Chlorine recognized the affective components necessary for students to learn chemistry. He also considered teaching an excellent opportunity to transfer knowledge, indicating that he had a teacher-centered identity and chemistry knowledge as an absolute construct transferred from one individual to others. He explained his feelings relating to student learning at the end of the semester:

> I know very heavy thing for students, chemistry. Because on day one you come into the class you have to learn many things, right? Why don't you cut the problem to be smaller and something very easier to digest? Because if you give them a big rock like that, they cannot do it; anything, but if you cut the information, into the smallest piece, it is easy for them to know. I mean the methods, because I know not only here, but a lot of friends, a lot of people they very good at chemistry. The reason is because they have very good method to learn and see in many schools, they are teaching chemistry very well, but right here not very much actually. I am sorry to say. (Chlorine, TBI, Apr. 13)

Chlorine did not take responsibility for his students learning or lack of learning. Instead, he deflected the burden to the lecture professors.

> I just hope that they cover better in lecture, so they come here we will feel more freedom; and yes, sometimes the labs and the lecture are very comfortable round here. They learn something from here they have not covered from lecture, is not very nice. They should cover stuff in lecture, and this one is just an illustration, you know. Of course, that's okay, that's okay. It's difficult for them teaching this whole program. (Chlorine, TBI, Apr. 16)

Chlorine indicated that students needed multiple representations of topics and only one of those representations was his responsibility.

During his final in-class reflection, Chlorine focused his ideas regarding how his instruction improved on understanding his students wants and needs more effectively. He believed if he knew them better, he could find better ways to instruct them. To enhance his teaching, Chlorine thought he should be a more dynamic speaker and have a better communication style. Chlorine was committed to his identity as a GTA. Chlorine believed he understood his responsibilities for teaching and because he was not planning on being an education researcher or instructor, did not feel the need to engage in the professional development. He believed he needed to be a friend to his students and the provider of chemistry information to properly perform his role as a GTA.

Carbon was the only GTA to grow from one epistemological developmental level to another during the semester. Carbon's TBI profile at the start of the semester indicated an absolute developmental understanding of epistemology (traditional 29%, instructive 47%, and transitional 12%) and was the only master's student to reach the transitional level of epistemological development (traditional 10%, instructive 43%, and transitional 48%). Although it was Carbon's first semester and she admitted to being uncertain in her role, she explained her belief about how she should behave:

> I can help and have the help of me, and then, if they have any confusion regarding the process, they can ask at any point. I will be there around to help them out. And the questions which are asked at the end of the lab report, I think that they should have some idea to do by themselves. Or if they can have any confusion, I can help them out to answer the question, but they have to do it by themselves. I think so. (Carbon, TBI, Feb. 12)

At the end of the semester, she had a more complex understanding of her role as an instructor.

> I just help them to connect the knowledge they have in their lecture class or what they have learned so far by studying chemistry and use their knowledge to determine if that works or not. Just to find out the correlation between the theoretical and practical. I think because I cannot give them more knowledge about chemistry or anything. I, as an instructor, explore how what they have learned in their lecture, they should be able to connect that knowledge and their practical use. (Carbon, TBI, Apr. 13)

Carbon understood that knowledge was not something she could transfer from herself to others; rather their knowledge was independently held and necessarily constructed by the students. Interestingly, she also thought of the practical experiences in the laboratory and the theoretical information from lectures as separate entities. Carbon wanted her students to connect theoretical knowledge from lecture to practical knowledge during the experiment. The role that Carbon took changed from being an information provider to an information connector.

Carbon admitted the hard part was knowing when her students had made the connections; she understood that sometimes she provided the information and they still did not understand. She thought students should be engaged during class by answering questions. “So yeah, they might be wrong, they might have the wrong answer, but that doesn't matter. Because at least, they are trying to think about the topic” (Carbon, Apr. 16). Carbon thought she became a more effective GTA when she used her connectedness talent to help understand the students’ perspective and provide students with abstract representations that helped them relate the concepts from the laboratory experiment to their knowledge from lecture. Carbon allowed students the opportunity to work the problems first before she gave them solutions. She wanted to improve her teaching by learning student names more quickly and thought her best quality as a teacher was her concern for students’ problems. Carbon had the lowest student evaluation score in her group, indicating that the student evaluations did not reflect her development as a reformed science teacher throughout the semester. As this was her first semester as a GTA her student evaluation scores will most likely improve with experience and familiarity with her role.

GTAs in both absolute and transitional categories used teacher-centered instructional approaches. GTAs in the absolute category provided information to their students and expected students to ask if they needed assistance or had questions. When the GTAs in the absolute group asked questions, the questions they asked were often closed-ended. GTAs in the transitional development group empathized with their students and knew that learning chemistry was difficult for some people. Transitional GTAs wanted to provide their students with the information they needed in learning environments that valued the student's practical experience and theoretical understanding. Transitional GTAs felt their role was to help students bridge their ideas about chemistry concepts and practical skills. The role each GTA took was dependent upon their epistemological development. Although both groups demonstrated teacher-centered beliefs and practices, GTAs in the absolute developmental level focused on providing information to students and GTAs in the transitional developmental level focused on student cognitive engagement before providing information. The last two categories of epistemological development had only one participant each: Fluorine was categorized as independent and Lithium was classified as contextual. Both had classroom environments that were more student-centered compared to the other GTAs, as reflected by their RTOP scores, TBI results, and the student evaluation scores.

Fluorine’s responses to the TBI indicated that at the end of the semester he was transitioning his beliefs about science teaching from teacher-centered to student-centered, traditional 11%, instructive 22%, transitional 42%, responsive 22%. He did not complete an initial TBI, and that limited my ability to comment on the professional development impacting his beliefs about teaching and learning; however, Fluorine had an eleven-point gain in his RTOP scores from the beginning to the end of the semester and showed an increase in his student evaluation scores from 3.7 in the Fall semester of 2016, to 4.5 (the highest student evaluation for the participating GTAs in the Spring semester of 2017). Fluorine also described his role as an instructor as being a bridge to help students be less confused about the information from the textbook and the ideas they hold about chemistry. Fluorine described how he knew when students understood a concept:

> If I ask them, why do you think so and they say, because I think like this. So, at least they start coming up with something, something, even if that is wrong. And then, they say something. Then, I say something. And, I can ask them, still from that part; okay so, remember, or like imagine, if this is like this. What you are saying, then what about this? So that will, yeah, that will help them too. And then

> finally, when they get answers, some of the students are really happy. Like, did you get it? No, and then okay. Go on, think about it. Think about it; and then, they start like jumping. I, yes, yes, yeah. It is like that. So, it definitely helped students. That's what I want. I don't want to give them the direct answer. That's the easy way that you can do simply if you want your student to make happy. And because you have an evaluation, and all those things, right. So, if you give them, say in regular part, you give the answer, so they’ll be happy. But you can, I think, but you can make them be happy, and also make them learn. So, you will also be happy. (Fluorine, TBI, May 5)

Fluorine believed that his role was to give students time to understand the experiment and help them connect the experiment to their conceptual understanding. He found that students were excited when they were able to build their conceptual knowledge while completing the investigations. Fluorine indicated that he had grown from a previous understanding of knowledge being an absolute construct that must be transmitted to the learner to a view of knowledge being an independent construct that must be developed by the learner.

