UNDERSTANDING THE SCIENCE PRACTICE-LINKED IDENTITIES OF PRESERVICE ELEMENTARY TEACHERS

by

Jocelyn Nardo

A Thesis

Submitted to the Faculty of Purdue University

In Partial Fulfillment of the Requirements for the degree of

Master of Science in Chemistry

Department of Chemistry

West Lafayette, Indiana

August 2019

THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF COMMITTEE APPROVAL

Dr. Minjung Ryu, Chair

Departments of Curriculum & Instruction and Chemistry

Dr. Marcy Towns, Committee Member

Department of Chemistry

Dr. Steven J. Burdick, Committee Member

Department of Curriculum & Instruction

Approved by:

Dr. Christine A. Hrycyna

Head of the Graduate Program

To my participants:

Thank you for your stories and for inspiring me to be the best researcher I can be.

ACKNOWLEDGMENTS

Thank you to my lab mates and friends who always supported me throughout this journey. Thank you for your words of encouragement and your words of feedback.

Without you all, none of this would have been possible.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Author: Nardo, Jocelyn, E. MA
Institution: Purdue University
Degree Received: May 2019
Title: Understanding the Science Practice-Linked Identities of Preservice Elementary Teachers
Committee Chair: Minjung Ryu

Science is an area of study with unique particularities concerning what "counts" as scientific practices where some learners are legitimized, while other learners are not. Such is the case for preservice elementary teachers (hereafter PSETs) – a population characterized by the literature as being in-need of science intervention. However, most of the literature deficiently conceptualizes PSETs' science learning, so I sought for ways to refigure their learning positively. Drawing from Van Horne and Bell's (2017) constructs of practice-linked and disciplinary identity, I offer that PSETs have nuanced, complex science identities that are influenced by their lived experiences inside and outside the classroom. To investigate the lived experiences of PSETs both inside and outside the classroom, 10 video-recorded, focus-group interviews were done while PSETs were undertaking an undergraduate chemistry-content course. Students were asked about their relationships with science as past elementary and high school students, as well as current undergraduate students. Students were also asked how they perceived their learning in the chemistry-content course. The research questions this work seeks to answer are:

- How do PSETs construct their science practice-linked identities?
- How does *Fundamentals of Chemistry* afford identity resources that contribute to PSETs' science practice-linked identities?

The data was coded for themes surrounding their science identities, teaching identities, and learning of each individual PSET. Using narrative analysis, I synthesized three allegories, "I am a science person," and "I am not a science person," and Ambiguous which aim to elucidate the spectrum of ways PSETs navigate science learning as a science person, a non-science person, and an unsure person. In addition to the PSETs' stories, I also analyzed how the chemistry-content course curriculum afforded PSETs with identity-building resources that helped science learning as current students and as future elementary teachers. I found that PSETs' science identities formed before the course impacted the ways they participated in the chemistry-content course (practice-linked identity), but the curriculum offered students opportunities to renegotiate their science

identities and practice science in ways that felt more legitimate to themselves and their prospective careers. Overall, I hope this work informs how instructors can design courses that are sensitive towards the needs of their students and highlight the importance of having a curriculum that affords students with the chance to re-engage with disciplinary practices in which their identities are legitimized as meaningful for their learning. If science determines practices that "count," science must also acknowledge *whose* practices are accounted.

CHAPTER 1. INTRODUCTION

1.1 Centering the Topic

Science is an area of study with unique particularities concerning what "counts" as scientific practices as defined by the discipline of science (Van Horne & Bell, 2017). For many learners, practices can impose implicit and explicit associations of self with science that impacts students' learning. These implicit and explicit associations of self constitute a "practice-linked identity," which is integral to how people perceive their learning as they participate [or do not participate] in the practices of a subject area (Basu & Barton, 2007). Associations of identity with learning that is designed for by an instructor is called a disciplinary identity, which becomes reified by participating [or not participating] in practices of the curriculum. Linking science identity and science learning, learning environments like undergraduate science classrooms function to either stabilize or disrupt science practice-linked identities by affording learners with different opportunities (i.e., identity resources) to participate in science practices (Furrer & Skinner, 2003) that afford disciplinary ways of knowing and being in science spaces (Airey & Linder, 2009). Having a practice-linked identity that aligns with a disciplinary science identity engages deeper learning of content material. Deeper learning of content material then propagates opportunities to connect science to who a learner is and who a learner is becoming within these science spaces (Dall'Alba, 2009). Therefore, undergraduate science-content courses should also account for the ways in which the disciplinary identity that is anticipated by the learning environment affords identity resources that help students cultivate science practice-linked identities. Cultivating science practice-linked identities create opportunities for science learning and participation that are contextualized in learners' lives and endure beyond undergraduate science-content courses (Van Horne & Bell, 2017).

However, studies have shown that when learners' practices are not legitimized as being meaningful for learning science, they are less likely to identify with science (Carlone & Johnson, 2007). For learners who feel they are not capable of doing science, cultivating a science practice-linked identity matters because these learners have been influenced by experiences mixed with academic success and academic failure in science (Jackson & Seiler, 2013). Such is the case for preservice elementary teachers (hereafter PSETs) – a population characterized by scholars as

having a “lack of science content knowledge” (Hoban, 2007, p. 75); “dislike for science teaching” (Tosun, 2000, p. 374); and “low personal self-efficacy [in science]” (Ramey-Gassert & Shroyer, 1992, p. 29). As a result, attention on science-content courses for PSETs has increased in recent years given that researchers and policymakers are concerned with the quality of science education in elementary schools and what that means for elementary students (NRC, 2012; NGSS Lead States, 2013). To address PSETs’ science preparation, many undergraduate teacher programs are providing science-content courses specifically designed for future elementary teachers like life sciences (Tessier, 2010), environmental sciences (Avard, 2009, 2010), and physical sciences (Schibeci & Murcia, 1999). The goal of these courses is usually to increase PSETs’ content knowledge in science (Schwarz, 2009); pedagogical content knowledge in science (Nilsson & Loughran, 2012); beliefs about science and science teaching (Tosun, 2000); attitudes towards science and science teaching (Beilock, Gunderson, Ramirez, & Levine, 2010); self-efficacy in science and science teaching (Cantrell, Young, & Moore, 2003); nature of science ideas (Abell & Smith, 1994).

In accordance, Bergman and Morphew’s (2015) literature review summarizes that science-content courses have helped PSETs have more realistic views on scientists; accurate ideas about the nature of science; confidence and better attitudes about science, science teaching, and science learning; and conceptual understanding of science-content itself. Nevertheless, some of the science-content courses PSETs take towards their degree still follow the typical university lecture-format structure of teaching (i.e., learning the same material in the same way as professional-trajectory students, engineering students, and other STEM-major students), which have shown to leave PSETs feeling inadequate (Reisert & Kielbasa, 1999) and ill-equipped to teach science at the elementary level given that the curricula are not designed with their needs in mind (Avard, 2010). These feelings of inadequacy can lead to feelings of illegitimacy, which has been shown to disrupt learners’ science learning, practice, and being (Barton et al., 2018). It is important to note that learners do not develop science practice-linked science in isolation. They must coordinate their science practice-linked identities across many other identities as students in classrooms, as employees in jobs, and as members in society—creating complex intersections of multiple identities that extend beyond the disciplines themselves (Allen & Eisenhart, 2007). These complex identity intersections act as contextualized resources that students can use to participate in learning

environments that afford their science practice-linked identity formation and consequential science learning (Van Horne & Bell, 2017).

Given that undergraduate science courses provide learning environments where PSETs may improve pre-existing perceptions about, attitudes toward, and relationships with science (Kelly, 2000), it is important that practitioners focus not only on *what* they teach but also on *how* they teach it. Research that sought to position PSETs as authors of their own science knowledge showed that not only were PSETs able to understand canonical chemistry qualified through their macroscopic, submicroscopic, and symbolic representations of phenomena but also were able to contextualize and represent how phenomena connected to their daily lives (Ryu, Nardo, & Wu, 2018). The study offered chemistry as a meaning-making tool for PSETs to learn how science is important and relevant for them and their lives as students and as teachers. However, little is known about how instructors incorporate science disciplinary identity into their curricular design and how curricula afford identity resources students can use to cultivate a science practice-linked identity in the context of preservice elementary teacher education. The research presented in this thesis aims to use identity as an analytical lens for examining how PSETs have cultivated and negotiated science practice-linked identities with a science disciplinary identity by participating in science practices as they learned chemistry while undertaking a content-course designed for PSETs.

1.2 Scope of Study

The chemistry-content course (hereafter, *Fundamentals of Chemistry*) is a class that is meant to give PSETs the opportunity to learn chemistry topics (e.g., matter, solubility, polarity, properties of gases, and properties of water.) by situating the material in everyday contexts. The lab component, which comes before the lecture component, promotes PSETs to explore chemistry topics and explain what they believe is happening in lab by leveraging their own real-life experiences and empirical data from the experiments performed. The lecture component afterward is designed to help PSETs test their conclusions from the lab experiments with what the science community has deemed canonical knowledge. The explicit goals of the course are to familiarize PSETs with the chemistry knowledge they will need to teach science at the elementary level according to state standards, while the implicit goals of the course are to offer PSETs a way to use science (specifically chemistry) as a way of knowing about the world around them.

For disclosure, I am a researcher who was asked by the instructor of the course to analyze the student interviews with the goal of understanding who preservice elementary teachers are and how they learn chemistry best. After watching the data set numerous times, transcribing the data set twice through, coding the data set purposefully and recursively, teaching the content-course as a teaching assistant and supervisor, and creating material for the content-course, I have come to see these students as complex learners who deserve better undergraduate science instruction that is informed by who they are. My hope is that the present study will deepen our understanding of how preservice elementary teachers come to know themselves as current science learners and future elementary teachers while they learn about and participate in science practices at the undergraduate level.

1.3 Problem Statement

The data set for this project consists of ten, video-recorded focus-group interviews that were done by the instructor of the course throughout the Fall 2015 semester. The questions in this section describe the overarching goals of the study and will be operationalized into research questions after a theoretical grounding has been articulated. To inform the study objectives, I ask the following guiding questions:

- How do preservice elementary teachers describe their learning and participation in science before entering undergraduate science courses?
- How do preservice elementary teachers describe their learning and participation in science during the *Fundamentals of Chemistry* course?

CHAPTER 2. LITERATURE REVIEW

2.1 Overview

This following chapter is broken into two major sections: "Research on Science Education for Teachers" and "Research on Identity in Science Education." The first section will describe literature on the impact that university courses have had on preservice elementary and secondary teachers, as well as in-service elementary and secondary teachers' science learning. The goal of the first section is to provide the broad view of how the literature has progressed in teacher education and establish the necessity of using literature discussed in the second section. The second section will describe the impact that research using identity as theoretical framework has had on the existing literature on PSETs' science learning. The goal of the second section is to elucidate the context for the conceptual and methodological frameworks that I will utilize in the study. After each of the two major sections, I will provide a summary called, "Synthesis for Scope of Study," to show how I will be drawing from the literature to argue for my research rationale.

2.2 Research on Science Education for Teachers

The following literature review was organized by looking in a variety of teacher education and science education journals: Journal of Research in Science Teaching, Journal of Science Teacher Education, Journal of Teacher Education, Journal of Chemical Education, and Journal of Chemistry Education Research and Practice because the context is to understand preservice teachers and how they view science and science teaching. I looked in the journals using keywords like "preservice elementary teacher," "early education majors," "student-teachers," and "primary school teacher." However, I also drew from literature that explored secondary preservice and in-service science teachers, and in-service elementary teachers to draw claims that could be generalized to preservice elementary teachers; for those studies, I specify the populations to make the claims transparent. I constructed the sub-categories (i.e., content knowledge, pedagogical content knowledge, nature of science ideas, attitudes, and self-efficacy) after reviewing the literature to understand what research has been done with PSETs specifically. I ordered the categories chronologically based on the constructs explored in the research studies with content knowledge being a somewhat older construct and with self-efficacy being somewhat newer

construct. However, it is important to note that these categories are not mutually exclusive and some more extensive studies cross-cut multiple of these sub-categories.

2.2.1 Content knowledge

Research on content knowledge in PSET science education literature typically utilizes Shulman's (1986, 1987) perspective. Shulman (1986, 1987) defines content knowledge as the "amount and organization of knowledge about a subject that a teacher has" (page 9). In accordance, Schwab (1978) summarizes content knowledge as 'having subject matter knowledge (SMK).' Schwab (1978) articulates that 'having SMK' requires an understanding of the nature of a subject area as agreed upon by the scholars within the field from which the subject area originated. Schwab (1978) argues that the structures (i.e., the nature) of a subject are both practice-oriented (i.e., substantive) and discursive-oriented (i.e., communicative), which work in tandem to decide how knowledge propagates within the community of scholars from a specific subject area. The practices that structure a subject area are responsible for determining the ways in which validity is established while the discourses that structure a subject area are responsible for legitimately conveying that validity to others within the subject community. Essentially, SMK is about understanding how knowledge in a field propagates. Research (see Jong, Veal, & Driel, 2002) focused on how PSETs learn these practices and discourses of subject areas to become better teachers have asserted that enhancing SMK is fruitful because there is a strong relationship between what teachers know and how they teach. Also, having SMK allows teachers to predict students' pre-conceptions on material so that teachers can create better learning environments that facilitate conceptual development.

Earlier studies that examined SMK often looked at in-service elementary teachers, but these studies do inform the literature on what PSETs *know* about science since the implications of the studies reference science-content and science-methods courses to motivate reform. Establishing the need to examine content-knowledge, Hodson (1993) showed that PSETs have "inadequate conceptions" of science concepts. In chemistry, PSETs' content knowledge has been investigated using misconception and alternative conceptions frameworks (Kruger & Summers, 1988; Kokkotas & Hatzinikita, 1994; Ahtee & Asunta, 1995), which implicate SMK as being the *outstanding* reason for why misconceptions in chemistry teaching and learning persist. These studies mostly employed interviews and concept inventories as their analytical tools to catalogue

what primary school teachers (Kokkotas & Hatzinikita, 1994; Ahtee & Asunta, 1995) and secondary high school teachers (Ahtee & Asunta, 1995) know about different chemistry concepts. However, other studies that did not use a misconception framework sought to understand *why* difficulties teaching chemistry concepts arose (Costa, 1997) and *why* specific chemistry concepts were most difficult for teachers to teach (McRobbie & Tobin, 1995). Both studies implicate lack of SMK as *one* factor in how content is communicated to students in a classroom given that teacher practice is influenced by a variety of constraints (i.e., state standards, state-mandated exams, school access to science resources, and other science teachers' ideas of science teaching).

To explain how SMK serves as a *factor* in teaching chemistry, Ginns & Watters' (1995) study explored the diversity of understandings that PSETs bring to science-content courses to investigate the importance of SMK for teacher learning. To assess elementary teachers' background knowledge in science, they drew from Yager (1991)'s constructivist learning model that asserts that the process of applying understanding, synthesis, application, and ability to use information should help PSETs develop basic science concepts. Their findings state that PSETs demonstrate many "inaccurate scientific concepts in the areas of science that form important components of elementary science curriculum" (page 219). They argue that having SMK is an important factor for solving problems within specific subject areas by helping PSETs think about scientific reasonings in the ways in which a subject area is structured, but do not assert that 'having SMK' alone ensures that teachers teach science more effectively. Moreover, other studies have shown that SMK is a factor that helps teachers organize his or her knowledge into mental models that promote efficient means of problem solving (Papageorgiou & Sakka, 2000). Papageorgiou and Sakka's (2000) examination of primary school teachers' ideas about the classification of matter showed that primary school teachers' lack of SMK impacts their teaching given that they perceive [and consequently present] topics in a "limited way" (page 245) since most teachers in the study relied on definitions of ideas, which siloed teachers' understanding of the material. As a result, teachers could not draw together relationships between concepts given that they could not reflect beyond the definitions of themselves. Therefore, 'having SMK' itself is less about knowing content for the sake of content and more about understanding how to arrange and connect definitions in meaningful ways. The findings from these papers justify De Jong, Veal, & van Driel's (2002) conclusions that understanding and enhancing SMKs does play an important role in informing teaching practices by anticipating students' preconceptions of the material. However,

many studies explain that SMK is *one* factor that reveals ideas about why teachers may or may not teach science effectively at the elementary level. Most importantly, these studies also reflect that examining SMK alone does not address the growing concern of *how* PSETs actually utilize their content knowledge in a teaching context.

2.2.2 Pedagogical content knowledge

To inform the ways in which PSETs may present content knowledge to students as in-service teachers, studies then began investigating a special form of knowledge inherent to teaching—pedagogical content knowledge. Shulman (1987) offers that pedagogical content knowledge (PCK) is defined as the amalgam of content and pedagogy that is "uniquely the province of teachers" (p. 8). PCK is the knowledge base that consists of how specific subject matter is organized, represented, and adapted, which is used by teachers to help students understand a specific subject area (Wilson, Shulman, & Richert, 1988). PCK is viewed as a transformation of SMK for the purposes of communicating content to students (Van Driel, Verloop, & De Vos, 1998); consequently, PCK lends itself to helping teachers become better facilitators in the classroom. 'Having SMK,' as the prior literature showed, is useful for predicting the ways in which students and teachers may think about different science concepts, but 'having SMK' cannot effectively ensure that the content is communicated to students effectively. Van Driel and colleagues (1998) surmise that PCK involves having the knowledge of student conceptions in a specific domain or topic; knowledge of representations of subject matter for teaching; and knowledge of learning strategies to overcome students' learning difficulties in a specific domain or topic. Therefore, PCK was theoretically constructed to operationalize SMK for the purposes of instructor teaching and student learning.

In the context of chemistry, De Jong and colleagues (2002) revealed that PCK helps secondary teachers select relevant demonstrations of abstract concepts to enhance learning and helps provide different strategies for presenting content material like stoichiometry since the teacher has different ways of conceptualizing the concept of, for example, "a mole." Moreover, coordinating these several knowledge components facilitates teachers to design and enact instruction in their classroom (Drake & Sherin, 2009), but has been found to be especially difficult for elementary teachers who are just developing this knowledge base (Grossman & Thompson, 2008) and tailoring this knowledge base for young learners (Abell & Roth, 1992). Given that

teachers are often mandated to adopt new published curricular programs (Ball & Cohen, 1996) and these curricula are often very generalized and vague (Enyedy & Goldberg, 2004), it is important that all teachers know how to modify curricula for the best interests of their students. Thus, enhancing PCK has been a goal for science-content courses to help PSETs critique and adapt science curriculum materials to their classroom practices (Beyer & Davis, 2012). Beyer and Davis (2012) offer that PCK allows PSETs to identify the potential strengths and weaknesses of materials so they can adapt them to enhance student learning. In addition, enhancing PCK is helpful to create educative materials for fostering science practices by engaging students in argumentation such that they can make predictions, collect and analyze data, and develop conclusions, which has also been supported by prior teacher education literature (Davis & Krajcik, 2005). Davis and Krajcik (2005) examined how K-12 teachers designing educative curriculum materials can promote teacher learning by empowering teachers to make instructional decisions by drawing on their PCK training. Designing educative materials drawing from PCK training allowed K-12 teachers to become self-aware of authentic activities that are related to a particular subject area since the PCK training helped the K-12 teachers help students recognize what constitutes the practices of a subject area.