Fluorine thought he would be a better teacher if he were more compassionate, and if he could convey chemical problems in such a way that everyone regardless of education level could understand. He planned to improve his teaching by thinking of ways to make the experimental concepts more accessible for students to understand. Fluorine thought his best teaching quality was that he spoke slowly, and he tried to provide students with the big picture to help them know what they were doing during class. Fluorine did not try to break the topics into small pieces for students to know how to relate practical and theoretical; instead, Fluorine presented a broad, big-picture of topic, and his role was to help the students construct their understanding.

Fluorine had experience being a GTA at another university and described the requirements at that institution during our interview:

> We had a every teaching assistant, must take one credit scientific teaching method course, for two years, I think. Continuously, like fall, spring, fall, spring, and that course is all about like theoretical part of the - like education department - they have a curriculum, how to teach, how to make - what is that? Rubric? How to make a lesson plan, and so those things. So, what we used to, we had to do is each week - I had to prepare my - a lesson plan, with a few questions. (Fluorine, TBI, May 5)

Fluorine’s previous experience as a chemistry GTA included a mandatory course related to teaching and learning chemistry, which might also have influenced his beliefs. The labs he taught were student-centered in that they required students to develop their procedures which were then approved by the GTA.

Although her student evaluation scores were similar to those of Fluorine, Lithium had an RTOP rating that was 5 points higher, indicating a difference in epistemological development without the TBI results. Lithium did not complete the TBI, as she conducted and scored the interviews. Although she believed herself to be reform-oriented, GTAs often rate themselves higher in epistemological development than they really are.

Lithium’s field notes provided insight into her beliefs about teaching. “I am excited about the physical science class I will be working with people new to understanding science” (Lithium, notes, Jan. 20). As the class began, Lithium reviewed the topics before the lab and thought of questions. “We will be measuring and plotting both circumference and diameter, meeting of math and science. How is what we are doing in lab relevant to your life? When do we use circles?” (Lithium, notes, Jan. 25) As the semester progressed, Lithium continued to discuss each meeting in terms of “we,” referring to the classroom, without making a clear distinction between teacher and students, indicating an understanding of knowledge as being contextually formed during each experiment.

> We made lemon batteries in class and received voltage readings that were either positive or negative. We talked a little more about electrons being negatively charged. The students seemed to easily understand and fill in the blanks. My students are getting better at working together to answer the problems. (Lithium, notes, Mar. 2)

Lithium showed a reform-oriented perspective in highlighting students’ abilities to work together during experiments. Although Lithium was recorded twice at the end of the semester, neither video had sound for a second RTOP score. Lithium believed that “although I have years of theoretical pedagogical training, putting active learning strategies into teaching an experiment takes time and preparation” (Lithium, notes, Apr. 19).

Lithium believed that even experts needed time to set-up learning environments that facilitated student growth, not only in propositional knowledge, but also in communicative interactions. Lithium was the only participant from the mathematics and science education doctoral program to participate in the study. Lithium thought she would be a more effective GTA if she understood why the experiments were chosen for each lab. She also believed it would be helpful to have open feedback between GTAs and laboratory coordinators – perhaps weekly meetings to discuss possible improvements or challenges they had faced. Lithium thought she was always trying to improve her instruction, and this semester she wanted to work on being quiet and allowing students time to explore their ideas. Lithium tried to develop questions to ask students so they would share their understandings. She thought her best quality as a teacher was that she enjoyed people and chemistry. She also thought her research into conceptual knowledge development helped her be a better teacher. Lithium had the highest RTOP score of any GTAs that participated and held a contextual understanding of knowledge development.

The GTA role-identity varied according to the epistemological developmental levels of the GTAs. In general, GTAs with more experience who were closer to completing their programs scored higher on each measure of chemistry teaching - RTOP, TBI, and student evaluations. Iodine was a notable exception, as was Carbon. The workshops appeared to catalyze epistemological growth in some GTAs while having little impact on others.

Workshop

Research Question Three: What were the graduate students' opinions of the professional development content?

To understand the graduate students perspective on the workshops, I synthesized their responses from in-class reflections with answers from GTAs that completed a post-observation. I also asked the GTAs if they had any feedback for the chemistry department. I included thoughts the GTAs had about their teaching environments with their opinions about the professional development. Most GTAs had positive comments about their professional teaching environment and the workshops offered by Dr. Neon.

Workshop participation was an indicator of GTA epistemological development for doctoral students, although similar growth was not seen in correlation with the involvement of master's students. Three of the ten participating, half of the participating doctoral GTAs attended four of the six workshops and felt the workshops were not relevant because they had been teaching these labs for several years already. Although, Hydrogen did not attend any workshops, she did have feedback for the department which I will share in this section. Cobalt did not provide a reflection, as the one workshop he missed was the last one.When we spoke in February, Cobalt observed that the lab set up and structure had gotten better over the ten years he had been a student at the university. Cobalt stated that everything was good for him as a GTA. The remaining five participants attended all six workshops. Bromine and Silicon had the least experience as GTAs, with the exception of Carbon. Carbon had just started this semester and was the only master's student to exhibit a transitional level of epistemological development. Fluorine and

Lithium both showed higher levels of epistemological development when compared to other GTAs and attended all of the workshops.

I wanted to start with Hydrogen’s perspective since she had been a GTA for two years and exhibited an absolute level of epistemological development. Although Hydrogen did not attend the workshops, her conceptual understanding of knowledge development impacted the way she taught chemistry. The first recommendation from Hydrogen was related to the materials needed for each experiment, and she continued with a specific example of how to streamline the student's ability to complete the investigation and attain the proper answer. Hydrogen talked about having a materials list as they do in the biology labs that told the students exactly what equipment to use. Hydrogen also expressed distress about the way the lab manual was written; she thought it was confusing for the students.

Hydrogen used an example from the electrochemistry lab, which I had observed. Hydrogen thought that the experiment would be more clear if students were told exactly how to change the concentration in the cells they had created during the investigation. As Dr. Neon pointed out during the workshops, students’ conceptual understanding only changes if they have a moment of disequilibrium in which their initial concept does not match the evidence. The electrochemical experiment, as presented in the lab manual, allowed students the opportunity to change the concentrations at either the anode or the cathode by any amount they wanted, which forced students to take charge of building their conceptual understandings. Hydrogen provided the exact concentrations for her students to use when looking for a voltage change, limiting their capacity as learners to observing only what she had suggested. Hydrogen believed she understood how to teach her students and said she could submit her recommendations for changes to the laboratory coordinator as a way to provide feedback about her concerns.

Sodium, Iodine, and Chlorine each attended four of the six workshops. Sodium completed his TBI in February and did not have any comments on the workshop at that time, although he did have suggestions for GTA training. Iodine reflected on the workshops and thought they were good, but he felt like he was “twiddling his thumbs” a little bit. Chlorine provided feedback about the department and the workshop and explained that he believed the workshop was relevant only for people studying chemistry education. They were all experienced GTAs and saw no need to develop their knowledge or skills as an educator, although they thought the information Dr. Neon presented was interesting.

Sodium talked with me about teaching and learning chemistry in February, and he also reflected on the benefits of the workshops in-class. Sodium discussed differences he had seen in the way professors developed their courses and acknowledged that some were always trying to improve by collecting input each semester and adapting their practices. Sodium’s transitional level of epistemological development allowed him to note the differences in individual practices, and he said that in talking to other GTAs he found they wanted to improve their teaching abilities. Although he did not feel like it had been a problem for him, Sodium thought the professional development of GTAs needed to be implemented for new GTAs.

Sodium had attended a different university for his master's program and discussed the plan they had for training GTAs. He thought that our understanding should allow GTAs to come in for their first semester and be assistant GTAs. He noted the difficulty with language that many international GTAs experience and thought that allowing GTAs the opportunity to observe how classes are taught here and how to interact with people would help. Sodium thought GTAs would be more confident if they could see another instructor and have a better idea of how to teach chemistry laboratories (Sodium, TBI, Feb. 6). Sodium believed that he benefited from the workshops because he was primarily a researcher and the techniques on how to keep students engaged and how to teach were helpful. Sodium also gained the understanding that general chemistry was tricky, even for experts (Sodium, Apr. 10). Sodium did not demonstrate growth in either his RTOP or student evaluations, indicating the workshops had little impact on Sodium's practices as an instructor. Sodium's previous experience as a GTA that included professional development could have factored into his level of epistemological development according to Connolly et al. (2016).

Iodine provided feedback relating to the workshop during the in-class reflection and again during his TBI interview. Iodine thought the diagram of student learning exits helped him in understanding his students, and attempted to explain which picture by describing "unchanged beliefs, new beliefs, etc." (Iodine, Apr. 10). Iodine was referencing the Appleton article and the activity the GTAs participated in during the fourth workshop. It is interesting that Iodine used the term "beliefs" to describe students' conceptual understanding. Iodine believed the workshop was interesting and thought it helped him to see the students' perspective. He used the example of the game 'Petals Around the Rose' from the third workshop to demonstrate what he learned in the workshop. Iodine now understood that he had to find different ways to explain a topic - saying something louder and slower did not help facilitate student understanding. Iodine felt that as a teacher he needed to break the experiment down in order for his students to understand how the operation worked. Iodine said he had not talked to anyone else about the workshop. He thought the workshop was good, but because he had been teaching the labs for awhile, Iodine assumed it would be more beneficial for new GTAs. Although Iodine expressed the idea that he had gained knowledge about his students' understanding of science, his results from the RTOP and TBI indicated that he still viewed chemistry knowledge as an absolute construct to be transferred from teacher to students.

Chlorine was the most expressive of the participants regarding his opinions related to the workshops and completed both TBIs. Chlorine attended four of the six workshops, missing the same two as Sodium (workshops four and five). When I talked with Chlorine in February, he stated that being a GTA was an excellent opportunity to transfer experiences to students. Chlorine thought that chemistry was not easy and required students to accept concepts without explanation. He thought it was most important to be a student's friend and let them know that they cannot learn everything in the first year (Feb. 16). Chlorine reflected that he benefited from analysing the different situations that were provided. Chlorine also thought the workshops helped him recognize the needs of students and instructors (Chlorine, Apr. 10). Chlorine's recognition of student understanding indicated his epistemological development level was independent, and his belief that knowledge should be explained indicated an epistemological developmental level that was absolute.

Chlorine discussed his participation in the workshops with me and explained that because he was not in education, the workshops were not a priority for him or the other GTAs. Chlorine apologized for not completing the readings and skipping some meetings. He explained that if he were going to be an instructor, the information would be relevant; however, his goals were to finish his degree and get to work. While Chlorine thought it was good to look at different instructors and students and that it was good to sit down and talk with other GTAs, he did not feel the concepts were relevant to himself or the other chemistry GTAs. He believed it was important for people like Dr. Neon and me – that study education. He solidified his case by saying that he had many friends that were GTAs and he had been friends with them since we took a class together three years before.

He said he knew his responsibilities as an instructor, “you need to understand who they are and what they need, that is it” (Chlorine, TBI, Apr. 13). Chlorine believed GTAs should be helpful with what students needed to learn and teach what they needed to finish the course. Chlorine thought students should respect him and know that he was giving them the information they needed to get a good grade. He believed all students needed was to finish the class with a good grade. He understood that his students had different conceptual understandings. “They are not idiots, but they just don't understand the problem. They just cannot see the picture of the chemistry, and you know, that, right? It is not only their fault” (Chlorine, TBI, Apr. 13).

Chlorine also considered his student's feelings, “I think you need to let them feel like they can learn” (Chlorine, TBI, Apr. 13). Chlorine viewed each person as having his or her own understanding of content knowledge indicating an independent representation of knowledge in learners. However, held on to the absolute representation of knowledge transmission. While he knew his responsibility was to provide students everything they needed to get a good grade, Chlorine warned, “don't expect too much from them, but don't look down at them” (Chlorine, TBI, Apr. 13). Although his answers to the TBI varied slightly from February to April, Chlorine did not progress to an independent representation of knowledge construction. His responses continued to indicate knowledge was absolute and should be provided by himself, professors, or books to his students.

When I asked Chlorine about thoughts he could offer the chemistry department regarding GTAs, he said for himself everything was good; however, his friends did not think GTAs should teach in the first year. Chlorine said they were not familiar with the instruments and did not know lab techniques. He believed he was okay because he had already worked as a GTA for several years. Chlorine remembered when some of his friends started as GTAs and had come to him asking questions like: “How to do this one? And how to run the lab? What is in here? What does that mean? What should we do?” (Chlorine, TBI, Apr. 13). Chlorine believed that the lab coordinators should be sure that GTAs were trained before they taught. Although he wanted to be sure it was understood that training should “apply for the new one. You cannot apply to the old ones, because they don't want to hear the same old story” (Chlorine, TBI, Apr. 13). Chlorine wanted the topics related to each laboratory taught to his students before they came to his classroom.

“They should cover stuff in lecture. This one is just an illustration, you know. Of course, that's okay, that's okay. It's difficult for them teaching this whole program” (Chlorine, TBI, Apr. 13). Chlorine believed “everything very nice around here. We have a very nice place, right here” (Chlorine, TBI, Apr. 13). Chlorine was good with his development as a GTA and thought everything was beautiful; his concern was for his friends and GTAs just starting the program who needed training.

Bromine and Silicon both attended all six workshops and completed their TBIs after the workshops. Neither GTA demonstrated epistemological growth during the semester - they were both in the absolute epistemological development level, and both felt they had learned from the workshops. Bromine thought that he had learned a lot and appreciated all the workshops. Bromine thought the workshops were beneficial because they provided strategies (Bromine, Apr. 10). Bromine thought he had learned how to teach with teaching strategies and explanations of the strategy from the workshops. During the TBI, he responded similarly to his end of class reflections and stated that he “ liked the strategies provided in the workshop” (Bromine, TBI, Apr. 20). Bromine did not have time to follow-up on the types of strategies; it was possible he was referencing the tips for questioning Dr. Neon handed out during the fifth workshop.