However, PCK itself has been heavily critiqued in the teacher education literature as being difficult to measure (Kagan, 1990) and thus difficult to "teach" preservice teachers (Baxter & Lederman, 1999; Nilsson, 2008). Kagan (1990) argues that PCK by its definition is an internal construct (cognition) and cannot be understood directly. When observing teachers, they may be utilizing only part of their PCK for a particular moment, which does not necessarily characterize a teacher's entire PCK. Nilsson (2008) extends that to cultivate PCK, PSETs in their content-courses must be given the opportunity to transform the content knowledge they acquire by reflecting on the discipline itself. By reflecting on the discipline of science, PSETs can become more aware of how they think about their knowledge base (content knowledge) in science and, therefore, what effective strategies might be helpful to make their knowledge base accessible for students (pedagogical content knowledge).

2.2.3 Nature of science ideas

Reflecting upon how to integrate and present content knowledge into the classroom supports authentic science practice and what it means to "do science" can be summarized in the literature as the nature of science (NOS). Many studies surrounding NOS and preservice teacher

education use either Lederman's (1992) or the National Generation Science Standards definition of NOS. Lederman (1992) defines NOS as the "values and assumptions inherent to the development of scientific knowledge" (p.331). These values and assumptions propagate from engaging in science practices, which can be defined as the way science is done as determined by the epistemological and sociological view of what science is and how science knowledge develops. This epistemological and sociological view is summarized as NOS, which has been cited as being a major component in promoting scientific literacy (Holbrook & Rannikmae, 2009). According to Holbrook and Rannikmae (2009), NOS can contribute to scientific literacy and practice by providing the ability to make socio-scientific decision-making. Essentially, a scientifically literate individual has the knowledge and understanding of scientific concepts and practices (NOS) that are essential for making informed personal and social decisions. Therefore, the use of NOS to foster scientific literacy and practice is a goal that many science educators and curriculum reformers agree should be an important outcome of schooling, especially in K-12 (Roth & Lee, 2016). For many teachers of science, scientific knowledge has been distorted as the "absolute truth" (Tisher, 1971) given that traditional instruction (i.e., relying on the textbook as the curriculum) has portrayed science as being rational and relational "facts" that undeniably follow a logical pattern (Holton, 1978). Because PSETs throughout their academic careers may have practiced science through didactic orientations that portray science as a body of static knowledge (Roth, Anderson, & Smith, 1987), PSETs tend to hold a positivist view of knowledge that may influence the ways they present science to future science students (Southerland & Gess-Newsome, 1999).

Given that many PSETs have adopted this narrow understanding about NOS when they enter science-content courses (Abell & Smith, 1994) teaching PSETs NOS explicitly and implicitly in science-content courses has been an initiative at the undergraduate level. Thus, emergent studies have aimed to elucidate the correlations between teaching NOS through explicit instruction or through implicit NOS instruction within science-methods courses and with teacher's science instruction (Bell, Lederman, & Abd-El-Khalick, 1998). Examples of explicit instruction are NOS themed assignments (i.e., developing a poster that outlines the principles of NOS) and reflective teaching assignments (i.e., asking PSETs to think about how and why they would teach NOS to their students). Examples implicit instruction are problem-based learning (i.e., deconstructing the static nature of science by presenting open-ended problems) and authentic inquiry (i.e., modeling how scientists think through and answer problems). Akerson and colleagues (2014) found that

regardless of whether NOS was taught explicitly or implicitly, NOS concepts (i.e., what NGSS defines as NOS) were shifted and PSETs could understand the importance of teaching NOS strategies (i.e., explicit, reflective, problem-based learning, and authentic inquiry) to future students as long as the PSETs learned the importance of nature of science teaching as a part of their science teacher practices. To help instill a science teacher practices, Simmons and colleagues (1999) found that science-methods courses are important spaces to help PSETs discuss reform-based pedagogies like inquiry instructions since new teachers often hold conflicting ideas about student-centered and teacher-centered instruction.

Other studies extend that teaching NOS in teacher training spaces has been helpful to think about the discipline of science itself and what practices are specific and important to doing science (Abd-El-Khalick & Lederman, 1998; Brickhouse, 1989; Duschl & Wright, 1989; Lederman & Zeidler, 1987; Palmquist & Finley, 1997; Wolfe, 1989). Most notably, Wolfe (1989) showed that science teacher's views about the nature of a discipline can influence students' views of science because students are exposed to the limited science practices. To understand PSETs' conceptions about the nature of science, Abell and Smith (1994) gave PSETs a questionnaire that asked 140 PSETs to define what they mean by "science." They found that because PSETs have a narrow understanding of the nature of science, their future classroom instruction would be more teacher-focused rather than student-focused. Another studied showed that although PSETs want to do hands-on activities in science teaching, they might not understand why they are doing it or how it relates to how knowledge itself is constructed (Grosslight et al., 1991). To mitigate this, Grosslight and colleagues (1991) argue that teaching the reasoning behind using, for example, models can help deepen understanding about what models themselves do and how they are created for both students and teachers. Therefore, students and teachers would learn that models can be used as a "tool of inquiry" and not just as a "package of facts to be memorized" (p. 820).

Nevertheless, there are disagreements about whether teaching NOS helps PSETs and teachers overall become better science teachers in practice (Abd-El-Khalick, Bell, & Lederman, 1998; Lederman, & Zeidler, 1987). For example, Lederman and Zeidler's (1987) study found that although the biology teachers had NOS views that were consistent with reform-based pedagogies, their teaching experience and contexts had more impact on whether they implemented these strategies into their classroom practice. Recently, scholars have theorized NOS as a belief about science that may influence science teaching (Yoon & Kim, 2016). Yoon and Kim (2016) asserted

that although PSETs may understand that scientists may have multiple interpretations of data, they did not necessarily translate that *belief* to accepting and utilizing students' alternative conceptions to co-construct knowledge during their field experiences teaching science to elementary students. Studies that have investigated beliefs of science teaching showed that beliefs are influenced by attitudes and self-efficacy, which may translate to consequential behavior (Riggs & Enochs, 1990). Thus, studies involving PSETs and science have also made an initiative in science-content courses to not only help PSETs understand science content and the nature of science, but also help PSETs reframe their attitudes about science itself.

2.2.4 Attitudes

Many studies that investigated teachers attitudes towards science have defined attitude using Koballa and Crawley's (1985) operationalization: "general positive or negative feelings towards something." Research surrounding teacher's feelings about science began when Blackwood (1964) published a nationwide survey on elementary teachers and found that there was a lack of interest in teaching science. Washton (1971) study revealed that many elementary teachers lacked interest in teaching science because they did not want to pass negative feelings towards science onto their students. Stollberg (1969) corroborated this sentiment by elucidating the effects of science attitudes on teaching and found that a negative or neutral attitude toward science teaching can be communicated to students. Britner and Pajares (2006) extend that the quality of science instruction and teachers' attitudes toward science can influence students' attitudes and achievement in science and in selecting STEM-related careers. Finally, the National Research Council (2012) endorsed that the development of positive attitudes toward science is an important goal for fostering better science education.

Many studies have shown that PSETs have negative attitudes toward science and science teaching are artifacts of learning in the K-12 system (e.g., Pendergast, Lieberman-Bertz, & Vail, 2017). For example, Siegel and Ranney (2003) explored the implications of these negative feelings about science in the high school setting and found that negative attitudes may result in less inquiry-based instruction and more avoidance of science topics. However, critiques of attitudes research in K-12 contexts argue that the data sources are descriptive accounts of teacher's experiences or are pre-post surveys, which do not elaborate how to change negative attitudes (Kazempour & Sadler, 2014). Other works attempted to investigate the reasons behind these negative attitudes

towards science (beyond the K-12 system) and found that these negative attitudes are more complex since attitudes can be related to content knowledge (Greenfield et al., 2009). To investigate how attitudes are related to content knowledge, Greenfield and colleagues (2009) found that some preschool teachers have feelings of anxiety given that they felt they would not be able to do a successful science lesson because they did perceive themselves as having enough content knowledge. The preschool teachers that perceived themselves as having low content knowledge did not make time for science in their classroom instruction. Other preschool teachers that identified as having more "content knowledge" in science and "better attitudes" found that they did make time to teach science daily.

Furthermore, studies have shown that PSETs believe science itself is just too hard for them to teach (Yoon & Onchwari, 2006) and students to learn (Brenneman, 2010). Brennenman (2010) showed that some PSETs believe science is too abstract for young children to learn, so they forgo teaching it especially when there are high accountability subjects like Math and English. Pendergast and colleagues (2017) offer that despite PSETs' negative attitudes and beliefs, many PSETs understand the importance of science in elementary classrooms even if there is a discrepancy between PSETs' attitudes about teaching and their actual practices. In the context of chemistry, Çam and Geban (2016) attempted to understand PSETs' chemistry motivations and attitudes. Using case-based learning instruction (i.e., emphasizing students' everyday ideas about science as they shared their ideas with other students in an 'active learning process' (p.77)), the researchers found that leveraging everyday experiences helped PSETs improve their attitudes toward chemistry. Other studies have also found that using problem-based learning activities that leverage everyday experiences helped PSETs learn to make everyday life connections with concepts that improved their attitudes and content knowledge in chemistry; PSETs reported feeling more confident and more likely to teach science in their future elementary class (Şenocak, Taşkesenligil, & Sözbilir, 2007).

Overall, studies on in-service teachers offer that science-content courses should provide PSETs with *enjoyable* material that can also be used didactically. Although attitude does play an important role in how PSETs plan and conduct science activities (Pendergast, Lieberman-Betz, & Vail, 2017), not all PSETs perceive themselves as having "adequate knowledge to teach science and felt uncomfortable discussing and answering children's science-related questions or using scientific tools" (p. 51). Thus, studies argue that it is also important to help PSETs feel capable of

doing science-related activities that are enjoyable since PSETs do understand the importance of teaching science at the elementary level despite their general feelings about it. In terms of theoretical underpinnings, Koballa and Crawley's (1985) definition of attitude has been criticized for being undertheorized. Aalderen-Smeets and colleagues (2012) instead offered a comprehensive framework on attitudes that captures PSETs' attitudes toward science using three dimensions: 1) perceived control; 2) affective states; 3) cognitive beliefs. Perceived control was found to be most indicative of whether PSETs would do science-related activities in class (Riegle-Crumb et al., 2015). Perceived control was theorized by Aalderen-Smeets and colleagues (2012) using constructs that frame "self-efficacy." More recent studies have moved towards using science-content courses to help promote a sense of "capableness" in PSETs to teach science.

2.2.5 Self-Efficacy

Although some studies[1] describe self-efficacy as a "locus of control" (i.e., perceived control) (Rotter, 1966), many studies trying to understand self-efficacy in teacher education draw from Bandura's (1997) definition: "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p.3). Since self-efficacy is considers what a person *believes* they can accomplish using their skills, *belief* is very interrelated to ideas about attitudes as mentioned previously and with self-efficacy (Kazempour & Sadler, 2015). Bandura (1997) offers that self-efficacy as a construct is a social cognitive theory that is meant to explain how certain patterns of behavior are generated and sustained, whereby a strong sense of self-efficacy improves an individual's personal well-beings and deepens the meaning behind patterns of their behavior. The belief of capableness (i.e., self-efficacy) is especially important for how teachers and teacher educators recognize themselves as being competent [or usually] not competent to teach science (Gorski, Davis, & Reiter, 2012). For example, a teacher may believe that teaching science is beneficial to helping students become more well-rounded learners or have more meaningful life experiences, but if they do not *believe* that they can teach science then they are not likely to teach science. The literature has suggested that PSETs have various influences that affect their self-efficacy: influences from field experiences (Davis, Petish, & Smithy, 2006) and influences from science-teaching-methods courses (Carrier, 2009) and science-content courses (Bergman & Morphew, 2015).

[1] See (Armor et al., 1976; Berman & McLaughlin, 1977; and Tschannen-Moran & Woolfolk Hoy, 2001)

Influences from field experiences on self-efficacy have had some mixed results on PSETs' teaching practices. Aydin and Woolfolk Hoy (2005) showed that there are three significant predictors of preservice teachers' self-efficacy beliefs: the relationship between the preservice teacher and the teacher mentor; the amount of support the preservice teacher receives by the school community (e.g., other teachers and field placement supervisor); and the frequency of field experiences the preservice teacher observes and teaches. Wingfield and colleagues (2000) found that first-year elementary teachers' self-efficacy increased after being exposed to authentic classroom experiences where they witnessed "good" (i.e., doing inquiry-based learning and facilitating professional learning communities) science teaching. Using the science teaching efficacy belief instrument (STEBI-B), the researchers asserted that preservice teachers' self-efficacy increased because they were engaged in context-specific learning and were encouraged by mentor teachers that the preservice teachers had observed on and taught with. Nevertheless, Capraro and colleagues (2010) found that although self-efficacy may have increased due to positive field experiences, field experiences do not always connect how theory looks when it is practiced in teaching given that the breadth and depth of the observations and teaching opportunities are inherently limited. Moreover, Wagler and Wagler (2011) found that there was no positive change in PSETs' science attitudes and self-efficacy, implying that it is not as significant as once supposed (Gencer and Çakiroğlu, 2007).

Instead, influences from science-methods and science-content courses on self-efficacy are more promising for PSETs' science self-concepts. For science-methods courses, McDonnough and Matkins (2010) examined how field experiences embedded in science-methods courses impacted PSETs' self-efficacy. The researchers found that science-methods courses that embedded field experiences were more successful at increasing self-efficacy in science than science-methods courses that were decontextualized because the preservice teachers had more opportunities to put what they learned directly into practice. For science-content courses, Avery and Meyer (2012) showed that PSETs enrolled in environmental biology, a content-course for preservice elementary teachers, increased their self-efficacy and connected theory to practice by providing a conceptual understanding of inquiry and scientific research. Bergman and Morphew (2015) offer that after a single semester of experiences and learning in the science-content course, PSETs showed a statistically significant increase in their self-efficacy and outcome expectancy of teaching science, which was measured using a version of the Riggs and Enochs (1990) pre-post assessment.

Although the class was a science content-course, there was an implicit goal to increase PSETs' self-efficacy, which supposes that there is a connection between self-efficacy and content knowledge. The researchers reported that they had PSETs work more interactively using inquiry-based labs situated in everyday contexts. In accordance, Palmer and colleagues (2015) found that by using everyday materials with PSETs rather than specialized scientific equipment designed for science majors provided a more tailored experience for PSETs to enhance their understanding and self-efficacy in science learning and teaching.

Overall, these studies show that self-efficacy is a construct that is deeply rooted in PSETs beliefs about whether they can learn science to effectively teach it. Studies have shown that PSETs have rooted beliefs about science teaching and learning that have been shaped by their participation as students in science classrooms for many years, which have not been generally positive (Pendergast, Lieberman-Bertz, & Vail, 2017). Most studies that examine self-efficacy use Riggs and Enochs (1990)'s survey that measures self-efficacy in a pre-post fashion for intervention projects. This methodology, which has been used in numerous studies in addition to the ones presented in the review (e.g., Barnes, 2000; Plourde, 2002; Wingfield, Nath, Freeman, and Cohen, 2000), only show that there are two types of important beliefs: 1) personal science teaching efficacy, which refers to an individual's belief about their ability to teach science; and 2) science teaching outcome expectancy, which refers to an individual's belief that teaching science using reformed-based practices (i.e., inquiry labs) will help students. Exploring self-efficacy as a function of beliefs about oneself has been fruitful for placing the research scope on the individual PSETs; however, many of these studies come from the perspective that frames PSETs as having "low" self-efficacy that must be increased using a variety of the techniques discussed. The emphasis on a deficit-perspective ignores the ways in which PSETs may be leveraging other capabilities to teach effectively despite their 'short-comings'; therefore, research should work to examine the ways in which PSETs do learn within science-content to then make claims about what can be done to enhance their science learning

2.2.6 Synthesis for scope of study

From the literature search, it is clear content knowledge, pedagogical content knowledge, nature of science ideas, attitudes, and self-efficacy are all important constructs in understanding how to help preservice elementary teachers, preservice secondary teachers, and in-service teachers

teach science in their classrooms. Many studies that examine content knowledge and pedagogical content knowledge argue that they are inseparable constructs that are hard to evaluate on their own and also irrelevant to isolate given that they work concurrently and recursively (Carlson, Stokes, Helms, Gess-Newsome, & Gardner, 2015). PCK has also been notoriously difficult to measure since it is an internal, cognitive construct such that isolating moments even in practice cannot fully uncover the intricate system from which teachers draw from to communicate content to students in-moment (Kagan, 1990; Barnett, 2003). Barnett (2003) extends that PCK research lacks significant impact on teacher education practices because the analytical evidence for what counts as PCK is often defined by the researchers and not by the teachers themselves. This is problematic given the original definition from Shulman places the origins of PCK with the teachers that implicitly draw from it to communicate content.

Moreover, assessing and utilizing nature of science ideas to inform practice has had mixed impact. Contrary to the original goal of learning about the discipline of science, researchers and curriculum designers often *define* nature of science which then become more descriptive "facts" about what science is. In fact, the Next Generation Science Standards has (in)conveniently defined what the nature of science is so that teachers can teach them and teacher-educators can design curriculum around it. McComas and Almazroa (1998) argue that providing a definition of nature of science is pragmatic for implementing nature of science instruction. However, understanding the nature of science (i.e., understanding the definition and the accompanying principles) does not always translate to informed teaching practices as seen in the study with biology high school teachers (Lederman, 1997). The argument can be made that making nature of science too explicit makes these ideas far too prescriptive where student-teachers are simply learning the declarative "principles" of nature of science, but not necessarily gathering a sense of what science *actually* is. Similarly can be said about research concerning attitudes. Providing positive experiences that juxtapose what has been done in K-12 education is an important part of teacher education (Edwards & Loveridge, 2011), but not many studies elaborate what specific features of their design lend themselves to altering negative feelings (Kazempour & Sadler, 2015). Kazempour and Sadler (2015) also comment that although having positive attitudes or higher self-efficacy may support more science instruction happening in the classroom, positive attitudes do not necessarily guarantee that the science instruction itself will be inherently non-transmissive and reformed-based

in that saying, “hands-on [is great]” (p. 266), but does not necessarily imply that preservice teachers will purpose that teaching slogan effectively to promote student learning.

In terms of self-efficacy, the literature has been largely constrained by defining self-efficacy using Bandura’s (1997) original theory. Bandura (1997) used self-efficacy as a mechanism for understanding human agency (i.e., how to understand why humans behave the way they do in a setting). However, many studies misuse Bandura’s theory promote a pre-post analysis that does not assess behaviors in the setting. They are merely assessing the “beliefs” people have about themselves but not connecting to or evaluating on PSETs’ behaviors. Moreover, these studies are often superficial in that they find that self-efficacy increases or decreases, but their methods cannot sufficiently answer what design features of an intervention support *why* that is. Self-efficacy as defined by Bandura (1997) is a process, not a product of the human condition. Thus, studies (i.e., (Carrier, 2009)) that use interviews and classroom video data better understand the nuances in experience that lend themselves to supporting or disrupting PSETs’ self-efficacy. It is important for studies to not only capture PSETs’ beliefs but also capture how PSETs reflect on the behaviors as informed by those beliefs of capableness (i.e., self-efficacy). Furthermore, framing PSETs as having ‘low’ self-efficacy that must be increased reproduces the idea that PSETs are bad at science, but does not frame to transform and problematize that conjecture. In essence, it is evident that content knowledge, pedagogical content knowledge, nature of science ideas, attitudes, and self-efficacy constructs play intricate roles in how PSETs view themselves and science; however, it has been difficult to view how these constructs are interrelated and contributing to PSETs’ science learning and teaching. From this critique, I offer that identity can lend itself as a more useful way of understanding how these constructs are interrelated and contributing to better account for who PSETs are becoming within science spaces. To continue, I will now offer the research precedence for using identity in other contexts to make an argument for why I believe this theoretical lens is most useful for my master’s work.

2.3 Research on Identity and Science Education

The following literature review was organized by looking in teacher education and science education journals: Journal of Research in Science Teaching, Journal of Science Teacher Education, Journal of Teacher Education, and International Journal of Science Education because the context is to understand how identity has served as a useful lens for studying how learners

adopt practices and "become" within science learning spaces. For identity research, I first examined James Paul Gee's (2000) paper that established the perspective of using identity as an analytical lens in education research. From there, I used google scholar to find literature reviews that summarized the impact of that theoretical lens on science education research. For the preservice teacher findings, I looked in the journals using the same terms as before (i.e., "preservice elementary teacher," "early education majors," "student-teachers," and "primary school teacher"). Rather than drawing from all teacher education literature, I explicitly drew from studies that examined PSETs' identities within either science-content or science-methods course to articulate my argument since the focus of my research in this thesis will examine PSETs' science identities as shaped by a chemistry-content (i.e., science-content) course. I used older papers in the section about PSETs to show how the literature has been advancing in the direction that my master's thesis will also take. In addition to identity as the "topic" of research, I also summarized the methods that some papers used to show effective ways for examining science identity development that will also provide precedence for my master's work.

2.3.1 Identity in teacher education research

In terms of education research, Gee (2000) offered that identity can be a useful lens for understanding who people are as related to how people act within a given context, pushing the definition beyond simply someone's race, class, and gender. Gee argues that a person's actions give rise to an identity as others recognize one another as different "kinds of people," where the recognition as a "kind of person" changes as the context changes. Here, identity is operationalized as a "kind of person" that is recognized in some way by the outside world. According to Gee's theory, there are four different perspectives on identity that are all constructed through power: nature-identity, institution-identity, discourse-identity, and affinity-identity. Although these perspectives on identity are different, they are not inseparable in either theory or practice. Gee's motivation to make these perspectives on identity into discrete categorizes is strictly for the analytical purpose of understanding how identities are formed and sustained within contexts. Overall, Gee's call to use identity as an analytical lens for education research has been well-received and has been especially influential for teacher identity research (Freese, 2006; Olsen, 2008). Nevertheless, a critique of this work argues that a clear definition which connects teachers'

identities to the context being examined has often been missing in research surrounding student-teachers (Beijaard, Meijer, & Verloop, 2004). Because identities are shaped by power that exist as social structures, identities are interpretive by nature and must be well defined by a study to be useful.

Beauchamp and Thomas (2009) conducted an extensive literature review to capture the different arguments for using identity as an analytic tool to process how students undergo an identity shift as they move from being a student, to being a student-teacher, to being a teacher. There are many arguments using identity to understand and explain how students develop into teachers, but for brevity I will focus the discussion surrounding the identities presented as narratives teachers create to explain themselves and their teaching lives (Olsen, 2008; Sfard & Prusak, 2005) since this will lend itself to understanding my methodology. Olsen (2008) offers that teacher identity can be understood as both a product and as a process where the product refers to the powers that shape identity are being acknowledged at the moment of analysis whereas process refers to how the powers that shape identity also extend beyond the moment of analysis, maturing over time outside the study. Reifying identity as product and process helps researchers understand identity in-moment (local context) as well as consider identity at-large (global context). In addition, Sfard and Prusak (2005) show how collective discourses shape a person's own life and the lives of others within a community of practice. Drawing from Wenger (1998), Sfard and Prusak (2005) showed that identity is the negotiated experience of self that involves a community membership and learning trajectory within a local and global context. These negotiated experiences of self are a result of *reflecting* on one's experience as an individual tells their story; therefore, it is not the experiences as such that simply constitute an identity, but rather the *reflection* of our own and other individual's experiences that makes up an individual's identity.

2.3.2 Identity in science education research for underserved learners

Research on identity in a science education context focuses on the learning processes of students from a multiplicity of identity markers including race, gender, ethnolinguistic heritage, immigration status, socioenonmic status, and ability (Calabrese Barton & O'Neill, 2008; Carlone & Johnson, 2007; Kane & Rink 2016; Varelas, Kane, & Wylie, 2012). Carlone and Johnson (2007) explain that examining science identity allows researchers to understand the following: the kinds of people promoted and marginalized by science teaching and learning practices; the ways students

come to see science as a set of experiences, skills, knowledge, beliefs worthy (or unworthy) of their engagement; and the emerging identities in science that will translate into society. As a result, studying a students' science identity can also examine how a student learns science itself and whether or not that student may pursue a career in science. Jackson and Seiler (2013) offer that positioning is propagated within classrooms by the associated norms and practices established by the "cultural models" (i.e., meaning-making tools for participation). These cultural models influence who is considered a scientific person in which their identity performances become the archetype of science identity. Archetypes are important markers for how learners position themselves in the moment of science instruction, which would then influence how they view themselves in relation to science in the future. Thus, studies (e.g., Brandt, 2008; Gilbert & Yerrick, 2001; Kane & Rink 2016) have shown that by broadening the norms and practices established by the "cultural models" of science, learners may begin to identify with science where this (re)positioning process of self-hood links individual social action to broader social change (Ivanič, 1998).

Positioning can then be operationalized as how a person self-identifies as they move toward and/or within a community of practice in which self-identification can become a marker of a person's location within that community (Davies & Harré, 2000). Essentially, all students learn to position themselves as they self-identify with science in different ways, which influences how they participate, learn, and practice science in the classroom community. Drawing from Holland and Lave (2009), Barton and colleagues (2013) assert that identity is a result of how learners position (i.e., figure) themselves and others within a science classroom environment where positioning is influenced by the past, present, and possible future cultural models of what science is and who traditionally does science. Barton and colleagues add that identity involves authoring oneself in science or in any domain and is especially important for broadening the participation, learning, and practices of people who have been historically underrepresented and marginalized by science. Authoring oneself allows marginalized groups and communities to make knowledge more accessible (Canagarajah, 1996). Kane and Rink (2016) offer that authoring in science, especially for minoritized learners, provides counter-stories that challenge the social, cultural, and institutional narratives that exist within and outside of schools. In accordance, Martin (2007) investigated how adult African American students in a community college leverage their racial identities as resources of resilience and resistance, which produced counter-narratives that

challenged deficit models of learning for underrepresented students. By constructing and sharing these stories, the narratives of science itself change to be more inclusive of the identities of different learners who then (re)construct science and its practices.

2.3.3 Identity in preservice elementary teacher science education research

It would be remiss to say there have not been studies that use identity as an analytical lens for understanding teachers (Collopy, 2003; Drake, Spillane, & Hufferd-Ackles, 2001). However, most of these studies focus around high school content teachers who identify strongly with a particular subject area (e.g., Enyedy, Goldberg, & Welsh, 2006). Studies with secondary teachers do inform our understanding of primary teachers as shown with the literature review surrounding preservice elementary teachers and the constructs of content knowledge, pedagogical content knowledge, nature of science ideas, attitudes, and self-efficacy. For this research endeavor, it is important to consider the specific context that surrounds elementary teachers who are far from having a strong sense of self as a science person or science teacher (Mensah, 2016). Many PSETs have a strong affinity to a variety of subjects, which means they have developed multiple content area identities that can be leveraged within science-content courses to promote specific skills, content, and PCK for each subject. Thus, in constructing their identity to become a teacher, PSETs leverage subject matter identities as well as a general teacher identity (Mensah, 2016; Upadhyay, 2009).

Previous research focused on cultivating science teacher identities as a function of increasing PSETs' self-efficacy and confidence to teach science by creating positive learning experiences with science within undergraduate science-methods courses, but do not connect how they were assessing science teacher "identity" itself (Forbes & Davis, 2008; Gunning & Mensah, 2011). Gunning and Mensah (2011) argue that self-efficacy is linked to science teacher identity given that self-efficacy is defined as a person's belief of their capabilities to organize and execute the courses of action required to gain results, so if a teacher "believes he or she will succeed in teaching science, he or she is more likely to do so" (p. 30). In the study, the researchers conducted participant-observations throughout the semester, collected reflective journals, and interviewed participants to analyze how the science method course developed identity through mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states. In mastery and vicarious experiences, PSETs were tasked with creating and conducting science

lesson plans. To enact verbal persuasion and physiological/affective states, PSETs were praised on their performances during these teaching experiences. However, identity itself was never operationalized nor measured directly given that the researchers conflated self-efficacy and confidence with science teacher identity. In essence, the researchers did not carry the theoretical lens of identity into the analysis.

In accordance, Forbes and Davis's (2007) study define identity as a "person's evaluative stance toward interaction…cast in the romantic folk language of "who we are" (Lemke, 2000, p.283)" (p.911). The authors understand identity as a function of PSETs' knowledge, beliefs, self-efficacy, and general dispositions towards teaching practice and do cite Gee (2000), Sfard and Prusak (2005), as well as Lave and Wenger (1991); however, the methods that they used to understand identity development do not compliment the theoretical underpinnings and Lemke's definition offers minimal interpretive power. The researchers chose to use a survey instrument and a pre-post interview for data collection, which understands identity simply as a product rather than as a process of becoming. The data was then analyzed for "frequency" where the researchers chose to conflate frequency with meaningfulness to measure whether the Remillard (2005) model that the survey was based on "worked." As such, the researchers were more focused on proving the validity of the survey instrument than with providing authenticity to the PSETs' identities for which they supposedly attempted to study. Overall, their methods could only show that PSETs were adopting "curricular identities," but could not provide a mechanism for understanding *why*. The theoretical underpinnings that the authors used necessitates that identity is fundamentally concerned with how people act and negotiate themselves in social spaces, but they did not collect any data to show how PSETs interacted with the curricular materials. The researchers focused too heavily on the survey results and underutilized the interview data to showcase PSETs' meaningful reflections of the curricular materials. The methods the researchers are using are not entirely sufficient to answer the questions they are asking in the study. In that context, interviews could have been the space where PSETs reflected on their choices on the survey and emergent identities could have been realized by the researchers and the PSETs themselves.

More recent literature that examines PSETs' teaching identities has focused less on constructs like self-efficacy and more on identity as becoming a science learner (Avraamidou, 2016; Carrier, Whitehead, Walkowiak, Luginbuhl & Thomson, 2017; & Chen & Mensah, 2018). Carrier and colleagues (2017) did a qualitative study that investigated how PSETs' memories of

taking science in primary school and taking a STEM-focused undergraduate course both contributed to their identity development as a science teacher in elementary school. They drew from Avraamidou's (2014) identity trajectory model and from Gee's (2000) perspective of identity as an analytical tool and found that there were many factors that affected science teacher identity that were both outside and inside the control of their STEM-focused course: "Teachers' experiences as students in science classrooms, teacher preparation courses and field experiences, and the continued marginalisation of science in schools all influence teachers' developing identities as science teachers" (p. 1745). Overall, the reform-based practices initiated in the STEM-focused course helped PSETs reevaluate the memories they had with science and science instruction whereby the interview process helped them reflect on their former position as a science learner in K-12. The PSETs were able to better reconcile their disinterest with science as a function of the instruction rather than as a function of science itself, which informed how they implemented instruction during their first-year field experiences.

Moreover, Chen and Mensah (2018) also showed how science-content courses also helped establish a community of practice whereby the science discourses and practices serve as mediating tools for science identity development. In framing the science-content course as a community of practice, the researchers were able to understand how learning content in the class could be meaningful for the ways in which PSETs learn to see themselves as 'doers of science.' To examine how learning content mediated the identity development process, the researchers used a collective case study method developed to consider individual PSETs' identities and the holistic development of the science-content course as community of practice. This was done using interviews, questionnaires, and observations of the students during the course that asked about their experiences with science before the course and during the course as well as how they saw themselves teaching science at the elementary level. The interviews revealed the importance of legitimization in "doing the science" within the science-content course because PSETs felt a greater sense of belonging as they were positioned as being capable learners. Overall, the three case studies used narrative analysis to illustrate how personal histories, university coursework, and teaching contexts were all interrelated and inseparable factors for influencing how PSETs develop science teacher identities.

Finally, Avraamidou's (2016) offers the groundwork which lead these studies to come to fruition. Avraamidou's work draws from Connelly and Clandinin's (1999) definition of narrative

to understand the stories of (preservice) teachers. Using this framework for exploring PSETs' science identities, Avraamidou showed how previous experiences, present experiences, and future experiences are all connected under the constructs of interaction, continuity, and situation. Identity is defined as "the ways in which a teacher represents herself/himself through her/his views, orientations, attitudes, knowledge, and beliefs about science teaching, the kind of science teacher she/he envisions to be, and the ways in which she/he is recognized by others. These attributes (i.e. views, orientations, knowledge and beliefs, actions) were used in this study to characterize each of the participants' science identities" (p. 863). The data sources for this approach drew from interview data, drawings, observations, teaching philosophy statements, and self-portraits where 3 of 25 participants were carefully chosen to do a more in-depth narrative analysis. The study explicated the importance of adopting an identity lens that works in dialogue with life histories to examine how science identities develop over time and how they perpetuate within and outside of science spaces. Avraamidou showed how PSETs are a complicated group of students who are in a constant state of "becoming" [science] teachers, which is always being influenced by the past, present, and future as they figure themselves in the world of elementary science teaching. Given the constant flux of construction, negotiation, and deconstruction, Avraamidou explains that science-content courses can offer tools than can stabilize or disrupt these identity trajectories; consequently, a fruitful avenue for research is to examine how science-content courses afford identity-building resources for PSETs.

2.3.4 Synthesis for scope of study

Researchers who use identity as an analytical lens for education research have argued that identity offers a multi-faceted, complex approach to understanding the ways in which the person that we are is shaped by different forms of power (Gee, 2000). These different forms of power (i.e., natural, institutional, discursive, and affinitive) contribute to the ways in which learners are recognized, legitimized, and become within spaces. The literature on science identity examines the ways that students position themselves within the community of science, impacting their science learning and future trajectories in science. When learners are not recognized and legitimized in science, their trajectory in science become more delocalized and/ or disrupted such that learners do not "become" science people, which influences the ways in which they practice in science contexts and imbue science practices onto others. Thus, it is imperative that science spaces are

constructed in ways that do not marginalize learners, especially learners who are already on the periphery of science. Studies have shown that some PSETs have been marginalized by the practices established by community of science given that much of their disinterest can be traced back to their own experiences with K-12 science education (Hetcher, 2011). However, more recent literature with PSET identities argues for approaches to research with PSETs that shifts the proverbial, deficit narrative to a more complicated, affordance narrative where the researchers elucidate how PSETs draw on multiple identity resources to become future elementary teachers that teach science using non-transmissive and reformed-based practices.

In accordance, Beauchamp and Thomas (2007) acknowledge that understanding teacher identity could enhance the ways in which teacher education programs, especially courses, are conceived; however, there is an issue in how to properly define and operationalize identity for a study. Since identity is interrelated with and influenced by a variety of constructs like self, emotions, power, discourse, reflection, and agency, science-content courses have numerous contextual factors that afford identity resources for PSETs to cultivate and negotiate their identity construction. Because identity is interrelated and influenced by a variety of constructs, project scopes have also taken into account the ways in which past experiences (i.e., experiences that PSETs bring into science-method and science-content courses) have influenced present experiences (i.e., experiences PSETs have while taking science-method and science-content courses). Therefore, literature that considers PSET's life histories have shown the ways in which science-content courses that use reform-based practices can play a prominent role in how PSETs figure themselves as capable science learners (Avraamidou, 2016). Most notably, studies have offered narrative inquiry as a productive methodological tool to examine identity (Olsen, 2008; Sfard & Prusak, 2005). PSET identity (Avraamidou, 2016) given that the ways in which people describe or "narrate" themselves is an extension of who they are within a given context (Bruner, 2004). For PSETs, understanding their science identity as a narrative construction is helpful to understand the ways in which they are positioned by the literature and other cultural models. My intention in writing a literature review this extensive was to present the dominant narratives that surround PSETs so that I may juxtapose them later in this thesis. For my master's work, I will be drawing from an identity lens to understand how PSETs who were undertaking the science-content course, *Fundamentals of Chemistry*, are "becoming" by (re)constructing, negotiating, and cultivating a science identity as they reflect on their chemistry learning within a focus-group-

interview setting. In the next chapter, I will discuss the theoretical assumptions that inform my study and how I will be operationalizing identity, learning, and narrative.

CHAPTER 3. CONCEPTUAL FRAMEWORK

3.1 Overview

I begin by explaining the epistemological and ontological orientations that frame the study. I then discuss how those frames contribute to how I operationalize identity in the study. Finally, I discuss how identity is related to learning and learning settings.

3.2 Epistemological and Ontological Orientations

My work is grounded on a post-structuralist viewpoint that positions knowledge as being subjective and created, which contrasts to the positivistic epistemology that knowledge is objective and definite (Waterhouse, 2007). Constructivists from a post-structuralist viewpointF claim that knowledge is socially created and is the way the world can be known, whereby language is the way in which we make sense of the world and represent the world to ourselves and others (Bruner, 1990). Bruner (1990) explains that knowledge is always in construction where construction is constrained by the concepts, experiences, and understandings that are available to ourselves and others. Lincoln and Guba (2003) extend the constructivist argument that because knowledge is social (as opposed to objective and definite) knowledge cannot be separated from the 'knower' given that his or her mental or linguistic registers of the world constitute the mechanism the knower uses to make meaning within social, mental, and linguistic worlds.

Post-structuralism comes from postmodernism, which explicates a state of uncertainty about epistemology and necessitates new and various ways to represent knowledge that create narratives of what reality itself is (Richardson, 2003). Richardson (2003) states: "The core of postmodernism is to doubt that any method or theory, discourse or genre, tradition or novelty, has a universal and general claim as the 'right' or the privileged form of authoritative knowledge," (p. 507-8). Therefore, post-structuralists propose that the different means that we can represent knowledge is dependent upon the knowledges available to a person. This view emphasizes the 'social construction of reality, fluid identities of self, and partialities of all truths' (Lincoln & Guba, 2003, p. 273). In terms of qualitative research, this viewpoint frames data as being a social construct of the research process itself and is therefore a product of the 'skills and imagination of the interface between the researcher and the researched' (Ball, 1993, p. 45). The researcher can

make claims from the data only through the knowledges that are available to her as she investigates the social, mental, and linguistic worlds from which participants draw upon and operate within that are discoverable to her.