Silicon felt as if the workshops had been an eye-opener for him to the student perspective. Silicon found the workshop to be beneficial for presenting an idea and for learning student names (Silicon, Apr. 10). Silicon believed the workshop had given him the opportunity to reflect on aspects of being a teacher that he had not considered before, like building friendships with students. In the workshops, Silicon learned how to be a problem-solver in his classroom by putting himself into his students' perspective. Silicon thought the workshops were excellent because he had seen GTAs in previous semesters teaching labs without knowing what students were investigating or why they were completing the experiments, GTAs had not written enough on the whiteboards. While participating in the workshops, Silicon learned to break down the initial barriers and communicate with students. He knew that sometimes it was not about getting the grade, and as a GTA he wanted his students to learn something (Silicon, TBI, Apr. 13). Silicon indicated that he appreciated and learned from the workshops, and he believed he had peers that needed the workshops to learn how to provide information to the students. Although Silicon thought the workshops had opened his eyes to the student perspective, he continued to demonstrate teacher-centered practices with an absolute understanding of knowledge.

Carbon attended all the workshops and demonstrated growth in epistemological development, as a first-semester master's student. Carbon believed she benefited from the workshops with the knowledge she gained about how students should be taught. She learned, as a chemistry GTA, it was essential to start with basic things and create a friendly learning environment that helped to make chemistry topics less complicated (Carbon, Apr. 10). When I asked Carbon to share her thoughts about the workshops, she promptly responded with a question, "do the workshops continue?" (Carbon, TBI, Apr. 12). I told her I did not know and she went on to say how valuable they had been to her this semester.

Carbon felt that she had learned a lot in the six workshops - even in just one hour Carbon thought we had learned something about how to be a GTA. Carbon thought that she had no idea how to be a GTA and she called herself a “blank GTA”. She explained that she did what Dr. Neon had told us to do and learned her students’ names. She thought that helped her to form stronger bonds with her students and believed she had improved as an instructor (Carbon, TBI, Apr. 12). Carbon’s RTOP scores showed little change in her practices as a reformed teacher; however, she was more confident in her abilities as a laboratory instructor. Her scores on the TBIs showed how Carbon’s beliefs about knowledge developed to transitional at the conclusion of the Spring 2017 semester, after participation in the workshops and actively applying skills gained from the professional development into her classroom.

Fluorine also attended every workshop and was the only GTA in the independent level of epistemological development. Fluorine found the workshops beneficial because they encouraged us to figure out many hidden problems and misconceptions related to teaching, while also encouraging us to see the perspectives of our students (Fluorine, Apr. 10). Fluorine was excited to talk about the workshop he liked best, which was getting the results from the Chemistry Concept Inventory (CCI).

Fluorine liked talking about misconceptions; during the second workshop, he was intrigued by the questions we missed as GTAs. “ I know, it looks like a really easy question, a simple question” (Fluorine, TBI, May 5). Seeing the misconceptions in himself and his peers spurred Fluorine to look for similar misconceptions in his students. Fluorine spotted a student in his classroom with a misconception about solubility and encouraged the student to collect the data and find out what the evidence suggested. Fluorine understood that chemistry concepts, such as the mole, could be very challenging for students. Fluorine sounded like a reform-based teacher at the end of the semester. He learned from the professional development, “And it is very important, like if you can help a student to come up with a good concept, I mean like correct a misconception, even one misconception. That is really a lot” (Fluorine, TBI, May 5).

While Fluorine found the workshop valuable, he felt that it was necessary only for new GTAs. Fluorine had previously talked about the science teaching methods course he had been a part of each week for two years as a GTA at a different university. When I asked about continuing the workshops, Fluorine took the opportunity to discuss laboratory teacher training. Fluorine thought that each lab coordinator should provide an introduction for new GTAs that included how to complete each experiment; he thought this could occur the week before classes start in the Fall semester. Fluorine felt that at the very least, GTAs needed an introduction to what were doing as laboratory instructors, “more than just a two-hour briefing” (Fluorine, TBI, May 5).

Lithium attended all six workshops and was the only GTA in the contextual epistemological developmental level. Lithium reflected on the benefits of the workshop and found her peer interactions to be the most useful. She believed the concepts and difficulties other GTAs held related to teaching similar experiments were the most valuable. Lithium thought that seeing areas where others struggled helped her to identify areas to improve as a GTA (Lithium, Apr. 10). Although not an international student, Lithium explained to Sodium in February that language was not the only potential difference students faced. Lithium said: “When I came here for graduate school, it was the first time I had been taught chemistry using didactic instruction” (Lithium, TBI, Feb. 6). Lithium’s previous experiences with student-centered instruction had encouraged her to construct knowledge with her peers. Lithium started graduate school anticipating that she would be shown around and know where to go and what to do before classes started. She was surprised when, “nobody told me, nobody showed you anything, they just handed you something, give you safety training and say ‘here you go’” (Lithium, TBI, Feb. 6). Lithium believed that GTAs knew they needed to learn because they were still students and continued to develop as teachers every semester. She did not expect her students to know the correct information or to have a good grade in her laboratory course. While talking with Silicon at the end of the semester, Lithium shared her expectations. “What I hope is that our students go away with a little bit more interest in science and chemistry, and that science is not so scary anymore” (Lithium, TBI, Apr. 13). Lithium wanted to use her experiences and conceptual understandings of chemistry to reduce negative feelings students had related to chemistry. She also believed students should be curious about topics, indicating the need for students to connect to content. Lithium might have started with an independent view of knowledge that developed through the semester into contextual, or she may have started at the contextual developmental level; either way, Lithium valued the perspective of her peers and encouraged her students to engage in understanding chemistry, indicating a contextual understanding of knowledge. Lithium also wanted the GTAs to interact more often with the lab coordinators.

Strengths Reflection

Research Question Four: How did the use of talent themes as defined by the Clifton StrengthFinder Assessment (CSFA) (Clifton & Nelson, 2010) affect the GTA practices or understandings of their role-identity?

Although four participants were asked to reflect using their talents only Carbon and Lithium mentioned their results from the CSFA. Bromine and Cobalt both answered the part of the question related to how misconceptions were formed with different ideas. Fluorine and Iodine were not asked to use their talents to address misconceptions and similarly answered the problem without addressing the formation of misconceptions in their students. Silicon was the only GTA not asked about their CSFA results to discuss the second piece of the issue and not attempt to resolve the formation of misconceptions. Lithium and Carbon knew how their talents impacted the classroom environment and tried to use those identified innate patterns of thoughts, feelings, and behaviors to limit potential misunderstandings in their students. GTAs’ responses to the misconception questions varied according to the initial demonstrated level of GTA epistemological development. When the GTAs were able to recall even one of their talent themes during the reflection, they exhibited an increased sense of substantivity in their roles as GTAs.