3.3 Identity and Narrative

Identity is defined as stories that unveil profound structures of intention and meaning and are characterized by dispositions acquired through culturally learned modes of being and valuing within social spaces (Madison, 2011; Sfard & Prusak, 2005). From a post-structuralist stance, identities are socially constructed and interpreted from the culturally learned knowledges (i.e., learned modes of being and valuing) that are constrained by the concepts, experiences, and understandings that are available to ourselves and others. By focusing on identity as an external process of socially constructed stories, researchers may better understand how identity produces different human actions that have different meanings depending on the norms, practices, values, and demands of the setting, born from the negotiation of overarching historical, cultural, and political processes (Carlone, Scott, & Lowder, 2014; Sfard & Prusak, 2005). For this work, it is important to interpret the stories of PSETs as "a narrative of expression" and "conception of identity" to better explicate how they see themselves as they are undergoing their coursework (Beauchamp & Thomas, 2007).

Drawing from Sfard and Prusak (2005), stories people tell are identity-making and identity-revealing processes given that people construct themselves as they present themselves to others. The activity of storytelling is an identity-making and identity-revealing process because people communicate the narratives of themselves. Thus, identities are what emerges in and through narrative as we externalize ourselves to ourselves and to others. Theorizing identity as a process rather than simply as an analytic product recognizes that identity is relational and dynamic given that it changes as a result of the social and contextual interactions that people have rather than as a result of an inner, spontaneous cognitive interaction (Juzwik, 2006). Given that identity materializes as the act of a "person's own narrativizations" (Gee, 2001, p. 111), identities are discursive and can be described as the discourses a person utilizes to tell her storied personhood. Identity is therefore a function of an identified person (A), an author (B), and the audience (C), producing a model that foregrounds the identified person ${}_{B}A_{C}$ (Sfard & Prusak, 2005). This model explicates the connections about A, B, and C as: the identified person (i.e., the participants), the

author (i.e., the participants or the researcher-participant), and the audience (i.e., other members of the participant community, the non-academic community, and/or the research community), which illustrates the discursive and co-constructed nature of identity.

Using Sfard and Prusak (2005)'s model of $_{B}A_{C}$, I define the identified persons (A) are the PSETs, the author (B) is me, and the recipients (C) are the other PSETs in the focus-group and the class instructor. Using this model, the focus of the researcher shifts from making essentialist claims that the narratives are "windows" to an intangible, indefinable entity. Acknowledging identity as a story constructed with multiple characters illustrates how "they are human-made; have authors and recipients; are collectively shaped even if told by the participants themselves; and are changed according to the authors' and recipients' perceptions and needs" (p. 9). Moreover, framing the study using the theoretical consideration of identity and narrative acknowledges the ways in which power acts upon the local and global setting. The acknowledgements of the local setting consist of the ways PSETs tell their story within the focus-group interview space as a function of who is in the room, room space, and time of year, while the acknowledgements of the global setting consist of the ways PSETs are positioned by the larger social, political, and cultural discourses that influence their access to different ways of describing their being and knowing within spaces. In my research context, I redefine identity as PSETs' reflecting on their lived experiences during a focus-group interview setting. Identity manifests as the ways in which PSETs reflect on past, present, and future stories of themselves in relation to science itself, science learning, and science teaching. To understand how past, present, future stories of participation constitute to PSETs' science learning, I draw from practice-linked and disciplinary identity constructs.

3.4 Identity and Learning

The relationship between learning and identity is defined as practice-linked identity: "one viewing participation in the practice as an integral part of who one is" (Cooks, 2009, p. 44), which essentially means a person is becoming within a learning setting is shaped by how they participate in a practice. Practice-linked identities are self-recognized by the learner as they reflect on why they engaged in practices of a discipline and what that means for their learning in that discipline. It is important to note that although learning and identity are related, learning and identity can also be looked at independently of each other (Nasir & Hand, 2008), but I believe that looking at learning and identity as linked through practice (i.e., practice-linked identity) is most productive

for my work. The practice-linked identity construct is historically situated within *Communities of Practice* (Wenger, 1998). Drawing from Wenger's (1998) *Communities of Practice*, Nasir and Cooks (2009) explain that participation and practice bridge learning and identity where as one learns and participates in the practices of a community, one becomes part of that community. Wenger (1998) offers that identity is an aspect of and results from learning, in which learning and identity involve shifts in relationships to people, objects, and memberships in communities of practice. Identity is socially constructed as a result the connections a learner makes with herself and the world around her. Learning transforms learners' identities because learning transforms the ways in which learners can thus participate in and draw from the other disciplines.

Practice-linked identities manifest as the way a learner perceives their participation within a discipline (Basu & Barton, 2007; Carlone et al., 2015; Nasir & Hand, 2008). Drawing from the idea of *Funds of Knowledge* (Moll et al., 1992; Vélez-Ibáñez & Greenberg,1990), Basu and Barton (2007) assert that learners practice within a discipline by connecting to their life experiences that emerge from participation, meaning there are many different, overlapping, and authentic ways in which one can practice and therefore identify with a discipline: as a consumer of the works and practices of a discipline; as a producer of new knowledge and products related to the discipline; as a critic who critically analyzes the disciplinary knowledge; and/or as a teacher who communicates disciplinary knowledge to others. Practice-linked identities are self-authored given that the learner cultivates how they want to practice and who they want to be by drawing from their experiences as they participate in academia and society. Examining how practice links identity and learning allows researchers to understand the ways in which learning settings afford learners with opportunities to author and negotiate their participation.

Here, I offer that using practice-linked identities as a construct allows me to understand how PSETs are reflecting on their past, present, and future participation in science practices and the particular ways that the PSETs' integrate those science "practices into the person she or he is becoming" (Cooks, 2009, p.175) as a future science teacher. Learners are making decisions about *how* they want to engage in scientific practices as afforded by the setting (Chinn, Buckland, & Samarapungavan, 2011). Chinn, Buckland, and Samarapungavan (2011) note that although learners may not necessarily be explicitly conscious of how or why they are engaging in science practices in a certain way (i.e., individuals may not know why they are valuing one knowledge product over another), their *reflections* of their practices communicate what learners believe is

valuable and derivative to their science learning. Understanding the affordances of a learning setting is fruitful for demonstrating how learning settings shape practices that connect to who the learner is becoming, which is understood through their participation in the practices of a discipline.

3.5 Identity and Learning Settings

Van Horne and Bell (2017) define a disciplinary identity as an identity that curriculum designers anticipate when they are creating learning tasks and objectives, which privilege certain disciplinary practices and therefore certain disciplinary modes of being. For example, doing lab experiments in groups helps promote the disciplinary practice of collaboration in science (i.e., students learn that science is done by working together). As mentioned above, learning settings can be supportive of moments that lead to the cultivation and stabilization of practice-linked identities given that learning settings are often designed with an intended disciplinary identity in mind (i.e., creating tasks to give students the opportunity to think like a chemist). Although these identity dimensions are often implicit to the curriculum designer and learner, it is important to note that curriculum usually frames the way learners may develop connections to subject matter ideas and practice different forms of disciplinary knowing (Van Horne & Bell, 2017). Disciplinary identities are constructed based on the discipline that explicates important practices of the discipline that learners should learn; it is not usually the province of the learner to define. Creating a curriculum that connects the discipline to learners' lives can co-construct learning situations that produce identity resources for which learners can leverage their own life experiences to "practice" in the discipline (i.e., cultivate practice-linked identities). From an asset-based view on learning, the curriculum should offer learners the space for them to view their life experiences as being meaningful for learning, which then influence the nuance of practices within a discipline, related disciplinary knowledges, and tools of inquiry (Banks et al., 2007).

Furthermore, science learning settings offer identity resources like designing and conducting experiments that then propagate evidence-based explanations and arguments (Lemke, 1990). Lemke (1990) emphasizes that science is a social, activity whereby participating in science practices helps learners experience science disciplinary ways of knowing like making observations, analyzing data, and writing lab reports. Although researchers have criticized that the science practices that learners engage in at school is often very removed from the professional scientific community (Brickhouse, Lowery, & Schultz, 2000), there is still merit in learners practicing the

norms, procedures, and language of school science given that learners are (if at the very least superficially) exposed to science figured worlds that may shape their practice and learning in future STEM careers (Olitsky, 2010). Olitsky (2010) showed that school science learning settings have a large impact on how learners see themselves participating in the science practices of the classroom, which can be changed to acknowledge learners' life experiences. By incorporating more opportunities (i.e., identity resources) for learners to connect the science to their roles outside of the classroom, learners with lower participation where able to cultivate a [school] science identity by personalizing the school science practices and drawing from their other identities inside and outside school. For the purposes of this work, I will be understanding how the curriculum of *Fundamentals of Chemistry* offers identity-material, relational, and ideational-building resources for PSETs to cultivate practice-linked identities in science that offer opportunities for PSETs to make sense of their current science learning and future science teaching, which I will now introduce.

Disciplinary identity is rooted in how learning spaces are structured by the instructor. Nasir and Hand (Nasir & Hand, 2008; Nasir & Cooks, 2009) have shown that the learning setting a) changes available identity resources a learner utilizes to understand and b) shifts participation, which relates to how other learners recognize one another and how a learner sees herself in the discipline. Referencing Lave and Wenger (1991), Nasir and Cooks (2009) explicate that identity resources support how learners can participate in the practices of a discipline. They operationalize three types of identity resources: "material resources (physical artifacts in the setting), relational resources (interpersonal connections to learners in the setting), and ideational resources (ideas about herself and her relationship to and place in the practice and the world, as well as ideas about what is valued and what is good)" (p. 44). Examples of material resources are typically texts (i.e., worksheets and PowerPoints.) that students physically *use* for their learning; although material resources are not usually people, if students *use* instructor, TAs, or other students superficially, then they can be material resources. Examples of relational resources are typically people (i.e., instructors, TAs, or other students) that serve as a point of comparison for the learner; the learner reflects on her learning and becoming because of interactions between other people in the setting. Examples of ideational resources are typically values students have for what is related to themselves and their learning goals; the learner is drawn to certain materials because she thinks it will help her in a future career or in her everyday life. Although identity resources are the property

of the learner (i.e., all learners may use the resource differently to shape themselves and their learning), they are made available to learners within the learning setting since the curriculum designer creates learning tasks by acknowledging the practices that learners should know within a discipline. Thus, curricula provide resources, but learners transform the resources into tools. The disciplinary identity frames the curriculum that affords students with identity resources to construct their practice-linked identity.

3.6 Summary

I will now describe how the constructs of narrative, practice-linked identity, and disciplinary identity are connected and related to my study context. From a post-structuralist stance, identities are socially constructed and interpreted from culturally learned modes of being and valuing that are constrained by the concepts, experiences, and understandings that are available to ourselves and others. I have defined identity as stories that unveil profound structures of intention and meaning and are characterized by dispositions acquired through culturally learned modes of being and valuing within social spaces (Madison, 2011; Sfard and Prusak (2005). Narratives provide the sociohistorical, collective contexts of meanings for actions, productions, performances, and disputes. The ways people cultivate an identity is through practice in that people learn how to practice by learning the dispositions necessary to tell stories of their participation. Thus, identities that are acquired through learning how to practice are termed, "practice-linked identities." Practice-linked identities elucidate how participating in practices can lead people towards or away from a discipline.

Science practice-linked identities refer to the practices that PSETs learn to participate in science learning setting communities. Because individual PSETs tell different stories that may or may not be related to science, the ways they practice science are different; therefore, every PSET has different science practice-linked identities in that practices do not have to be exclusively learned from the school context. Some of those authored science practices are legitimized by the science learning setting community while others are not, which means some science practiced-linked identities are legitimized while others are not. The science learning setting community is co-created by the instructor and the students where the instructor implicitly draws from a science disciplinary identity to create learning tasks and objectives for students to practice. The learning tasks and objectives for students to practice offer practice-linked identity resources that can support

how learners can participate in the practices of a discipline. There are three types of identity resources: "material resources (physical artifacts in the setting), relational resources (interpersonal connections to learners in the setting), and ideational resources (ideas about herself and her relationship to and place in the practice and the world, as well as ideas about what is valued and what is good)" (Nasir & Cooks, 2009, p. 44). Essentially, the *Fundamentals of Chemistry* course serves as a science learning community setting, designed implicitly from a disciplinary identity. The *Fundamentals of Chemistry* course affords PSETs with identity resources in the form of learning tasks and objectives that PSETs utilize to cultivate their science practice-linked identities.

Examining science practice-linked and science disciplinary identity together sponsors the dialogic process between students and instructors as they are both performing and contributing to the science learning setting community and science practice-linked identities. Theoretically considering the *Fundamentals of Chemistry* course with a disciplinary identity frame allows the practice-linked identities that PSETs' articulate to be understood in context of the curricular affordances. Since practices that originate from the course are not understood arbitrarily as practices PSETs just did to do, these practices were done with the purpose of fostering science learning and that learning is understood as contributing to their becoming. To understand how PSETs cultivate their science practice-linked identities in the shadow of the *Fundamentals of Chemistry*'s disciplinary identity, I offer narrative inquiry.

CHAPTER 4. METHODOLOGY

4.1 Overview

I begin by explaining the epistemological and ontological underpinnings of narrative inquiry that I utilize within my work given there are many ways to discuss narrative as a construct and narrative inquiry as a tool for inquiry and praxis. Afterward, I describe the precedence for using narrative work to understand the storied lives of teachers. I then explain the general role of the researcher within narrative work and the type of analysis that I will draw from to construct the analytical chapters (i.e., the narratives) of this master's work. Finally, I will discuss the general limitations of using narrative inquiry as a methodology to frame the study and better ground the implications that can be generated from using this analytical tool with this type of data set.

4.2 Ideologies in Narrative Inquiry

Story as artifact is rooted in the epistemological assumption that people are both living storied lives and telling storied lives through texts as they reflect and present themselves to others (Connelly and Clandinin & 1990). Therefore, metaphysical experiences become the proverbial stories that portray how a person interacts with and explores within the social, cultural, and institutional narratives of others (Clandinin & Rosiek, 2006). The social, cultural, and institutional contexts of narrative are elucidated by Dewey's theory as "dimensions" of narrative (1938): 1st Dimension: The personal and social (interaction); 2nd Dimension: Past, present, and future (continuity); and 3rd Dimension: Place (situation). Clandinin and Connelly (2000) summarize these three principles of narrative dimension as "stories have temporal dimensions and address temporal matters: they focus on the personal and the social in a balance appropriate to the inquiry: and they occur in specific places or sequences of places" (p. 54). The notion of narrative dimension in Dewey's theory captures how "dimension" structures experiences and therefore narratives. Since experience is structured by these principles of space, capturing experience is not possible through traditional means. Narrative inquiry acknowledges space by attending to the temporal and complex nature of experience and does not seek to categorize it.

Stories are more than a data source/object that can be nominally categorized into a paradigmatic scheme (Bruner, 2004). In a paradigmatic model, objects can be reduced to their

commonalities where knowledge of these objects can be unequivocally communicated. Bruner (2004) argues that human actions, which develop from people's past experiences, are not objects. The lack of object-ness means human actions are inherently unique and not unequivocally communicative, so they cannot be unequivocally categorized. The assemblage of experience through story can be used to understand new human actions by means of analogy. Through analogy, the goal of an assemblage of stories is to find what is familiar in new stories but also be open to the nuances that can emerge from stories both old and new (Lave, 1988). By exploring the differences in human actions through narrative inquiry, the temporal emotional and motivational meanings of stories are maintained and connected.

Consequently, the result of using narrative inquiry is a story that retroactively links past experiences that maintain these temporal emotional and motivational meanings, not reduce them into schemas of the present. Identity is viewed as a discursive activity and a 'communicational practice' of telling others who we are (Sfard & Prusak, 2005, p.16). Bruner (2004) explains that narratives become what we 'tell about' our lives and is the way in which we give our lives meaning as we identify who we are in the narrative of our being. However, narratives themselves are not simply discursive works, but the experience of crafting an identity work itself. Story-telling is the performance of identity negotiation and is also symbolic of powerful local interactions and broader social structures as the narrator decides how to position themselves and others in the story (Wortham, 2004). Watson (2006) adds that telling stories is doing identity work because telling a story extends beyond the teller and must also consider who the story is being told to, which shape's the teller's identity and produces collective storytelling. In the context of science, identity has been useful for identifying how students construct their identity in relation the discipline itself.

4.3 Precedence for Narrative in Teacher Education Research

The literature surrounding student-teacher identity also offers that identity shapes and is shaped by the discourses used to construct the narrative of oneself. Discourses are known as the languages that people use to communicate themselves to others. In context of a post-structuralist paradigm, discourses are the medium by which these realms of interpretation that are constructed by concepts, experiences, and understandings of people. Currie (1998) highlights the importance of discourse through self-narration: "we learn how to self-narrate…through the process of identification with other characters. This gives narration the potential to teach us how to conceive

ourselves, what to make of our inner life, and how to organize it. The discourses that people draw from emerge from the larger social, political, and cultural discourse communities that people belong (Holstein & Gubrium, 2000). Holstein and Gubrium (2000) offer that people are not completely subjected to or subjected by the discourses that people live in given that each person has the agency to author how they use their discourse. Thus, discourse is not something that should be seen prescriptively as "an explanation of how specific actors come to take on individual identities [requiring] some attention to them as engaged in relationship, not simply positioned as performers or spectators" (Munro, 1998, p. 33). Munro (1998) argues that "discourse determinism" (i.e., the use of discourse to *validate* existences of identities) discounts the agency that people have and circumvents the heart of discursive identity given that it is *how* people *nuance* discourse (not explicitly the discourses themselves) that their identities lie and tell.

The "narrative turn" in education research began when advocates wanted to understand the storied lives of teachers (Bullough, 1989; Grumet, 1987; Pinar, 1975). Before the advent of narrative inquiry, teachers were viewed as being unaware of how they were reproducing inequitable social structures. Through teachers' oral and autobiographies, reductionist views of curriculum that dichotomized education as "teachers" versus "students" was dismantled. Curriculum redefined by narrative inquiry as the "course of life," became the space where students' and teachers' lives are being lived simultaneously and influenced consequently. In this new definition of curriculum, teachers reproduce and revolutionize social structures; communicate and reinterpret curriculum context; and cooperate with or act against the students (Connelly & Clandinin, 1990). Given that narrative inquiry was a methodological tool to help explore teachers' lives, I offer that this methodological tool can be useful to explore the identities of PSETs as they understand themselves while undertaking a science-content course.

4.4 Role of the Researcher

In traditional qualitative methods, researchers examine data for emergent, common themes that are recursively tested until the meaning made from the data can produce a model that properly encapsulates the data and potentially predicts what would happen in other settings. However, narrative inquiry accomplishes model-making by creating emotionally situated stories rather than through the traditional means of producing research "findings" that are meant to explain, predict, and control future outcomes (Barone & Eisner, 1997). By employing narrative inquiry, researchers

not only become more empathetic towards their participants but also position the knowledge co-constructed with participants as more than propositional text (i.e., statements for the researcher to accept or deny). The stories we tell about our participants are created, destroyed, and reimagined as research questions are drafted, participants are selected, artifacts are collected, texts are written, and stories are (re)told. Researchers are always making conscious and unconscious choices about how they want to position participants to the audience—readers, journal editors, other researchers—so, researchers must be aware of how they frame their study and what they want to say because of that framing. Thus, the concepts of validity, reliability, and generalizability are not appropriate measures of rigor within the methodological consideration of narrative inquiry; instead, narrative inquiry is concerned with the apparency and veracity of story. Researchers come to know participants' experiences, their own experiences framed by the participants' experiences, and the co-construction of a new research experience (Clandinin & Connelly, 1998).

Narrative inquiry is a collaborative research practice where inquiry itself forms a relationship as the storied lives of the researcher and participant unite. The relationship between the researcher and participant becomes the mechanism of knowing. Cultivating a research relationship takes time, space, and voice, where eventually the process of mutual storytelling and (re)storying results in the research story (Hogan,1991). Voice is the mode by which stories become reified. Britzman (1998) best highlights the modality of voice:

> "Voice is meaning that resides in the individual and enables that individual to participate in a community…The struggle for voice begins when a person attempts to communicate meaning to someone else. Finding the words, speaking for oneself, and feeling heard by others are all a part of this process…Voice suggests relationships: the individual's relationship to the meaning of her/his experience and hence, to language, and the individual's relationship to the other, since understanding is a social process."

Elbow (1986) explicates that the process of developing voice starts with the "believing game," which is a way of leveraging the relationship between the researcher and participants. In the "believing game," the researcher first listens to the participants' stories without questioning the participants' validities and authorities. By affirming the participants' stories, the researcher affirms that the participants are rightfully the authority of their own experiences. Connecting to the researcher in this way develops relationships that empower participants as they come to recognize the space and voice that the [research] relationship offers (Hogan, 1991).

4.4.1 Focus group interviews

It has been well-established that interviews are co-constructed spaces whereby the rules of the interview are governed by procedural language that serves to create 'reality under consideration' (Wittgenstein, 2003, p. 6). Although the interview can be understood as an 'unnatural' situation, Gubrium and Holstein (2003) suggest that 'natural' situations are not necessarily more realistic where the latter supposes that the participant's 'real' self would emerge. Instead, non-interview spaces are conceptualized as 'indigenous settings' that are also constructed, but in ways that are less in the researcher's influence of power (e.g., creating questions, selecting the room, picking physical seating). Again, this reiterates the relational and dynamic nature of identity where it is constructed based on the contextual features of a situation (e.g., who is in the room, the time of the interview, the room itself) Nevertheless, Wolfson (1997) warns that regardless of construction, interviews serve as a defined 'speech event,' where researchers exert their entitlement to ask questions of participants and elicit their answers, which will always shape the data that is collected in a way that serves the researcher's agenda. Therefore, it is important the researchers are aware of how the interview setting can "give back" to the participants in-moment. Fairclough (1992) explains that although interviews can be cathartic, giving the participants a therapeutic and liberating opportunity to 'confess,' it is not simply a consequence of the process, but rather how the process is framed (i.e., what and how questions are asked).

Jensen and Lauritsen (2005) add that researchers view interviews too narrowly as "confessionals" that elucidate objective truth, explaining that truths are always situated in the context from which they emerged, but once they are abstracted for research they cannot be objective. Kvale (2006) analogizes modern researchers to prospectors who often see themselves as striking a rich stream of data in the way prospectors see themselves striking gold. Thus, the goal of research simply becomes a process of data mining: taking, syphoning, refining, and distilling where the researcher's job is to remove the impediments that guard truth through special treatments (Rapley, 2001). Rapley (2001) shares that these special treatments include notions of maintaining neutrality where the researcher constructs a performance of 'being impartial.' However, as Rapley adds, this rehearsal of impartiality is still a performance of being and is not neutral in any conventional sense given that its function is still to elicit information and not to be 'neutral.' On the other hand, interactivity (i.e., being overly personable) is also a performance to gain information and is also non-conventional. This binary supposes an 'incompossibility' (Derrida,

1998) of being that suggests that whether you act or do not act, the researcher is always performing. In a focus-group interview setting especially, the interviewer is not typically positioned as an investigator, but rather as a facilitator or moderator (O. Nyumba et al., 2017). O.Nyumba and colleagues (2018) offer that focus group discussions bridge the academic and social experience that attempts to research the local knowledge of a community, which means participants tend to feel the power of the researcher less. Participants are also able to build on one another's ideas in meaningful ways that show similarities and differences to their own life experiences.

Reframing interviews under a post-structuralist paradigm brings significant consideration to 'objectivity,' 'validity,' and 'reliability' (see **Chapter 5: Positionality and Analytical Approach** for more on *my* reliability). Qualitative research that draws from post-positivistic paradigms explains that interviews can be 'contaminated' by interpolating the interviewer too heavily in the process (i.e., the effect of interviewer bias) (Waterhouse, 2007). As previously mentioned in analysis, researchers who see themselves as prospectors are viewing interview settings as a [gold] mine of knowledge. However, Holstein and Gubrium (1995) reject that model, which they refer to as 'vessel of answers' and instead endorse a model of interview settings as being a 'stock of knowledge' where knowledge is "simultaneously substantive, reflexive, and emergent" (p. 30). Drawing from Everett Hughes concept of "going concerns" (p. 95), Holstein and Gubrium (2000) explain the that the role of the researcher in narrative inquiry is to develop an understanding of the resources from which these narratives are constructed and the ways in which the participants utilize them. Essentially, "going concerns" refers to the resources that participants use to construct themselves that emerge because of the many different institutions that participants live within. Institutions are the reified domains of society that presuppose how members of that institution are to 'be' and 'act' in those spaces. Examining the 'going concerns' of a space like an interview allows the researcher to examine how participants speak their subjectivities as they elucidate the institutions that they are part of through associated discourses.

Therefore, the interview can be understood as a co-construction where knowledge is dependent on both the interviewer and participant, framing them as 'active agents' in the interview process. The aim of the researcher in analysis is then to understand the different ways in which meaning from the interview can be known while acknowledging that the researcher and the participant may have different interpretations of the knowledge emergent from the interview setting (Scheurich, 1993). In essence, understanding the interview setting as being co-constructed

and the research process as being constructed allows researchers to focus more on their service to their participants and less on their slavery to [false] objectivity. O.Nyumba and colleagues (2018) extend that the findings should be shared with the participants (i.e., member checking) so the participants can speak to the apparency and veracity. However, the researchers acknowledge that member-checking in the focus group context is especially challenging because each participant has their perspective on how the interview went; they cite Sandelowski (1993), Morse (1994), and Angen (2000).

4.4.2 Analytical process

Bruner (2004) makes the distinction between two types of narrative inquiry: 1) analysis of narratives (i.e., studies whose data sources are stories that produce paradigmatic categories of experience) and 2) narrative analysis (i.e., analysis of actions, events, and happenings that produce stories). For the purposes of my work, I will focus on the latter rather than on the former. Josselson (2004) offers that in the paradigmatic model of data analysis, analysis (i.e., creating codes and coding the data) and interpretation (i.e., making claims about the coded data) are separate entities whereby the analysis is viewed as objective and interpretation is viewed as subjective. However, analysis and interpretation in narrative analysis is understood as inseparable constructs in that researchers analyze narrative data to interpret the meanings that participants are making about themselves, their surroundings, and others. Thus, researchers in narrative inquiry seek to understand how the stories participants tell are latent with plotlines that relate to societal and cultural structures, which means analysis and interpretation are done simultaneously. As such, narrative analysis is simply honest and forthcoming about their interpretive scheme while analysis of narrative attempts to establish an air of objectivity by dichotomizing analysis and interpretation. Reissman (2008) adds that all research, regardless of paradigm, is interpretative at all stages in that researchers are always making choices both conscious and unconscious of how they will understand and present their findings.

The product of the analysis in narrative analysis is not structured around a paradigmatic research design (i.e., analysis of narrative), the mode of interpreting and communicating the data sources still adheres to some qualitative considerations that qualify narrative analysis as rigorous (Josselson, 2004). The goal in narrative analysis is to interpret data by recursively testing whether evidence exists for each interpretative claim during the analysis process (Polkinghorn, 1998). The

researcher's role in the analysis is to produce a plot that orders anecdotal descriptions of people's accounts into a meaningfully resonant story. Vanhoozer and colleagues (1991) summarize the process of ordering as "just as painting is a visual representation which shapes or configures space, so narrative is a verbal representation of reality which shapes or configures time" (p. 37). Anecdotal descriptions of people's experiences (i.e., data sources) can be interviews, journals, public and personal documents, and observations. The scope of data sources depends on the story's ordering and is decided upon by the researcher and the participants (Stake, 1988). The emergent stories are an interpreted, analytical narrative that elucidates the idiosyncrasies and complexities of a person (Polkinghorne, 1995).

The analytic development of the story from the data sources is a recursive process whereby the researcher must develop a plot that can capture the temporal, emotional, and motivational meanings surrounding selected anecdotal descriptions of people's accounts. The plot development follows a "hermeneutic circle," defined as the creation of a text by simultaneously considering how constituent plot devices contribute to the beginning and the end of the story (Polkinghorne, 1995). Given that the analysis produces an emplotted story, not all anecdotal descriptions of people's accounts have elements that will be vital for communicating temporal considerations, so some aspects are removed. The process of selecting specific anecdotal descriptions of people's accounts is referred to as "narrative smoothing" (Spence, 1986). Spence (1986) asserts that narrative smoothing is not about ignoring elements from data sources that contradict the emplotted narrative but rather is about deciding which elements are necessary to produce a cohesive story. The act of communicating an experience through language is the first layer of narrative smoothing and is performed by the participant. When researchers and participants create the plot for the story, they are simply imposing a second layer of narrative smoothing. Consequently, narrative smoothing exists in both the informal and formal versions of the anecdotal descriptions and is not considered a breach of apparency or veracity (Carr, 1986). In addition to narrative smoothing, other literary tools like metaphor, irony, parody, and satire are used to evoke the richness and complexity of everyday life in the story (Kim, 2015).

4.5 Limitations of Methodology

Waterhouse (2007) explains that using narrative and stories as research should provoke the ways in which the action of selecting and retelling participants' stories structures the way the

researchers and the research audience comes to "know" about the participants. Thus, the researcher who is positioned of the "teller" is ethically responsible for how knowledge about the participants is constructed. Grumet (1990) explains that language and discourse express the interface between the researcher's own subjectivity and the public intersubjectivity of the participants. Munro (1998) adds that because the subject (i.e., the participant) is always in 'production,' the researcher must always be aware of language and the discourses she uses to describe them given that language and discourse are acts of epistemology: "narrative can both contest and reproduce positivistic notions of power, knowledge, and subjectivity although the researcher makes claims to the contrary" (p. 12).

This is especially important when the participants are not involved in the narrative writing since the participants are not consciously co-constructing the words the researcher uses to describe his or herself. Goodson (1995) advises that narratives do not and cannot tell fundamental truths given that stories themselves only become meaningful when they are analyzed and interpreted by the researcher in the social and cultural context from which they emerged. He argues that used improperly, narrative can be just as colonizing and redirecting as non-narrative methods. Narrative is not simply a new way to display data, but rather a way in which data can be understood empathically.

4.6 Summary

Post-structuralism supposes that narratives are reified through the languages that are available to a person. Language governs and constructs a person's reality such that these languages are (dis)organized into a person's story in that we are all living storied lives as we tell others stories of ourselves. PSETs tell their stories in the focus-group interviews and share their past, present, and future science practices. I interpret the practices that contribute to PSETs' practice-linked identities as plots (i.e., important factors) to the story of their science learning and becoming. Since I interpret identity as a story of becoming, I analyze and interpret the data as elements of a larger narrative—the collection of individual stories. (Re)counting or (re)storying the PSETs' individual stories does not alone elucidate the larger narrative; consequently, I look across the individual stories to understand the major themes presented in the data to construct the larger narrative of preservice elementary teachers and science

CHAPTER 5. STUDY CONTEXT

5.1 Overview

I begin by explaining the participant population and the design features of *Fundamentals of Chemistry* that lend themselves to supporting identity and learning. I then discuss the research questions that I have operationalized using the theoretical and methodological frameworks and the data sources collected from the sample to answer those research questions. From there, I explain my researcher positionality and the analytical approach that I have utilized to compose the analytical chapters of this work. Finally, I offer the limitations of the study context to take with you while reading through the analytical chapters.

5.2 Participants and Curriculum

The population of learners being investigated are students enrolled within the chemistry-content course pseudonymed as *Fundamentals of Chemistry* at a public Midwestern institution; students and PSETs are used interchangeably as synonyms in the remainder of the document. The chemistry science-content course is a two-credit, one semester-long introductory chemistry course that consists of a two hour and fifty-minute lab and a fifty-minute lecture once a week. Demographically, the students that enroll in this course are typically White women who are elementary education majors (i.e., preservice elementary teachers), ranging from sophomores to seniors. At the public Midwestern institution, PSETs are required to take 128 credits: 40 being education-courses, 12 being extracurricular, 60 being other departmental/program courses, and 16 credit hours being in science-content courses (i.e., two semesters of biology, one semester of chemistry, one semester of physics, and one semester of Earth and Space Science). The science-content courses available at the public Midwestern institution are designed to teach elementary education majors the science content needed at the elementary level; available classes include physics, environmental science, biology, and chemistry. The aforementioned information was taken from the website and course-catalogue of the public Midwestern institution. For the purposes of this work, I focus on a chemistry science-content course. Research has shown that PSETs tend to have more negative experiences with physical sciences (i.e., chemistry and physics) rather than natural sciences (i.e., biology and environmental science) that influence their learning and future

teaching (Bursal & Paznokas, 2006), and because I had access to this population being employed by the chemistry department at the public Midwestern institution. The sample investigated were students enrolled within the Fall 2015 semester of *Fundamentals of Chemistry*.

Fundamentals of Chemistry is as a project-based learning space whereby the curriculum, instructional approach, and instructional practices are linked by the disciplinary identity of chemistry (i.e., what chemistry practices should students know and be able to do after taking the course). In project-based learning, the classroom is meant to support meaningful and transformative forms of learner's agency, sense making, and learning about options for their future identities that connect to themselves in and outside of school by creating a hybrid space whereby everyday experiences are considered as meaningful to the classroom and scientific community (Bang, Warren, Rosebery, & Medin, 2012; Van Horne & Bell, 2017). Framing the curriculum as a problem-based learning setting acknowledges that the curriculum affords students with material (e.g., equipment, techniques, phenomena of the natural work), relational (e.g., membership, relationships, access to roles), and ideational (i.e., seeing oneself in the practice) identity resources to cultivate their science practice-linked identity (Nasir & Cooks, 2009); therefore, the *reflections* that students have surrounding the curriculum can be understood analytically as contributing to their learning and being.

To accomplish a problem-based learning setting that leverages students' experiences as being meaningful to classroom and science community learning, the instructor of the course encouraged intertextual connections and modeling practices (Ryu, Nardo, & Wu, 2018). Students met in lab before the lecture component to investigate and experience the ideas that would later be covered in lecture. Lecture, which happened after lab on a different day, would revisit the experiments conducted in lab by relating the concepts to examples that were grounded in students' everyday experiences. The chemistry topics were situated accessibly using everyday phenomena, for example, notions of density, electronegativity, polarity, and intermolecular forces were explored using household substances like water, acetone, and rubbing alcohol. Other topics were selected by the instructor based on her interest in socioscientific issues like climate change, negative impacts of plastics on the environment, and health concerns related to nutrition, which she felt would be important to promote scientific literacy. Although the class offered informal reflection by promoting using open-ended questions of the lab manual and homework assignments, formal reflection was incorporated into the class through readings whereby students were asked to

read articles every week taken from *ChemMatters* (published by the American Chemical Society) and relate the articles to their learning and lives.

In accordance, the instructor drew from Sevian and Talanquer's (2014) review of crosscutting disciplinary concepts of chemistry to elucidate the following: chemical identities, structure-property relationships, and chemical causalities through modeling practices. In the lab and lecture components, the students were asked to work collaboratively and explain observable phenomena by describing or sketching what they presume to be the behavior of submicroscopic particles. They were then asked to revisit and revise their sketches after communal consensus that was informed by the evidence gathered during lab, the "literature" gathered from the class, and support by the chemistry experts (e.g., the instructor, graduate TAs, or videos with scientists). Sample questions instigated in the lab were, "Explain why water forms a dome-shaped droplet, as opposed to alcohol that forms a flatter droplet, using submicroscopic behaviors of water and alcohol molecules", or "Explain why soap water forms bubbles with a sketch of submicroscopic views of bubbles." Students also generated models to predict phenomena, such as "What do you think happens to a balloon when you put it in the freezer? Explain your prediction using particle behavior," all of which was guided under Cooper and colleagues' (2017) paper on supporting modeling practices in general chemistry spaces. Students were tasked to author their own model and revise it to become meaningful for them and their learning rather than simply copying the canonically-defined model of the phenomenon.

Relating to problem-based learning, many of the phenomena that were investigated were complex—many did not have one specific answer and had high interpretive value. The experiments done in the lab were positioned as tools, not as simulations of phenomena, such that the learning labor was placed on the students to gather useful information that could be then abstracted for the socioscientific phenomena under investigation. Although students were responsible for learning canonical chemistry ideas (i.e., two midterm and one final exam was given in the class; the assessments consisted of multiple choice, true-and-false, and free response), most of the points were given to *how* students reasoned through their answers rather than placing the learning goal on achieving one, "right" answer. In addition to endorsing practices of science sense-making, the instructor also designed practices that would be beneficial to PSETs as future elementary teachers. Drawing from Stuckey and colleagues (2013), the instructor attempted to make the chemistry concepts relevant to students' future careers by doing experiments that would

be potentially doable in the elementary context and adopting the NGSS (2014) principles of collaboratively developing and revising models as well as using models to describe and/or predict phenomena. Overall, the goal was to utilize intertextuality and modeling as curricular design features of the problem-based learning setting that would afford meaningful science learning.

5.3 Research Questions and Data Sources

To provide expository interest for my master's work, I introduced the problem as:

- How do preservice elementary teachers describe their learning and participation in science before entering undergraduate science courses?
- How do preservice elementary teachers describe their learning and participation in science during the *Fundamentals of Chemistry* course?

Given the introduction of the theoretical and methodological frameworks, I operationalize the problem into research questions:

- How do PSETs construct their science practice-linked identities?
- How does *Fundamentals of Chemistry* afford identity resources that contribute to PSETs' science practice-linked identities?