As a reminder, all GTAs that completed the Clifton Strengths Finder Assessment were asked to report their results during the third workshop. We brought in a strengths champion who talked about the potential impact that identifying and using talents in a leadership capacity could have on a person’s career. In the book provided during Workshop Two, Rath and Conchie (2008) discussed the importance of establishing a leadership team that had strengths in each of the four leadership domains - executing, influencing, relationship building, and strategic thinking Dr. Neon emphasized the leadership pillars of compassion, hope, trust, and stability that were also critical components of teaching. Each case in Chapter Five, contained the talents as reported by the participants. Figure 59 represents an overview of the distribution of talents themes from each leadership domain in the people that had taken the assessment previously as reported by in a team leadership report by Gallup (2016) to the participating GTAs. The distribution in the combination column chart and line graph represented areas of difference between GTAs and others. When percentages of responses are compared in Figure 59, we see that the distribution of executing talents was similar for both samples; however, a spike was observed in the strategic thinking domain for chemistry GTAs when compared to Gallup's population sample. In this sample, the distribution of talent themes found in the relationship building and influencing domains indicated a smaller amount of these talents were available for the formation of strong leadership teams.

When I interviewed GTAs after the workshop, I asked about their thoughts related to the CSFA. Carbon was the only GTA to recall any of her talents. After completing the assessment and talking about the talents, I offered to meet one on one with any GTAs that wanted to discuss their results in more detail. No participants contacted me, and the only other time GTAs were explicitly asked about their results was in Workshop Four. Carbon and Lithium were the only two that reflected with their CSFA results while Bromine and Cobalt answered similarly to the other participants in their absolute developmental group, Silicon and Iodine, and transitional, Fluorine.

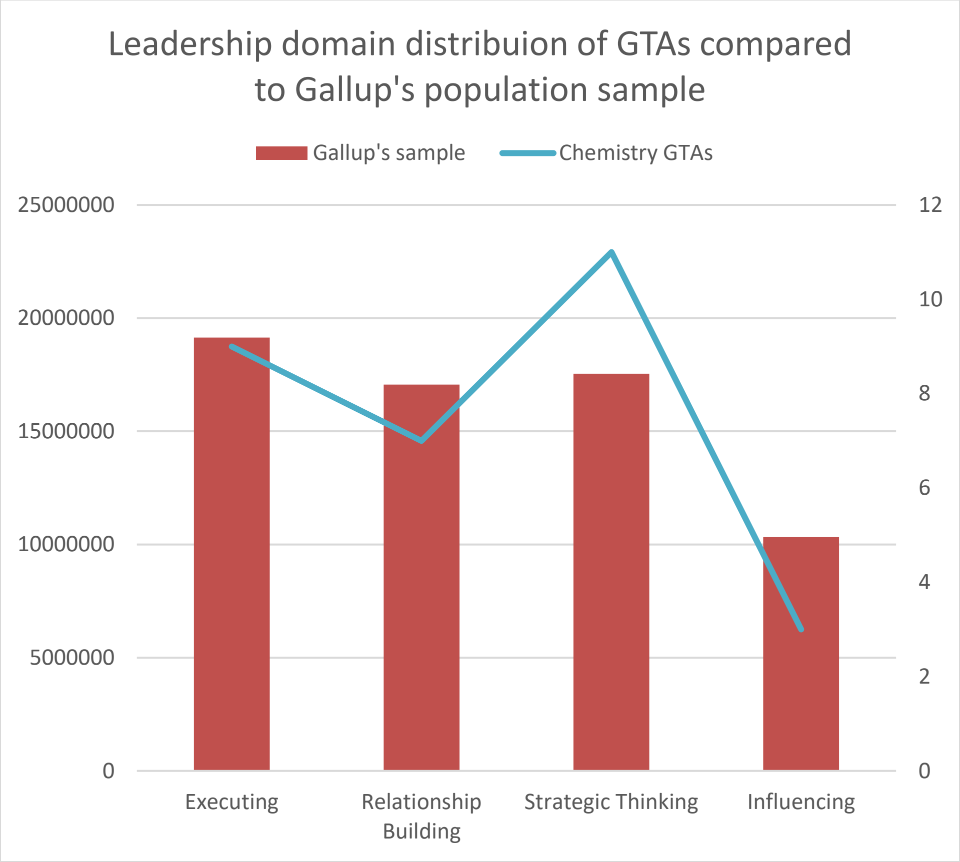


Figure 59. Distribution of leadership domains chemistry GTAs (n=6) compared to the population sample collected from Gallup (n=13557165).

GTAs were asked to reflect on the information presented during the previous workshops and in the readings in two different ways. Silicon, Iodine, and Fluorine answered the first question:

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? Discuss your answer and contrast your ideas to what Bodner said. Explain how using your knowledge of potential student misconceptions can help you better connect ideas in chemistry, so your students' understanding has minimal misconceptions. (Dr. Neon, Mar. 13)

To summarize Bodner's (1991) ideas, he concluded several things about knowledge and the formation of misconceptions in GTAs. Bodner claimed that graduate student misconceptions were instructor-driven. He highlighted the use of complex vocabulary used in conjunction with simplified formulas as potential areas for students to build misconceptions. Bodner also claimed that knowledge was constructed independently, and that knowledge was not the same as understanding. He found that misconceptions were resilient to instruction, given they were still maintained by graduate students that had completed hundreds of educational hours learning chemistry.

Bromine, Carbon, Cobalt, and Lithium answered the alternative question:

> Why do people working on graduate degrees in chemistry have misconceptions in general chemistry topics? Discuss your answer and contrast your ideas to what Bodner said. Explain how using your individual talents, as defined by the Clifton Strengths Finder Assessment, can help you better connect ideas in chemistry, so your students' understanding has minimal misconceptions. (Dr. Neon, Mar. 13)

We tried to make the change minimal so that the only difference was the inclusion of independent results from the CSFA. The answers were not as varied as I had hoped. Most GTAs addressed only one part of the question asked in their responses.

Interestingly, GTA interpretation of the question and beliefs about the formation of misconceptions were different when related to their level of epistemological development. Bromine, Carbon, Silicon, and Iodine each demonstrated an absolute understanding of epistemological development in their initial TBI or RTOP scores. Although asked different questions, Bromine and Iodine gave similar answers in that they both thought GTAs were proficient in one area of general chemistry, such as physical, organic, or inorganic and assumed GTAs had forgotten the concepts from general chemistry, which they had known previously. Carbon similarly thought GTAs neglected seemingly irrelevant or basic information as they became increasingly specialized in their research area. Silicon was the only GTA not to address the formation of graduate student misconceptions; he believed student misconceptions could be solved by providing detailed information, explicitly stating the objectives and showing connections (reflections, Mar. 13).

Fluorine, Cobalt, and Lithium were more developed epistemologically. Fluorine was not asked about his results from the CSFA, and he believed the formation of misconceptions occurred when the material was skipped in the learning process, in favor of learning about more interesting topics. Fluorine acknowledged an affective component to learning indicating a personal investment on the part of the student. Cobalt was the only GTA, other than Lithium, to mention engaging previously held conceptual understandings with the evidence from class or textbooks as undergraduate theoretical knowledge of chemistry was obtained. Cobalt believed the misconceptions came from a variety of perspectives in books and things being explained differently in lectures. Lithium thought learning was an on-going dynamic process and assumed misconceptions were the result of experience or information being falsely accommodated while merging with original conceptual representation. As GTAs evolved in epistemological understanding, they were able to form a more detailed description of the knowledge creation relating to chemistry (notes, Mar. 13). Cobalt thought of knowledge as a stable construct with multiple images, and Lithium indicated knowledge changed as understandings improved with the accommodation of new concepts.

Carbon and Lithium both addressed the minimization of misconceptions by using their talents, while Silicon believed providing information to be the most effective technique for eliminating student misconceptions. The level of epistemological development did not predict if the respondent included their talents or if they addressed minimizing misconceptions in their classroom. Silicon and Carbon both started at the absolute level of epistemological development; however, Carbon grew into the transitional level of epistemological development. Carbon (like Lithium) thought she could use connectedness to minimize student misconceptions. Lithium also noted how her talents of input, communication, and relator could be used to gather information regarding student conceptions and provide the relevant knowledge to help them construct an understanding of chemistry topics from the information contained in the laboratory (reflections, Mar. 13). Carbon and Lithium thought the results from their CSFA indicated patterns of thoughts, feelings, and behaviors that could help them be effective in their roles as GTAs and both mentioned their talents in the final workshop.

During the end of workshop reflections, Carbon again noted that connectedness could help her be a better GTA, while Lithium improved her role as a GTA by monitoring the use of her communication talent (notes, Apr. 10). Carbon noted her talent of connectedness explicitly regarding what she believed would make her a more effective GTA. Carbon focused on developing relationships with her students and allowing them to provide solutions to their problems. Carbon reflected on and named her talent of connectedness, and she grew in epistemological understanding of knowledge development.

Lithium did not explicitly name her talents of input and communication as she had previously; instead, she talked about monitoring how she used her talents in the classroom environment. When initially asked about using her talents in the classroom, Lithium indicated her talents in communication and input would help provide information for students (Lithium, Mar. 13). When responding to Dr. Neon’s questions in April, Lithium indicated she planned on improving her instruction by thinking of questions instead of providing information. Lithium recognized that how she used her talents in the classroom impacted her students’ ability to construct knowledge and admitted the weakness of using her talents of input and communication to provide information to the students while in the classroom; although, she claimed she was, “trying to shut-up” (Lithium, Apr. 10). Lithium showed metacognitive engagement in her practice as a GTA in that she planned, implemented, and reflected on the way she portrayed herself. Lithium monitored her practice as a teacher and reflecting with her talents in mind made her aware of the way her talents impacted the classroom environment.

Both GTAs that answered the reflection question using a talent demonstrated an increased awareness of how they impacted their students understanding of chemistry concepts. The ability to see how their talents influenced students allowed Lithium and Carbon to find ways to increase their understanding of student perspectives. Lithium had more experience as a GTA and demonstrated an increased vocabulary regarding psychological theories and demonstrated growth in knowledge of her role as a GTA. Lithium and Carbon were both unique cases for other reasons. Lithium as a researcher and Carbon was in her first semester as a GTA.

Implications for GTA Professional Development

Although one phenomenological research study is not generalizable and should be considered in context of how this study was designed and implemented for transferability. There are assertions that can be made from this research. First, regardless of GTA beliefs, the professional development opportunity served as a catalyst for the development of student-centered beliefs and teaching practices for the participants. The amount of impact was limited by the engagement of GTAs both during and outside the workshops. Second, the doctoral GTAs developed student centered teaching skills congruent to developing a more sophisticated epistemological understanding. Third, developing an understanding their talents as a strength for mentoring students gave GTAs Lithium and Carbon agency in their role.

The ten cases presented in this research highlight the importance of professional development opportunities for developing STEM GTAs’ identity. This Professional development allowed GTAs to construct and adapt their professional identity in collaboration with peers and the facilitator, a chemistry department representative. Following the model from Marbach-Ad et al. (2011) the implementation of a six-workshop professional development was enough to catalyze change in their GTAs. Although not every GTA believed they received professional benefit from the workshops, all the participants that attended workshops had a more student-centered teaching belief system than Hydrogen. And as previously established by Sandi-Urena et al. (2011) the implementation of student-centered instructional techniques increased the use of evidence-based practices by GTAs that are necessary as scientists. The level of doctoral GTAs participation and their engagement in developing conceptual pedagogical understanding outside of the workshops clearly showed increased epistemological development in Cobalt, Fluorine, and Lithium compared to the cases of Iodine, Chlorine, and Sodium. The divide in the cases and participation of GTAs could potentially be avoided. If the professional development continued, there would be no cause for the GTAs to "forget" to attend. As Carbon stated, the workshops helped her to build a conceptual understanding of her role as a GTA that aligned with the identity promoted by the chemistry department.

I followed the suggestion put forth by Luft et al. (2004) and used the science teacher professional knowledge bases (Gess-Newsome, 2015) as a foundation for my analysis. In doing so, I added the area of assessment knowledge to STEM GTA identity which was a domain more than assigned by Herrington and Nakhleh (2003) who had found that GTAs and students thought they should have expertise in the other four professional knowledge bases. The bases of professional teacher knowledge align with the five RTOP categories and as shown in Figure 6.1, each level of epistemological development had a corresponding increase in RTOP score. Two categories, communicative interactions and procedural content knowledge, were consistently low and this indicated that GTAs needed opportunities to develop their skills in these categories, which could be promoted. The professional development also gave GTAs the opportunity to question practices that they did not agree with in the classroom environment or the laboratory manual, which helped to eliminate the possibility of a GTA changing the intended lesson design in their presentation, as Hydrogen did during the electrochemistry experiment.

Finally, this represents the first documented use of the CSFA in the professional development of GTAs and the results indicated that a taking the assessment and providing a brief introduction was not enough to create an understanding of their CSFA results related to their teaching practices. Implementation of CSFA as a tool for GTA professional development did prove useful for Carbon in her first semester. She was able to see how her strength of connectedness positively impacted the learning environment she provided for her students. Lithium had a more sophisticated understanding of talents and was able to see how her talent of communication could negatively impact the potential for communicative interactions between her students. Their understanding of talents allowed them to see how adapting their personal behaviors impacted their students' conceptual construction of chemistry knowledge. Carbon's ability to quickly recognize her agency as a GTA might be the result of her knowing that she could impact her students with her strengths as Liesveld et al. (2005) indicated. Providing GTAs opportunities for further mentoring and coaching in the use of their talents as strengths might increase the efficacy of implementing student-centered practices in science learning environments.

Directions for Future Research

As is often the case when completing a research study, answering the questions related to the development of teaching practices in chemistry graduate students increased my curiosity about the alignment of teaching practices, teaching beliefs, and ability to implement student-centered teaching techniques. The first and most interesting to me was the growth observed in Carbon, as opposed to Bromine and Silicon. I am also curious about the concept Chlorine presented related to the knowledge and skills developed during the workshops - he thought the topics presented in the professional development only applied to individuals interested in educational research. The final aspect that deserves further investigation is related to the results from the CSFA, as shown in Figure 59. When I aligned the amount of workshop participation and level of epistemological development for each GTA with their RTOP scores and student evaluations, several aspects were apparent that need further evaluation.