To answer the aforementioned research questions, I draw from ten, video-recorded focus group interviews conducted by the instructor of the *Fundamentals of Chemistry* course. To answer the first research question, I created three analytical chapters (see **Chapters 6, 7, and 8**) that discuss the science practice-linked identities of a "science person," "non-science person," and an Ambiguous person (PSETs that I could not identify how they self-identify). I examined the past, present, and future practices that the PSETs mentioned as being salient to their science learning and then I expanded on how those practices informed how they are becoming. I drew the theory for the analysis from the practice-linked identity construct mentioned in the theoretical framework. To answer the second research question, I created one chapter (see **Chapter 9**) that investigates their present science practices in the context of the *Fundamentals of Chemistry* course. The chapter describes the PSETs from the previous three chapters and elucidates the identity-building resources that PSETs used as tools for their science practice-linked identity constructions. The curriculum afforded identity-building resources that PSETs utilized to construct their science practice-linked identities. I drew the theory for the analysis from the disciplinary identity construct mentioned in the theoretical framework that assesses the identity-building resources (e.g., material, ideational, and relational).

Logistically, there were thirty-three participants in total with each focus group interview ranging from two participants to six participants. The interviews ranged from forty-minutes to two-hours and took place throughout the Fall 2015 semester, which means there are no pre-and-post experiences—only recollections and projections of past and future experiences. The focus-group interviews were semi-structured but did not closely adhere to an interview protocol (see "**Positionality and Analytical Approach**" and **Appendix X** for *constructed* protocol). The total enrollment number for the course during the Fall 2015 semester was sixty-seven students. All of the students enrolled were asked by the instructor to participate in the study and all were incentivized with IRB-approved extra credit points that were only dependent upon participating in the study and not upon the quality/quantity of response. Due to a lack of demographic variety and adherence to participant confidentiality, I will not disclose the demographic information of the students aside from: the great majority of the participants were white-and-female-presenting students; there were *some* white-and-male-presenting students; and there were *some* Asian-and-female-presenting students. To gain insight into the *Fundamentals of Chemistry* curriculum, I mostly draw from participants' recounts of the course by privileging and honoring their position as students. I also draw from my own experience working as a teaching assistant in the course, the instructor's *explicitly documented* account of her curriculum design (see Ryu, Nardo, and Wu, 2018), and *informally documented* meeting notes with the instructor regarding the data analysis.

5.4 Positionality and Analytical Approach

To account for my researcher positionality, I acknowledge that reflexive positioning involves the intentional repositioning of one's self within a given situation (Davies & Harre, 1990). In this situation, I am a chemistry-education researcher investigating the community of preservice elementary teachers taking a chemistry-content course. Before I begin the discussion on analysis, I would like to share my research journey. I was given this data set to work with by the instructor of the course and my researcher advisor during the end of my first semester of graduate school. I wanted to work with underserved students and my advisor had convinced me that this student population needed more research, which I agreed was important. Truthfully, I did not understand how to do research (and arguably I still do not) and I struggled to make sense of the focus group data. I first transcribed the ten interviews very loosely, creating an abridged transcript that summarized what was said by each participant. I sub-divided the transcript into different "sections"

that corresponded to general topic questions that were asked during the interview. I looked through the data set with different research questions and coded the data inductively trying to look for themes. I had countless Nvivo files titled different combinations of PSET focus group data research topics as well as Microsoft Word documents with highlighted texts in different colors organized into charts. I had utilized different class assignments to write literature reviews, coding schemes, and proposals for this data set. I even submitted and was accepted to AERA based on a previous iteration of the data that explored the boundaries PSETs have in adopting reform-based science practices in the classroom.

But, every time I presented my data analysis, it was somehow "wrong." I internalized my inability to interpret the data as an inability to do research, and I almost gave up. Once I realized my shortcomings, I tried to think about how I could frame the data in a way that could also capture my process doing this work, which lead me to narrative. My advisor had me work for *Fundamentals of Chemistry* as a teaching assistant to give me some perspective on the data. Although I was not a TA when the data set was collected, I realized that being a TA in the *Fundamentals of Chemistry* course was meaningful for the different, iterative times I read through my transcripts; I even went back and closely transcribed the interviews again, producing a verbatim transcript with removed verbal fillers (i.e., um). Those interviews helped me become a better teacher to them and helped me create curricular resources for the class. I believed that our course was meaningful to the students, which helped me believe that I could do work that would transform the research that has been done with PSETs rather than simply reproduce it.

For the analysis, I chose narrative inquiry because I want to acknowledge PSETs as complex learners who cannot be reduced to simply their science ideas. Using narrative provides the methodical flexibility to construct the *essence* of a participant that can then be understood discursively and theoretically rather than making claims about the participants directly, which reduces and decontextualizes their words (see Munro, 1998). To do that, it is important to establish trustworthiness. Trustworthiness (Lincoln & Guba, 2003) is a concept that research-narrators must establish before beginning their research-telling. Lincoln and Guba (2003) have supported that there are two main ways to establish research-narrator trustworthiness: establishing interrater-reliability and performing member-checking—this work has neither of those elements. I offer instead that I am an "unreliable," reliable narrator (Lather, 2000). Lather (2000) offers that there are many indeterminacies of language that function in an un-understood web of power, meaning

that even relying on the pseudo-safety of interrater-reliability and other “behind-the-curtain” acts of research polishing, there is no escaping the certainty that language is uncertain.

To define what I mean by being an “unreliable,” reliable narrator and establish credence, I draw from Olson’s (2003) review of fallible and untrustworthy narrators. The author draws her review from considering narrators in popular literature, not education research. However, given that I am integrating literary elements into research, I believe it is important to also honor the traditions of fictional work that provide immersive, palatable, and social commentary. Drawing from Booth’s model, Olson summarizes that there are four types of reliability breaches: unreliability, untrustworthiness, inconscience, and fallible. Unreliability and untrustworthiness occur when the narrator deviates from general normative standards that are implicit in the domain of the work. When the narrator is unreliable, she is purposefully acting outside the normative view of how to be (i.e., knowing the methodological considerations of using narrative inquiry, but acting outside of it). When the narrator is untrustworthy, she is purposefully acting outside the normative view of how to be for *her own benefit* (i.e., knowing the methodological considerations of using narrative inquiry, but acting outside of it to further my own agenda). Both breaches speak to the personhood of the narrator, meaning she cannot be trusted on a personal level. In contrast, inconscience and fallible occur when the makes unconscious mistakes about how she perceives herself or the fictional world of her characters (i.e., participants). When the narrator is inconscience, she is unaware of her mistakes, but is receptive to correcting them. When the narrator is fallible, she is acknowledging the limitation of her skills. In my research, I would like to position myself as both inconscience and fallible, meaning that I understand that the stories I will produce and the manner I will produce them can be [and should be] challenged to push my understanding of the subjective worlds of my participants and also my understanding of how to do narrative analysis. I am humbly claiming that my stories are incomplete (i.e., I am inconscience and falliable), but I am also selfishly claiming that my stories are done to the best of my ability (i.e., I am reliable and trustworthy).

For the analytical chapters, I draw inspiration from Watson’s (2006) process of narrative. She poses that transcription is a translation whereby there is no simple and transparent way to render speech into writing. She uses underlining, bolding, and italics to highlight different emphasis that the participant denoted. She removed most hesitations (ers, ums, and stutters) and added punctuation/English grammar where appropriate for readability. I also acknowledge that

because she did not publish a methodological piece on how to decide what is and is not appropriate, my transcripts might not be edited with the same criteria she used. All ten interviews were transcribed twice as mentioned above (first using an abridged transcript method and the second using a verbatim transcript method) and were examined to investigate each PSET individually using Nvivo to code for each PSET's science identity, science learning, and teacher identity. Once transcript quotes were organized into these three codes, individual profiles of each PSET were created that summarized how PSETs learned science/chemistry in the *Fundamentals of Chemistry* course and how they saw themselves utilizing that knowledge in their personal and professional lives. The profiles were then grouped based on PSETs' self-identification: "I am a science person," "I am not a science person," and Ambiguous. PSETs that qualified under the category of "I am a science person" had to mention that they considered themselves "science people," or that they "liked science" whereas the PSETs that qualified under the group of "I am not a science person," had to explicitly say they were "not science people," say "I don't like science," and/or say they saw themselves as another kind of person. The reason attitudinal dispositions were included as a criterion for this demarcation was to make the data more robust given that very few PSETs actually identified as "I am a science person." Although there were some PSETs that did not strongly identify with or de-identify with science, there were many PSETs that did not explicitly say what kind of person they were or what they liked. To honor that, I decided to create a category called Ambiguous with no quotes to denote that this was a group I created.

After the profiles were grouped, I began to read through them and find the "emplotted" story (Connelly & Clandinin, 1990), which would roughly synthesize the larger themes of each sub-data set. As mentioned in **Chapter 4: Methodology**, not every element of every profile was used to create the final story. For transparency, I will include a "narrative worksheet" at the end of each chapter that will showcase where the pieces of each narrative emerged from the corresponding data set transcripts. I created stories by finding quotes from the PSET focus-group transcripts that related to how they practiced science before, during, and after the class. I then created characters and the story surrounding the selected quotes depending on the larger themes of the data-set and the amount of quotes that could be attributed to a character's development. This will answer the first research questions that illustrates the different, emergent science practice-linked identities. Given that there are three sub-groups (i.e., "I am a science person," "I am not a science person," and Ambiguous), there will be three analytical chapters that answer the first research question. To

answer the second research question, I will be cross-examining the emergent narratives of the sub-categories to write a narrative that examines the affordances of *Fundamentals of Chemistry* course for the identity-building resources. The outline of the four analytical chapters will be: the list of pseudonymed PSETs that identified as belonging to the sub-category, the narratives with central character(s), a discussion of the narrative that will theoretically connect to the theoretical framework, and the narrative worksheet that I previously described. It is important to note that given the amount of PSETs in each sub-group, the number of characters in the narratives might be different to showcase the nuanced ways of being a "science person," "non-science person," and ambiguous. The fourth analytical chapter that explores the *Fundamentals of Chemistry* course will discuss the design features that practitioners may utilize for creating a course with an intended chemistry disciplinary identity as explicated using the theoretical framework.

5.5 Limitations of Study Context

As mentioned above, there are many constraints that have influenced the framing of this data set and thus the claims that can be made from it. Foremost, I would like to acknowledge the logistical concerns associated with the data. The age of the data set is a concern given that it was collected Fall 2015 meaning that the data set will be almost four years old at the time of defense and older at the time of publication. This means that the saliency of the curricular design features that I am potentially exhorting practitioners to use might be outdated or common practice. Although there were several major themes present among all ten interviews, the interviews themselves are not completely uniform in that the interview protocol was not strictly followed. I have constructed an abridged interview protocol from the data set that outlines the major themes that I believe to be present among all ten interviews. I also describe generally what each theme consisted of in each section of the interview transcript (see **Appendix A**). However, given the co-constructed nature of the interview setting as expanded upon in the methodology section, I believe that the interviews are still comparable, and the variable nature allowed the variety of responses to be recorded. I would also like to elucidate the underutilization of the *focus* group interview context in that although there were multiple people in the interview, I examined the interview by individual participant. Although I believe the focus group interview helped the PSETs feel more comfortable speaking to the course instructor, I have not methodologically qualified the value of a *focus* group over an *individual* interview.

Moreover, there are ethical concerns associated with the data that should also be considered. The participants did not necessarily gain any direct benefit from being part of the study aside from the extra credit points. Being interviewed by the instructor of the class may have caused PSETs some distress, especially when they had to critique elements of the curriculum. As mentioned before, there was no background information available to me (i.e., their gender, race, ethnicity identification, major information, and year in program) aside from what was mentioned in the interview itself. In accordance, member-checking is something that I did not do in that I did not have the PSETs read the stories that I wrote in this thesis; this information might have been possible to retrieve if I acted on it sooner. I also acknowledge my own limitations given that I am a third-year graduate student who has never done narrative analysis and has done traditional paradigmatic coding (i.e., creating inductive codes and iteratively coding the data), which may add a colonizing influence on how I construct the narratives. Again, as I position myself as inconscience and fallible, I recognize that I am not part of the community of PSETs and I do not claim to “know” their experiences simply because I have read the literature and examined some interview data.

CHAPTER 6. ANALYSIS AND DISCUSSION OF "I AM A SCIENCE PERSON"

6.1 Overview

The first section consists of all the participants that self-identified as being a "science person" with a table containing the quotation I used to put them into this group. Given that I do not know the demographics of these participants, I did not put any information into the chart. As mentioned above in Chapter 5: Study Context (see **Participants and Curriculum**), the demographics of the sample participants are female- male-, White-, and Asian-*presenting*, meaning that this is information that I have *inferred* from the participants; therefore, I do not feel comfortable using these feature to tell the story unless participants explicitly self-identified their demographic background while sharing their oral history as documented by video and consequential close-transcription. The second section is the narrative itself that blends the essence of each participant into a composite character, "Lina," which serves as the analysis. The third section is the discussion of the narrative that draws from the theoretical framework to answer the first research question. The theme of this chapter is *reconstruction* of characters based on the language that PSETs utilized in the interview setting (see **Appendix B** for **Narrative Worksheet**).

6.2 Participant Subjects

The table below contains the PSET pseudonym that they self-selected during the interview with the quote that I used to group them as a "science person." Again, to make the data more robust, I broadened the selection criteria to also acknowledge PSETs who like science since the other PSETs either did not say whether they liked science or not or explicitly said they did not like science. So, these PSETs either said that they liked science/science courses or that they were a science (i.e., biology) person.

Table 1: PSETs' Science Experiences

PSET Pseudonym	Allegorical Character	Data Source
Amanda		[00:04:07.21]: Am: Yeah, I guess with Ann I have always enjoyed like science classes. Like I remember freshman bio. I was not good at it, but I liked the dissections. I had so much...I would be the first one to do it and the other person would be like *disgusted face* I would not touch that. It was the best.
Ashley	(As Lina)	[00:01:29.28]: Ash: They were good. I really like Math and science a lot, so I tend to try harder, I guess in the sciences classes because in English and Art isn't really my thing, so...
Bethany		[00:08:22.23]: Be: I think I actually enjoy this chemistry class a little bit better because it's more conceptual rather than like calculation and like the math part. I think that the science part...the science part of chemistry...it's all science, but I like it (science). Um, I think that the math part and the calculations and the abstract thinking um...it was really, really tough.
Denise		[00:38:13.22]: Den: I mean I have taken a lot of science and math classes. I wouldn't say that I am better one side than the other and that's kind of why I went into education because I am well-rounded, I guess and I like all of them. I am interested in all of them, so yeah.
Erika		[00:03:13.00]: Er: Yeah, I liked it too, like I kind of felt in high school you knew that you had to take it, so I think it was harder to enjoy because everyone just wanted to get a good grade in the class and everyone just wanted...everyone knew they had to take it, so it felt like you weren't choosing, "Like, oh I get to take biology." Everyone was more like, "Oh I have to take this class, so..." And it was also neat to like see the different areas of science that you like because it's all science, but also different. Like, I was more of a biology person. I don't know I just loved biology
Karen		[00:01:07.29]: Ka: Yeah, it was optional. It was kind of like you had to apply for the course to get into it [Minjung: Why did you take that class?] I used to want to be a biology major. That's what I used to want to do was be a bio major when I first came in for like a semester.
Quincy		[00:07:21.14]: Q: Well, I like science. I am actually a bio TA. I actually like science a lot.

6.3 Narrative Analysis

Drawing from Sfard and Prusak's (2005) model, ${}_{B}A_{C}$, the identified person who is the subject of the story, A, is allegorically named Lina; the author, B, is me; and C are the other members in the interview room and reader who are acknowledging Lina (i.e., Lina is telling her story to *other* PSETs, Minjung the instructor and to *you*). The story is told from Lina's third-person point of view and attempts to blend the essences of Bethany, Quincy, Erika, Denise, Ashley, Amanda, and Karen. Thematically, these students report liking science or being science people.

The other character (student) does not have a name to distance herself from the "I am not a science person" PSETs; the character only acts as mechanisms of reflection for Lina and not a subtle retelling of "I am not a science person," category. The narrative dialogue mostly consists of *direct* participant quotes. However, there are interpretive and transitional dialogues in the narrative. For the participants, Quincy, Karen, Erika, and Denise were even interested in entering STEM-fields before eventually becoming elementary education majors. All of these students had positive experiences with science either at a young age or in high school or genuinely always felt they liked science. In terms of the course, Lina is somewhat ambivalent about her performance—most PSETs (Bethany, Denise, Erika, Ashley, and Karen) like the course while other PSETs (Quincy and Amanda) find the course not as applicable to elementary education.

6.3.1 Exposition

The scene is a small, yellow room with a large window that extends to the top of the celling. Under the window is a table large enough for four people—there are three chairs around it. At the center of the table is a microphone and a box filled with Halloween candy. On the other side of the wall with the window is a camera perched on a tripod. The interview room is ready. Minjung moves toward the camera and presses record. The red light blinks on.

6.3.2 Story. Scene 1-Past

"Well, I mean I always knew I liked science even from an early age," Lina smiles warmly as she looks around the room anticipating her gaze would be met with the same warmth. The other student's eyes move to meet her gaze, but her mouth does not move. The other student did not welcome her response. Lina keeps smiling, averting her eyes down towards the table. Minjung smiles at Lina and clears her throat, "So, you liked science even as a child? Can you tell me a little more about that?"

"Um, like about being a child or likin—," "Err, yes, sorry, about liking science," Minjung eagerly offers.

Lina continues, "Yeah, I guess it started with my dad. He brought home all those science kits and weird like outside stuff for me to test with them. I would always come home from elementary school and he would ask me what I had learned that day. I'm not even sure why he did that because he doesn't even work in science, but like he always thought science was cool since

and was always really excited about it," Lina explains. She looks around the room again, testing whether or not her explanation is accepted this time. The other student rolls her eyes disapprovingly.

The other student clears her throat, "Yeah, I mean, I have never been good at science, so I feel like it's just not for me." The student looks at Lina satisfied.

"Well, like, science wasn't necessarily easy for me. I wouldn't say I was good at it either, but I just tried a lot," Lina tries to explain herself, "I also wouldn't say I liked all the science classes because I feel like I am better at biology than I am at chemistry or physics... but they're both more interesting to me than like English or Art," Lina sighs, "Actually, chemistry was my least favorite class. My teacher was a very nice person and she even won awards for being a great teacher. But, I hated the actual class. All we did was memorize the periodic table and formulas with math problem. I struggled a lot. I felt like chemistry wasn't the science for me. It made me nervous thinking about taking this class because I didn't know if I would be okay."

Lina starts fidgeting with her hands, unsure of how the other student would respond. The student says, "Yeah, I get that. I always felt like chemistry and physics were just really hard." Lina shuffles in her chair and reaches for her backpack underneath the table. She pulls out her water bottle and begins to drink from it as she continues to listen to the other student. The other student adds, "For chemistry and physics, you just have to be wired to do that."