Carbon had several differences from Bromine and Silicon, although they were all master's students that attended every workshop, Carbon's beliefs about her role as a laboratory instructor changed. The factors included being married to a more experience chemistry GTA, reflecting on her teaching practice with her connectedness strength, and being in her first semester as a GTA. Carbon demonstrated a transitional level of epistemological development while Bromine and Silicon continued to maintain an absolute view of knowledge development. Dolce (2003) noted that when a role was taken it remained stable until challenged. Although information presented in the workshops differed from the understandings portrayed by Bromine and Silicon, their concept of having to provide knowledge to be received by the students did not change. The stability of this GTA role as it develops over time could inform the development of techniques that facilitate GTA development by promoting moments of cognitive dissonance relating to their roles as GTAs. Continued research into the factors that impact epistemological growth in the first semester as a GTA versus subsequent semesters deserves further investigation.

The epistemological development that was observed in Lithium, Fluorine, and Cobalt (who each attended five or six workshops) was not observed in Iodine, Sodium, and Chlorine (who each missed two or more workshops). Although Sodium did not provide rationale for missing the workshops, Iodine and Chlorine both believed they did not need to attend the workshops because they were experienced GTAs. Their belief was contrary to the evidence presented by Sanger (2008) and Sandi-Urena et al. (2011) who found implementing student-centered instructional techniques supported the development of knowledge and skills necessary to perform scientific research, and to the evidence of epistemological growth in their peers. The mindset of GTAs regarding the impact of professional development is another area that deserves further research.

The GTAs who reported the results from their CSFA all agreed the assessment described patterns of thoughts, feelings, and behaviors they exhibited. The results also indicated that compared to the general population (n=13557165), the chemistry GTAs that participated in this study did not exhibit as many talents from the relationship building leadership domain. Although the sample size was small (n=6), the chemistry GTAs had a smaller percent of talents in the relationship building domain compared to the population sample (Gallup, 2016). A more through statistical analysis could help to determine if other STEM programs have a similar pattern. A lack of leadership talents in the relationship building domain could account for the emotionally cold climates noted by Strenta et al. (1994) as one of the reasons undergraduates moved away from STEM majors and into other majors. The epistemological development observed in Lithium and Carbon indicated that an understanding of talents in the classroom could be a catalyst for gaining a more sophisticated understanding of knowledge formation. Research into the distribution of talents themes and into professional developments designed to develop CSFA talents into strengths for teaching Liesveld et al. (2005) could lead to a deeper understanding of the connection between GTAs and undergraduate student retention.

Chapter Summary

The contents of this final chapter represented an overview of the research study I conducted into the epistemological and pedagogical development of chemistry GTAs as they participated in workshops designed to increase their knowledge and skills related to their practice as laboratory instructors. The evidence collected during the Spring of 2017 was used to synthesize the cases of ten chemistry GTAs that participated in the study. I found that graduate students’ epistemological development was related to their beliefs about science education teaching and learning. I also found that participation in the workshops increased the development of student-centered beliefs in several instances. The engagement of GTAs varied as did the impact to practice related to professional developments. I recommend that chemistry departments offer continual professional development each semester to support the science teaching identity of the chemistry GTAs. The study offered a brief glimpse into the potential impact of CSFA that is one of several interesting areas of potential research that resulted from this study of chemistry GTAs.

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APPENDICES

Appendix A

IRB

INSTITUTIONAL REVIEW BOARD

Office of Research Compliance,

010A Sam Ingram Building,

2269 Middle Tennessee Blvd

Murfreesboro, TN 37129

IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Thursday, December 15, 2016

Investigator(s): Tasha M. Frick (Student PI) and Amy Phelps (FA)

Investigator(s') Email(s): tmf3d@mtmail.mtsu.edu; amy.phelps@mtsu.edu

Department: Chemistry

Study Title: Explorations of chemistry graduate students' professional teaching assistant identity

Protocol ID: **17-2020**

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category *(7) Research on individual or group characteristics or behavior* A summary of the IRB action and other particulars in regard to this protocol application is tabulated as shown below:

IRB Action	APPROVED for one year from the date of this notification	
Date of expiration	12/31/2017	
Participant Size	50 (FIFTY)	
Participant Pool	**Adult (18+) MTSU Students**	
Exceptions	(1) Permitted to collect identifiable information (Full name, M#, Student evaluations, and Clifton Strengths Finder assessment) (2) Audio/Video recording is allowed (3) Artifacts from the class can be collected with consent	
Restrictions	**(1) Mandatory informed consent** **(2) The participant must be a GTA taking 6900** **(3) The data must be deidentified and all participant records including audio/video tapes must be destroyed**	
Comments	NONE	
Amendments	**Date**	**Post-approval Amendments** NONE

This protocol can be continued for up to THREE years (12/31/2019) by obtaining a continuation approval prior to 12/31/2017. Refer to the following schedule to plan your annual project reports and be aware that you may not receive a separate reminder to complete your continuing reviews. Failure in obtaining an approval for continuation will automatically result in cancellation of this protocol. Moreover, the completion of this study MUST be notified to the Office of Compliance by filing a final report in order to close-out the protocol.

IRBN001 Version 1.3 Revision Date 03.06.2016
Institutional Review Board Office of Compliance Middle Tennessee State
University Continuing Review Schedule:

Reporting Period	Requisition Deadline	IRB Comments
First year report	11/30/2017	INCOMPLETE
Second year report	11/30/2018	INCOMPLETE
Final report	11/30/2019	INCOMPLETE

The investigator(s) indicated in this notification should read and abide by all of the post-approval conditions imposed with this approval. Refer to the post-approval guidelines posted in the MTSU IRB's website. Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Amendments to this protocol must be approved by the IRB. Inclusion of new researchers must also be approved by the Office of Compliance before they begin to work on the project.

All of the research-related records, which include signed consent forms, investigator information and other documents related to the study, must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data storage must be maintained for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board

Middle Tennessee State University

Quick Links:

Click here for a detailed list of the post-approval responsibilities. More information on expedited procedures can be found here.

Appendix B

INSTRUCTIONS FOR INVESTIGATOR

The following is a template for a complete informed consent document. As a guide, it can be partially revised to fit your study. However, the first two (2) paragraphs and all questions need to be included, as required the by the Office of Human Research Protections.

If you choose to alter or waive consent for your study, you must provide justification to do so. Fill out the appropriate portion of the Request for Waiver or Alteration of Consent and attach it to your IRB application. The form can be accessed at http://www.mtsu.edu/irb/irbforms.shtml

If a question is not applicable to your study, simply insert n/a. You should also eliminate suggested language (in brackets and red type) if not pertinent to your study, to enhance participant comprehension. If used for a parent/legal guardian, alter language to refer to child.

Should you have any questions or need additional information, please do not hesitate to contact my office.