Lina stops drinking and starts humming in agreement, "Yeah, I totally agree. I don't know. When I think of science people I feel like they are very smart and I feel like they have all this knowledge that not everyone necessarily knows about—" The student stops her, "And you said you are a science person?" Lina shuffles in her chair again and taps her fingers undecidedly on her water bottle. She looks uncomfortably at the student with her mouth pursed.

Minjung shuffles back in her chair, too. Minjung notices the students seem a little uncomfortable, but she is unsure how to proceed. Minjung tries to settle the tension, "That is a very good question. But, what does it even mean to be a science person? Let's think about that for later in the interview. Li—wait, that is your pseudonym you picked, right?"

Lina and the other student both laugh. Lina responds, "Yeah, Lina is the name I picked. It's a really nice name." The other student chimes, "I like Lina, too."

Minjung continues, "Yeah, me too. So, Lina, do you feel like the *Fundamentals of Chemistry* class is similar to your high school chemistry class?"

6.3.3 Story. Scene 2-Present.

"Oh, it is pretty different from my high school chemistry class. I was actually pretty nervous thinking it would be the same. In this chemistry class, I find the labs are helpful to go back and study especially the wrap up questions and going through the activity because once you've done it, you can go back and read your notes, it's easier to understand it. Like I remember why that happened. I didn't really have that "why" understanding in high school," Lina explains. The other student offers, "Yeah, I really like the labs and talking to other students. That's really cool and it helps me understand," Lina continues, "I was going to say like in science you are constantly asking questions and then you are always like learning more and more. So, it's good to be asking questions and in science classes you are always in collabs and always working so you always need to collaborate with someone. Yeah, and like having real-life materials. Things...that's one of the biggest things because if you haven't had these experiences, it's so much harder to think about, so using materials we are familiar with, it makes it not only less intimidating but we are able to think about it on a deeper level because now we have had these experiences—"

The other student chimes in, "Totally agree, it was really hard for me since I never really liked science but doing the labs with everyday stuff is pretty cool."

Lina adds, "Yeah, like chemistry used to be in my head like in a beaker pouring things in there like watching it explode, like that's what I'd seen on TV when people are in chem labs and like that was in my head what it was, so here's definitely shown me how much. Like, how many more different ways it can be applied, like it could be applied like everything like in life basically. And so, it's really...I mean when you look at clouds you're like oh I know clouds are formed because blah. I don't know it's an understanding of, like a deeper understanding about it and I really thought to apply it to everyday things so...," Lina trails off in thought. Minjung smiles to herself listening to her students talk about the course.

Minjung wants to know more about what the students find challenging in the course, but she does not want the interview to shift. Minjung decides to let the students say a little more, "Wow, that is great. What else do you feel has been useful for your learning in the class?"

"I go through all the labs then I go over the PowerPoints and then relate the PowerPoints back to the lab because the PowerPoints are more information detail, whereas the labs are more the concepts and so I'll connect the two. It's also a lot of teamwork. Even if they're not, like you said building off of each other. I have a really good friend. She's a chem major and so I ask her

questions, especially for...I think it was the pre-lab...when we did moles. Like, not this pre-lab but last week's. So, I ask her and then I look through the PowerPoints and the lab," Lina exclaims.

"You know, I haven't tried doing that to study, so I think that's really helpful. I am gonna try that for the next exam. I usually just google keywords and stuff from kids websites to have them explain to me like a kid would," the other student offers.

"Yeah, I google a lot, too. I just...basically like what she said...google keywords and sometimes it's really confusing because some websites will like go in a lot of detail and then we don't really necessarily go into that, so I look at the kid's websites and see all the things there," Lina endorses the student. They share a look across the table. The student pulls out her phone and starts typing. She shows her phone to Lina.

"I use this one a lot. Have you seen this website?" The student passes her phone to Lina.

Lina giggles, "Oh my goodness, YES! I used this for the last homework about the bubbles! Or…. I think it was a homework...I just thought it was so cool how the website showed how it could pop and talk about the different layers of the bubbles."

Minjung follows up, "I have heard other students in other interviews say that when they do not understand they use google or the YouTube videos for kids. That is very creative. What are some things you struggle with in the class?"

Lina begins, "Well…and this might sound a little harsh, but I'm out of state paying so much money and I shouldn't be using google to help my answers. I'm paying money for Purdue to help me, either a book or a teacher. Not from google. So, I feel like in terms of my money's worth or something..."

"Yeah, I think relying on google to find information is kind of scary because what if I don't know if the website is correct. I don't know," the other student mentions.

"And I think another disconnect might be that the material that we're going through it much more in-depth. Like we're not going to talk about molecules and things like that with our kids, but I do think it's important that we understand how it works because then we're going to be able to explain it this does. But like I do think it's important for us to know, so I think a lot of the times people are kind of like I'm not going to teach my kids about molecules. Why do I need to know about them? But, like it is still important for us to know about them," Lina clarifies, "I feel like the goop...what was it the…Oobleck was really cool like to do. I'm going to do that over winter break with my kids…well, not my, my kids. I'm a nanny. But anyway, yeah because it's an easy concept

like solid, liquid, gas like just talk about that and then have them make it and then be like well which one is it, it’s a liquid now, but it's a solid so maybe they might get a little confused but be like it's both.”

“So, this might be a good time to think about the question from earlier, what do you think science is?” Minjung pulls out cards from a bag underneath her desk. She places them on the table in front of the students. “The cards have adjectives written on them. You can use these cards to help you think about science.”

6.3.4 Story. Scene 3-Future

The other student stands up and starts arranging the cards all over the table. Lina helps her. Lina places three cards in front of her, moving her water bottle to make room. She opens the bottle and takes another sip of her water. She keeps eyeing one of the cards on the table. As she puts her water bottle down, she picks up a card and flops it around. Lina shows it to the other student.

“Definitely imaginative because we don't always see what we talk about in class. And then in lecture we have those groups where we talk about questions where you ask us and this one kind of...I feel like this is kind of a personal thing like you can't just be like you guys need knowledge, but if there is a topic someone if really interested in and we can do more research about it and do more research with it in the classroom,” Lina defends her choice.

“Yeah, I get that. For example, with moles you have to think about it because you can't think about...I mean you can obviously think of molarity, but like imagine what's going on because you can't always see what we are talking about,” the other student agrees.

“Mhm, and this other card. Collaborative. I thought because different scientist always build off what one says and they have to work well with each other,” Lina adds, “It's not like reading where you read your book indecently quietly. A lot of science deals with working with other people and helping them with concepts.”

“Then you can like ask each other questions because you are working together and it’s so much easier,” the other student reflects.

“Yes, I feel like that's just kind of a natural thing because if people weren't inquisitive, there wouldn't be any research on anything or like any development of anything because nobody would be like oh what happens if I try this. So, I feel like that's just kind of a natural and really important aspect to anything science related. Yeah, definitely inquisitive because you are because

when you are doing the lab like you are watching the experiments and a lot of times you are like why does that happen there and thinking questions in your head and then you go to lab and you answer the question right now. So, it's like while you are doing it, you are thinking of question. Like inquisitive is like the reason you said for when you teach science in elementary you have to be constantly curious and asking questions. It's like asking questions and questioning why things happen—.

"So, why do you think it's important to teach science in elementary school?" Minjung asks right as Lina finishes her thought.

"I think if you are teaching children specifically with science, having them aware leads to them being curious because kids are naturally curious where they know the deeper questions they are going to have, which means they are potentially going to learn or experiment," Lina says.

"Yeah, getting kids curious and excited," the other student answers.

"I also feel like there is that level of you are setting the stage for their attitudes about school moving forward, whereas in the older grades or in high school, they already have this idea in their head about what school means to them. So, there are still those students who are still kind of excited about school, they like to go. But, then there are those kids who are like no I don't like this. I don't want to do this and it's hard to change their minds after that," Lina takes a breath, but "I just feel like positive outlook is important. That's the thing I love about elementary educations. I don't know, I feel like this kind of goes with that in terms of chemistry because we have to think when we're doing stuff, we have to think about how this would apply to other aspects of our lives or how could we teach it or how could, like what activities could we do for it so I think that kind of gets us thinking about yeah this is my experiment, but how else could we modify. Like, what else could we do? How else could we apply it? Type of thing for that."

The other student puts her elbows on the table and cups her face, "But, like don't you think we go too in-depth?"

"Hmmm. Yeah, to be honest, I want more professors to prove to me why we are going in this much in-depth, how much is.... like, will students actually ask me this in my classroom? Where's the proof that this will benefit me in my classroom instead of just saying you're learning this just as background, just to get the credits. I want proof like this will help me, so...that's what I want if professors choose to go that in-depth. I want proof of why this is helping me," Lina grabs one of the cards in front of her and begins to bend it. Lina looks down at the table.

Minjung looks at Lina, “Have you thought about why you are taking science classes? Like, how would you use what you learned in them in your future class?”

“It’s funny that you say that because I was just talking to my friend the other day—actually, the chemistry friend who helps me a lot and she asked me that. I think like you do teach elements of physics and chemistry to elementary students. Maybe it's not as complex and you are not doing the math involved, but you are definitely in science are teaching physics and they just don't know the terms physics yet and by having us trained in all the different sciences and trained really well in it just makes us more qualified to be able to explain it to them because the more you understand something the more you can explain it to someone else…I guess I also love kids and I love the effect that an elementary teacher can have on younger students because that's when you are really teaching them the fundamentals, so if you have a strong elementary school teacher who teaches you how to add really well, how to multiple really well or just like those fine mental skills, that's what you carry on the rest of your life.”

“In what ways would you do that?” Minjung says as she leans back in her chair.

“I mean to me, it's a lot of exploring and figuring out for yourself. Because like I was saying, remember how we did a lot of math and like yes there is a lot of math in science but as I am now learning that just because I can do that math doesn't mean that I understand what is going on. It's more so the concepts and being able to apply those in real life, so I mean like even just learning about the different phases of gases and liquids, being able to look at that and say like how is that going to change at different altitudes. It's actually usable, Lina reflects, “And since they are younger, they may not know all the correct terms like intermolecular forces or polar versus nonpolar, but they'll remember that. Those basic concepts and as they continue their chemistry education throughout the rest of middle school to high school and then college. Those are things that will stick in their head and then they'll learn all the terms that go along with it. Because I feel like in elementary school I didn't actually do that much chemistry or like lab. Like an actual hands-on chemistry assignment. It was more like writing stuff done and things like that so...but I think that integrating experiments and labs into elementary schools is becoming a lot more done. Like more teachers are doing it, which is really awesome.”

“That is awesome! I am really glad to hear that. I know that people have been pushing for more science,” Minjung says almost under her breath.

“Yeah, but, but I feel like elementary schools really do lack. I would agree because a lot of the science I remember doing in elementary school wasn't even presented as science. So, a lot of times it was like let's look at a bean seed and like I didn't see that as science it was like playing with plants. You know? I was just lucky enough to have a dad who was really nerdy with science and was like hey we are going to do this and we're going to find this out and we're going to we did science experiments without me knowing it, but that's kind of what sparked it for me” Lina smiles to herself.”

The other student smiles, too. “So, then would you say you’re a science person?”

“Yeah, I would say so. To me, science is what is happening at all times and I think that's the one thing that I'm fortunate for science and like kids don't get exposed to it at a younger age and they just automatically picture like Albert Einstein or like really complex things going on and they don't realize that science is what they are constantly doing,” Lina sits up straight, “So, with that, I think anyone can be.”

Minjung lets the room fall silent for a few moments. Lina and the other student start looking out of the window. Minjung meets their gaze and looks out of the window, “It is a really nice day out. I think this is a good place to stop. Thank you so much for your time and if you have any questions about the class or the interview, let me know.

“Thank you!” The red light blinks off.

6.4 Discussion

To situate the narrative, I wrote the composite story centered around Lina based on major themes that related to the six PSETs: 1) liking science classes before entering undergrad; 2) enjoying the challenge of science classes; 3) feeling somewhat alienated in the focus-group interview; 4) perceiving the class as “doable” chemistry, but not necessarily applicable to elementary education; and 5) wanting to teach science to get kids curious about the world. The themes were generated by looking across the Nvivo nodes and by referring the analytical memo-profiles that were made for each student in the sub-cohort; for direct quotes that support each theme, see **Narrative Worksheet** section in **Appendix B**. Converging on one allegorical character’s story was intentionally done to showcase the similarity of experiences from these PSETs who identify as science people or people who like science but should not be interpreted as the standardized experience of science people or people who like science. Research question one

will be addressed using Lina's narrative, which is a discursively constructed identity that builds from the thematic analyses of Amanda, Ashley, Bethany, Denise, Erika, Karen, and Quincy.

In scene one, the past practices that Lina mentioned as salient to her science learning and being revolves around her father and high school classes. Her father would bring science kits home for Lina to play with such that it was part of her home-life routine. This affordance may have made science more accessible to her, especially given that she mentions how her father's career was not in science and was still encouraging to "play." For high school, Lina gravitated towards science, especially biology because it was more hands-on given the dissections she did. Although physics and chemistry were difficult for Lina, she still enjoyed the classes, but she tends to try harder in those classes because they were interesting and had math. Lina had a great biology teacher and had mixed feelings about her chemistry teacher; Lina felt that her chemistry teacher was very engaging but felt her chemistry teacher was very traditional having her memorize the periodic table. She also felt that science people should be smart and have extensive knowledge about the world around them. As a result, Lina was nervous entering the *Fundamentals of Chemistry* course because she was not sure what kind of instructors she would have and what kind of chemistry she would be doing. The past practices that Lina mentioned as salient to her science learning and being include playing with science kits, dissecting animals, struggling in math for chemistry and physics, enjoying her chemistry teacher's charisma, memorizing the periodic table, and believing that science people were smart. These past practices linked to Lina's science identity before entering the course where she entered as a nervous science learner; I will explore this in scene two.

In scene two, Lina progressively realized that her interest in science was not shared amicably by the other student. She has somehow been positioned in the interview as being "smarter" since she explained her history with science as mostly positive. This made her nervous as she began to discuss her progress in the course. Lina discussed how she was nervous entering *Fundamentals of Chemistry* because she did not know what to expect from the course given her mixed experiences with high school chemistry. Eventually, Lina explains that she has had to work very hard in the course to do well. The most overwhelming topic for her to grasp was moles, but through collaboration with other students in the class, googling information in a kid-friendly way, questioning everything in lab, and being persistent in learning Lina was able to do well in the course. Upon hearing Lina's reflections about what she did in the course, the other student began to feel more comfortable. The student and Lina even found themselves agreeing and

commiserating about the course's depth. Moreover, Lina explained that her biggest frustration with the course was that she did not feel the material was easily applicable to the elementary. There were some labs that were easier to do like the Oobleck, but that most of it was hard to adapt. Overall, Lina started to change her perspective on chemistry—she no longer considered chemistry to be beakers and flasks, but rather a way to examine them. The present practices that Lina mentioned as salient to her science learning and being include collaborating with other students in lab, googling information from kid websites, questioning lab practices, and challenging the applicability of content to their future. These present practices linked to Lina's science identity during the *Fundamentals of Chemistry* course allowed her to reflect on the kind of elementary teacher she saw herself as in the future; I will explore this in scene three.

In scene three, Lina described the type of elementary teacher she wants to be after she leaves the program. For the most part, she believes there is so much value in teaching elementary students science. She wants to be an elementary teacher that gets her students to ask questions and be curious. To Lina, science is about understanding why things happen versus what happens, so it is important to learn the content in-depth enough to explain it. Lina believes doing experiments with elementary students to get then excited about science is also her role as a science teacher because their attitudes about learning science are still developing. This reflects her change in disposition towards the *Fundamentals of Chemistry* course. She explains that it is important to provide elementary students with a foundation for science, so they can succeed as they learn more in-depth material. Lina acknowledges that much of her elementary education was not focused on science, but that teaching children science through everyday phenomena helps elementary students become interested and learn. The future practices that Lina mentioned as salient to her science learning and being include valuing science teaching, inspiring elementary students with science, providing elementary students with a foundation, doing experiments with students, and acknowledging deficits in elementary education. These future practices linked to Lina's science identity after the *Fundamentals of Chemistry* course elucidate what are the important meta-messages Lina has gathered from the curriculum.

Finally, to elucidate Lina's science practiced-linked identity, I am reintroducing the definition of practice-linked identity to qualify what a practice is and how it contributes to a science practice-linked identity. Practice-linked identities manifest as the way a learner perceives their participation within a discipline (Basu & Barton, 2007; Carlone et al., 2015; Nasir & Hand, 2008).

Drawing from Funds of Knowledge (González et al., 2006), Basu and Barton (2007) assert that learners practice within a discipline by connecting to their life experiences that emerge from participating in a figured world, meaning there are many different, overlapping, and authentic ways in which one can practice and therefore identify with a discipline: as a consumer of the works and practices of a discipline; as a producer of new knowledge and products related to the discipline; as a critic who critically analyzes disciplinary knowledge; and/or as a teacher who communicates disciplinary knowledge to others. Practice-linked identities are self-recognized by the learner as they reflect on why they engaged in practices of a discipline and what that means for their learning in that discipline. Here, *practices* are the ways Lina acknowledges she participates in science that *link* how she views the discipline of science and herself.

I have narratively constructed Lina by considering her past, present, and future practices in science. In her past experience, I wanted to make it evident that she did not necessarily like science because she was good at it—Lina liked science because she had some positive experiences starting from an early age. However, not all her science courses were positive, which is why I presented her experience with chemistry to be mixed. I did this to prevent the simplification that good experiences with science always means good science identity. I also wanted to communicate that Lina perceived that she was doing well in *Fundamentals of Chemistry* because of the effort she was putting into the course. By complicating her experience with chemistry, I was able to capitalize on Lina's persistence and hard work, which I showcased through her fruitful practices in the course. Lina entered the class nervous because of her mixed relationship with chemistry from high school, but she learned how to utilize the materials in the course to become a better science learner and future teacher (see **Chapter 9** for more information regarding *how* the curriculum afforded those opportunities). She had reservations about the course. Lina still sees herself as a future elementary teacher first and her main concern is making sure she is the best elementary teacher she can be. She believed the class materials were helpful, but they were not intuitively adaptable to the elementary student context. Lina has changed her perspective on chemistry while taking the course and sees herself inspiring students to question the world around them and get them excited to do science. It is important that they have a better elementary science experience than she had.

CHAPTER 7. ANALYSIS AND DISCUSSION OF "I AM NOT A SCIENCE PERSON"

7.1 Overview

The first section consists of all the participants that self-identified as being a "not a science person" with a table containing the quotation I used to put them into this group. Given that I do not know the demographics of these participants, I did not put any information into the chart. As mentioned above in **Chapter 5** (see **Participants and Curriculum**), the demographics of the sample participants are female- male-, White-, and Asian-*presenting*, meaning that this is information that I have *inferred* from the participants; therefore, I do not feel comfortable using these feature to tell the story unless participants explicitly self-identified their demographic background while sharing their oral history as documented by video and consequential close-transcription. The second section is the narrative itself that blends the essence of each participant into several composite characters, "Margo," "Penny," and "Sarah," which serves as the analysis. The third section is the discussion of the narrative that draws from the theoretical framework to answer the first research question. The theme of this chapter is *reconstruction* of characters based on the language that PSETs utilized in the interview setting (see **Appendix B** for **Narrative Worksheet**).