Compliance Officer

compliance@mtsu.edu

Box 134

Sam Ingram Building 011B

(615) 494-8918

Principal Investigator: Tasha Frick

Study Title: Explorations of chemistry graduate students' professional teaching assistant identity

Institution: Middle Tennessee State University

Name of participant:
____(print) Age: ___________

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**

   The purpose of this study is to explore chemistry graduate teaching assistants professional identity relating to teaching beliefs and practices. Group dynamics will be explored using the Symbolic Interaction theoretical framework. The role taken while GTAs participate in a chemistry education professional development will be examined. GTAs coursework, including weekly reflection about instructional practices focused on content articles compared to GTAs that use talents as a focus for reflection, will be analyzed. The results will include a grounded theory on the development of graduate teaching assistants' transitions as related to learning environments.

2. **Description of procedures to be followed and approximate duration of the study:**

The study will take place with chemistry graduate teaching assistants (GTAs) taking CHEM 6900 in Spring 2017. Before the class, interviews will be conducted and should take about an hour to complete. A similar interview will be given at the end of the Spring 2017 semester. In addition, participants instructional practices, during one of their scheduled laboratory classes, will be observed and video recorded by a pair of researchers before and after completion of CHEM 6900. I will not only be a researcher during the Spring 2017 semester, but also a participant in the CHEM 6900 course during which time field notes will be collected. The CHEM 6900 class will be video recorded to capture both peer and instructor interactions. After each class, field notes and videos will be reviewed to identify areas of potential growth in teaching and learning knowledge. All coursework submitted by participants will be analyzed in conjunction with their evolving GTA identities. Group work will be audio recorded and open interviews will be conducted to lend clarity to events that appear influential on participant teaching beliefs or practices.

Expected costs:

There are no expected costs to participating in this research.

3. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:** The risks associated with participation in this study are no greater than those normally encoutered in daily life as an graduate student enrolled in CHEM 6900.

4. **Anticipated benefits from this study:**
   a) This study should help to inform the scientific community about the development of GTA teacher beliefs and practices as they participate in professional development providing a much needed understanding of the transitions between belief and practice.
   b) Participants will have a deeper understanding of their knowledge of teacher practice.

5. **Alternative treatments available:**

   You will be expected to complete all assignments per the course syllabus and as indicated by the instructor of record. Each class will be video recorded, which is voluntary. Being audio recorded while working in small groups is also voluntary. If you wish not to participate in either aspect of the research project, you may let any of the researchers know at any time by completing the form to opt-out of recording.

6. **Compensation for participation:**

   There is no compensation for participation in this project.

7. **Circumstances under which the Principal Investigator may withdraw you from study participation:**

   You will be withdrawn from participating in the study if you no longer wish to participate or if you do not complete the research assessments.

8. **What happens if you choose to withdraw from study participation:**

   If you decide not to participate your data will not be used in the research project. Any data collected during this study will not influence your grade in the course, though completion of classroom assignments as requested by the instructor of record is required per the course syllabus.

9. **Contact Information:**

   If you should have any questions about this research study or possible injury, please feel free to contact **Tasha Frick** at **763-482-2390** or **tmf3d@mtmail.mtsu.edu** or my Faculty Advisor **Dr. Amy Phelps** at **Amy.Phelps@mtsu.edu**

10. **Confidentiality:**

Names will be redacted, and data will be kept in researchers' offices or in storage in the Science Building room 1143. Any recordings will not be shared publicly and will be kept on password protected computers at all times. All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board or the Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.

11. STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY

I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

____________________ ____

Date Signature of patient/volunteer

Consent obtained by:

____________________ ____

Date Signature

Tasha Frick, MSE PhD Candidate and Researcher

Appendix C

Good (morning/afternoon) – I am here to ask each of you to participate in my dissertation research. In the past several decades, chemistry education research has focused on increasing the effectiveness of chemistry teachers at all grade levels. Until recently, very little attention has been focused on the development of graduate student teaching ability. We have created a course, based on the key finding from literature, for teaching chemistry labs effectively at MTSU. The essence of the six week course was developed at the University of Maryland and has been found to increase scores on GTA evaluations.

In order to document growth in knowledge related to teaching and learning chemistry over the next semester, I will be recording our classes with video and audio. If you do not wish to be recorded, please fill out the form for opting out. In addition, one of my colleagues and I will come to observe your laboratory instructional practices in one lab section that you are teaching before and after completing this course. This observation will also be recorded to ensure validity of data and to be used as a reflection tool during interviews, if needed. I will also interview everyone before and after completing the course in order to discover your beliefs about teaching and how those beliefs correlate to classroom practice.

In order to gain full perspective of your GTA identity, I will be conducting interviews throughout the semester, in addition to analyzing assignments completed during the course. Once the analysis is complete, I will send you a copy of your case study. To ensure that our interpretations of events are similar, you will need to review the narrative and return it to me, noting any discrepancies.

I am excited about the chance to get to know each of you and learn about your unique perspectives. Although we will only have six weeks, my hope is that the knowledge we construct through this study will help to inform others about the development of chemistry graduate student educators. If you would like to share your perspectives about education in chemistry, please sign the consent form and I will set up an upcoming time for your initial interview. If you have questions or wish to stop participating at any time, talk to myself or Dr. Amy Phelps. Thank you for your time.

Appendix D

Classroom Observation Checklist

Lab Instructor Name_____________________________ Room#_____________

Date________________ Time__________ Lab section number (CHEM????:??)___________________________________

Explicit Instruction Well Organized Classroom Literacy Rich Science Classroom

____Teacher states the objective

____Teacher asks open-ended questions

____Students interact with each other on content issues

____Teacher causes thinking about connections to other scientific ideas and to real world applications

Comments & Example:

____Students routinely follow established rules & procedures

____Smooth transitions

____Students accountable for learning

____Teacher has positive interaction with students

____Creates a learning environment that results in a community of people collaborating to make sense of scientific ideas

Comments & Example:

____Authentic reading/writing in science observed

___ Uses appropriate scientific explanations

____Teaches science vocabulary

____Teacher asks students to clarify and justify their ideas in oral and written form

Comments & Example:

Lab Activity Assessment Technology

____Safety rules, appropriate procedures observed

____Students formulate questions and devise ways to answer them

____Students answer a question or solve a problem using open-ended instructions

____Students work cooperatively to make sense of scientific ideas and solve problems

Comments & Example:

____Assesses students' prior knowledge

____Checks for understanding periodically during lesson

____Students are able to present and explain solutions to their classmates

Comments & Example:

____Students use scientific tools & technology to reason, make connections, solve problems and communicate.

Comments & Example:

Reflections Comments

3 – 5 Observations:

What was the teacher doing?

What I heard the students say?

Things I observed which indicate that the teacher knows and responds to the different student learning needs and modalities?

How did the teacher evaluate the learning and progress of the students?

What were some instructional strategies that were used?

How did the teacher know that the students were able to learn what was being taught?

What evidence did you see that the students were learning?

What connections can you make with some of your course content?

Question stems were used to make sure that the lesson's objective was met?

What were the students able to do during the observation that indicated they learned the content taught?

What helped make this a successful lesson?

How did the students work?

How much time did students spend on the lesson you observed as interested, involved learners.