7.2 Participant Subjects

The table below contains the PSET pseudonym that they self-selected during the interview with the quote that I used to classify them as a "not a science person." Again, to make the data more robust, I broadened the selection criteria to also acknowledge PSETs who strongly dislike science in general (i.e., not specific classes, but science as a discipline). I also included students who said they were another kind of person (e.g., "I'm a math person"). I divided the PSETs into three characters to represent the complexity behind this group given that the literature tells one story about PSETs who "dislike" or are "not science people."

Table 2: PSETs' Science Experiences

PSET Pseudonym	Allegorical Character	Data Source
Barbie		[00:03:01.12]: B: I loved...like right now? Oh, I liked it. I like math more, but in high school I didn't [like science]
Erin	(As Margo)	[00:02:09.00]: E: When I was in high school, I took biology, chemistry, physics so senior year you didn't have to take one. I took 3 years. I have never liked science (I'm sorry) I just never really enjoyed the subject at least for me. There's not a lot of like structure and labs and everything are kind of like...I like to see stuff. Like I am really good at Math and stuff like that and I just feel like there is less structure in it. Um, biology in high school was okay for me and I remember chemistry and physics was very tough and everyone struggled through it and it was always, "Why did we take the course" because it was really complex and we had teachers...and they were really good at trying their best to explain it, but there were always times when people wouldn't understand but I mean eventually I did well in the course and all that business and stuff. And it was definitely a struggle. I remember chemistry and physics were for me.
Reagan		[00:38:34.13]: Rea: I like probably math, but not geometry. I like the plug-and-chug math. I like to see an answer. I like to know you can put it back in and you know that you go it and like reading, but I don't know how I feel about teaching reading. I'm more of the grammar side. The commas and the periods and stuff that there is always a right way to do it whereas writing styles, there are a thousand different writing styles. Only one way or one place that period should be or that comma should be and I think that relates to the math, also because there's one answer, which science is like that to an extent, but a lot of times it's hypothesis and it can be
Sporty		[00:37:05.23]: Sp: I think it's interesting that you guys say that because I'm such a math person like math makes so much sense to me just because you always do the same thing and like for me if I would have had either in high school or now the math reasoning behind the application, I feel like I would really get it. In high school, all I did was balance equations and like I couldn't tell you why I was doing it, but now like if I went back and somehow connected this to what I was learning then like I feel like it would be a lot clearer to me like everything that goes on. But, I think that just depends on the person, like I said, I am a math-person. I like formulas, I like lists. It makes a lot of sense, but you have some people that are like I don't...
Gina		[00:01:44.22]: Gi: I took honors chem, which was really hard for me. I'm not a science person. I am like the opposite. I like Math, but like science is not my forte, but I like to push myself, so I took honors chem, which was terrifyingly difficult.

Table 2 continued

Britany		[00:06:35.05]: Ba: I just didn't choose to start off with sciences just because...science is not really my favorite. And then it got to be the point where it was like oh, you needed to have all these sciences before you can take this block and so that's why I'm in this class now.
Ally	(As Penny)	[00:23:43.01]: Ally: I feel like that's my biggest thing about science classes have always been really hard for me. I think I just have that mindset that started back in high school because I didn't do very well in my chemistry class. I kind of set that for myself and I shouldn't have, but I think that's the biggest thing for me is that I struggle with them. Same with math, but those topics I have just told myself that I'm not good at that, so now I've just not been successful as I could have been, and I think that's my biggest thing.
Renae		[00:07:24.10]: Ren: I don't know science has never been...I guess maybe it's never been a strong suit for me, but I never really even like putting science into my everyday life. Because I feel like maybe I wasn't given enough science in elementary school at a younger age in order to even want to learn it if that makes sense.
Lilian		[00:22:33.19]: Lil: Like, there's just so much to it and it's so complicated that like the broad term of science covers anatomy, physics, chemistry, biology, and all this other stuff and I mean we're not "science people" who go in-depth, but we do have to teach the kids. You can't just get out of that, it's in the standards, but it's not anything crazy like dissecting a sheep brain. But, it's just the broader, the more simple, broader concepts that you are going to teach these kids that one day they are going to build upon. Like, we lay the foundation of doing this and doing that and middle school and elementary school and then high school and college and these little tiny things we didn't think about, we built upon in college and that's what our kids are going to do because by the time they are the age of college, they are going to have to know.
Jordan	(As Sarah)	[00:04:12.22]: J: I think my worst [class ever] was science...I mean I didn't really like chemistry...but the worst class that I had, the worst teacher was, anatomy, human anatomy.
Gretchen		[00:03:21.15]: Gr: Science is my worst nightmare. It's just not my, I don't know, I don't have that side of the brain, I guess. It wasn't too bad. I had a 4.0 in high school until I got tot chemistry and then I got my first C ever, so it was not good. But, I don't know why. I think it's just because chemistry, if I can't physically see it, it just doesn't work in my mind very well, so I'm more of a visual...strictly a visual learner, so not being able to see all of the little atoms are like...doesn't really help me much.
Taylor		[00:00:52.02]: T: They were usually my lowest scores in science especially chemistry.

7.3 Narrative Analysis

Drawing from Sfard and Prusak's (2005) model, ${}_{B}A_{C}$, the identified person who are the subjects of the story, A, are allegorically named Margo, Penny, and Sarah; the author, B, is me; and C are Minjung and the reader who are acknowledging Margo, Penny, and Sarah (i.e., they are telling their story to Minjung the instructor and to *you*). The story is told from Margo, Penny, and Sarah's third-person point of view. Thematically, the PSETs who I have blended into Margo see themselves more as liking Math or other subjects; the PSETs who I have blended into Penny see themselves as finding science generally difficult, which has made their ability to participate in science a struggle; and the PSETs who I have blended into Sarah dislike science itself and are put off by it. Margo is meant to showcase that some PSETs have expertise in other subjects than chemistry, especially subjects like Math that have been recognized as important for learning science (Van Driel et al., 1998). Penny is meant to showcase that some PSETs have experience with science that has not necessarily been positive because they struggle in it but understand that science is important to learn. Sarah is meant to showcase that some PSETs genuinely dislike science and are more in-line with what the current literature has captured. Researchers have shown that PSETs "lack of science content knowledge" (Hoban, 2007, p. 75); "dislike for science teaching" (Tosun, 2000, p. 374); and "low personal self-efficacy [in science]" (Ramey-Gassert & Shroyer, 1992, p. 29). In creating these allegories on "not science people," I attempt to present the spectrum of experience that the literature has largely explored. The narrative dialogue mostly consists of *direct* participant quotes. However, there are interpretive and transitional dialogues.

7.3.1 Exposition

The scene is a small, yellow room with a large window that extends to the top of the celling. Under the window is a table large enough for four people—there are four chairs around it. At the center of the table is a microphone and a box half-filled with Halloween candy. On the other side of the wall with the window is a camera perched on a tripod. The interview room is ready. Minjung moves toward the camera and presses record. The red light blinks on.

7.3.2 Story. Scene 1-Past

"Um, so, today I wanted to talk a little bit about your experiences with science and science classes—" Minjung begins speaking but catches Margo and Sarah making faces to themselves. Minjung stops and grins, "What?"

"Noo, noo! Sorry, Dr. Ryu! That just made me think of high school and everything. That was like a rough time," Margo remarks as she takes a sip of her water bottle.

"Yeah, science was pretty…how should I put it…I think nightmare is a good way to put it. Yeah, nightmare is pretty accurate actually," Sarah agrees.

"Well, that is what I want to talk to you today about and oh, err, you can call me," Minjung pauses then lifts her voice a little, "Mia."

"Mia, cool. I like that," Sarah continues, "Well, let's see. Uh, do you want to know about like the classes or the teachers or—"

"Yeah," Minjung interjects. Minjung opens her notebook and flattens a new page. Minjung places her pencil case in front of her and pulls out a pen.

Sarah pauses unsure, "…Okay, so everything then. I think I just had really bad science teachers growing up honestly. Like, my anatomy teacher was the worst she was like," Sarah raises her voice, "'"Here are the answers. Here are your notes. Here is the exam.'" Margo laughs, almost knocking her water bottle on the floor. Penny who is sitting on the other side of Margo and Sarah smiles quickly.

Margo chimes in, "Oh my Gosh, me too! My biology teacher gave us everything to memorize. Apparently, if you could memorize all the answers then you did fine. We had these big coloring books and we just had to color in for a ton of points. I didn't like it, but looking back I feel like I knew what was expected of me like I knew what I had to do to get an A. I just felt like the information was just out there for me and it was up to me to know it, but like sometimes I feel like with science classes the information is not really as accessible. Like, I really have to dig for it."

"That's…interesting. You used coloring books," Minjung says as she looks over to Penny, "Were your high school experiences with science similar or different to theirs?"

Penny jumps a little when she realizes the question is directed to her. Penny nods in agreement with Margo, "That's how mine was…it was similar to that like we didn't do hands-on

stuff. We didn't do experiments or anything like that. In chemistry, we just worked a lot more with the periodic table more than anything and looked at the periodic table and found it—"

"Ugh, I don't like anything about science TBH. I'm sorry, I am not a science person," Sarah interrupts Penny, "Like in my chemistry class, I got there and within the first 3 days I knew I was going to do terrible in the class. The room didn't have any windows. It was all dark and it was a depressing environment and the teacher wasn't very nice," Sarah takes a breath and starts pointing at the walls, "Yeah, like if I had science in this happy yellow room with a big window maybe I would have liked it more!"

Penny clears her voice and shuffles in her chair, "I feel like my biggest thing about science classes being really hard for me has been my mindset. I think I just have that mindset that started back in high school because I didn't do very well in my chemistry class. I kind of set that for myself and I shouldn't have, but I think that's the biggest thing for me is that I struggle with them. Same with math, but those topics I have just told myself that I'm not good at that, so now I've just not been successful as I could have been, and I think that's my biggest thing."

Minjung leans towards Penny and tries to think of something to say. Minjung wants to ask more about mindset, "What does she mean by mindset?" Minjung sighs and looks back at her notebook again. Minjung decides to continue, "Yeah, it's tough. Was there anything about science that was good in high school?"

"Actually, my chemistry class was okay in a like a less awful way. I actually took honors chem, but I honestly should have probably failed it as hard as he made it. And then he curved and to have to curve all the way to get a C from an F, which means it wasn't taught very well. I did good in the parts of chemistry that involved a lot of math and I know physics has a lot of math, too. But, like chemistry math makes sense to me. I like Math, but like science is not my forte. I like to push myself, so I took honors chem, but it was terrifyingly difficult," Margo says all the while clicking the cap of her water bottle open and closed.

Penny clears her throat again, "Yeah, I felt like in high school, there was a lot more balancing equations and stuff than we do in our chemistry now. Now, it's different."

Minjung leans towards Penny again, "How is chemistry or like science different now from before?"

7.3.3 Story. Scene 2-Present

Penny looks down into her lap, a little nervous to respond, “So, in high school chemistry, I felt like it wasn't as...it was hands-on. It wasn't as relatable. But, here I think it makes it a little more relatable than my previous science because we are actually hands-on doing things with real products that we use every day.”

A smile creeps onto Minjung’s face. Minjung looks down and scribbles something into her notebook.

Sarah looks sideways towards Margo as if to signal her disapproval. Her and Margo share a concerned look and then Sarah begins, “Yeah, I guess I would say that. But, it’s still kind of hard. Like even without the math…” Sarah lowers her voice in a mimicking tone, “’How many moles are in this many particles?’” Sarah continues in her normal voice, “Whatever, like it's just hard to grasp the wording. Like electronegativity is cool, but you can't like visualize it. Chemistry is just hard to visualize, but the labs help sometimes. It's not something that will help me understand moles by looking at clear water and putting a probe in it. That didn't really happen for me. I can tell with other labs we are doing like the one where we are making ice cream, static electricity like the ball sticks to the wall kinds of things I can understand those better because I can see it, but when we are talking about molecules. Yeah, those kind of things, then I kind of am not as great in those. I like the visual experiments that we do.”

“Yeah, I agree with Sarah,” Margo adds, “Sometimes the labs help and sometimes they don’t. Like, I could solve equations in high school to find a mole, but I don’t really know what a mole is. Like, I know how to find the moles for this and blah blah blah, but I was like...Even with that lab, I still don’t really know what a mole is,” Margo’s voice raises a little, “But, I like working with Sarah in lab.” Sarah pumps her hands in the air and exclaims, “Yeahhhh, woooah!”

Minjung leans back in her chair and puts her pen to her lips, “So, that’s how you two know each other. I can tell you are friends.”

Penny grins, “Your labs sound fun. My lab… sometimes I really feel like having lecture before lab would have been a little bit easier during lab. I feel like it would have, not like sped up the process, that's not what's important, but I wouldn't have had a little more of a knowledge base.”

“No, honestly, same,” Sarah looks at Penny as she speaks, “Because it was rough just going off the pre-lab just because I hadn't seen some of these concepts in so long and I know that I could email the TA, but when I was working on it, it was kind of late. And even the stuff we used to

study, I just feel like it's a little bit overwhelming and a little bit over my head," Sarah's words shift and begin to sound more lamented, "Yeah, I can't fully grasp it all so it's just frustrating. As I read, it turns from intense reading to like skimming just because I get so overwhelmed by it. I am just not a very good student, I guess."

Margo's face starts turning red as she prepares to speak. She feels frustrated for her friend. Margo breathes out her nose as she continues, "And, it sucks when you are being assessed on something, but you don't really know what it is or you do know it, but not in the way you wanted it. I get really upset when I get a bad grade. I am not one to give up on grades. For me, grades are everything. I always read through materials and google like it's my job."

Minjung furrows her eyebrows, but quickly smooths her face again to hide her disapproval. She pauses and looks into her notebook as she thinks about how to clarify what they mean. Minjung sighs and tilts her head to the side, "Could you say more about that?"

Margo and Sarah stay quiet. Margo opens her water bottle and begins drinking from it.

Penny clears her throat and tries to clarify for them, "I guess, I can kind of get what you mean. That was also something I was going to say about our lab group like there's a lot of the time we have questions and our TA would come up and she'll say to collaborate with other groups and see what they got because there are lots of times we all got different answers and so we're like well what did we do wrong? And we got this answer right and this answer right and maybe we just came up with two different right answers or maybe they are both wrong or maybe one's right and one's wrong. Like, we had to figure it out. But, I think that was just a great learning experience. The TAs really make the lab better because they could have just easily been like, okay let's take a look at this instead of the rest of them and like hinting that was the one to look at, but instead she was like collaborate. Figure out what's going on like let's figure it out and get on the same page again. So, I appreciate that. Those are experiences I would want to have with my future students."

Margo snaps her fingers and points towards Penny, "That's it. I don't think it would bother me nearly as bad if we could do it, explore it, and then maybe have our laptops and look it up really quick. And it's very helpful when the TAs are both in there because with just one of them in there, it's hard for them to come around and get to everybody because we all just shoot our hands up, but with both of them in there it's helpful because they are able to help everyone in lab more. And the homeworks, like the prelabs, are hard to do with our current class format. Since the lectures are after the labs, it's a little frustrating because you don't know. Then you look it up and you find out

for yourself and you reteach it and they teach it in lab and I really think doing the homework before is actually helpful even though it's frustrating."

"Yeah, Margo and I are always asking the TAs for help. But, to help with the prelabs and homeworks or whatever, I sometimes go to a chemistry for kid's website and it was really helpful even though it's a little silly since it's for kids and in really simply terms. Since it's for kids. And it helped with my focus," Sarah says in a low voice somewhat embarassed.

Margo smiles at Sarah reassuringly as she begins talking, "Yeah, sometimes, I'll also go on the internet if I don't understand a topic like as in-depth as I want to know it. For example, polar and non-polar. Um, I kind of wanted to refresh my memory, so I googled polar and non-polar and I found a nice little activity thing that let you look at polarity and nonpolar things and why are they polar and why they are attracted. So yeah, sometimes I'll go on the internet and google it. Sometimes I'll go and look at YouTube videos, I love YouTube videos. I love it especially with chemistry because they show you, so I look at YouTube a lot when I am studying because it's nice to see it visually."

Sarah shuffles in the chair nearest Minjung and peers at her sheepishly, "I will say though that I feel like I learned more science in my years at Purdue than my whole entire life. Pretty much probably because it's just like a lot at one time and I had to take physics and I had never taken physics before in my life, so that was kind of opening like a whole new world to me. Like, my brain never thought that way and so I had to like train my brain to think in the science way of how things work like electricity and also there's stuff that I've never thought about and I just, it just happened and I just think about it extensively and so I kind of look at the world with a different perspective, I guess."

Minjung taps her pen on her notebook, "How does science help you see the world with a different perspective?"

Sarah continues. "For me, I thought science was like objective and there was a right or wrong answer and you have to find the right answer. But now, I think that sometimes it can be more memorable if you do it wrong because if you do something wrong like if you caught something on fire then you'd be like yeah… that's not how that works. I still think being right is important, but also I think exploring why something is wrong, you know?"

Margo nods in agreement, "Mhm, and at first I was skeptical about having lecture after lab and now I really like it because you get to explore, explore and then come to you and get it put

into words for you. I remember in high school, we asked our teacher about science and we were like can you be creative in science? And she was like creativity doesn't count in science because it is very concrete. But, here it's not like that. It kind of makes me like it less, but I appreciate it more."

"I actually was going to say. I think being creative, collaborative, and inquisitive are important parts of science," Penny puts her hands spread out on the table, "Like, somewhere decided that they were going to figure out why this table is this table. Like, somebody one day was like I'm going to figure out what this table is besides that it's made out of wood. And even more than that you have to ask questions and work with people. There are scientists out there that have thought of something, but I mean like yeah where a lot of stuff has already been proven and stuff like that, but there's so many things being disproven nowadays. Like, this used to be amazing for you and now they're like this causes cancer. Yeah, everything causes cancer nowadays, but like I mean you have to imagine what you're going to look and then you have to experiment and you might collaborate with somebody on it because like if you have an idea of something, you almost want to share it with somebody because you just have to have that help of like thinking of like why would somebody take a kite out in a thunderstorm. Like, why would you do that? And he imagined that, that was going to happen and there's electricity now."

Sarah responds, "And that's the stuff that is important to teach little kids in the future—"

Margo jumps in aggressively, "But is that what we are learning to do in these elementary ed classes? Sometimes, I wish it were more relevant." Margo looks at Minjung quickly and then looks away embarrassed.

Minjung adds unfazed, "You know, students have actually said that to me in other interviews. In what ways do you think the class could be more relevant?"

Margo becomes more relaxed and looks at Minjung, "Like, I'll never have to teach complicated things. But I do feel like we need to learn the theories behind things and like why kids need to be able to do things. I just want to be told like why. So, we know that we might be learning something more complicated, but like it's good that we know it because in this grade they have to have this information and like that would even be great at the beginning of a PowerPoint just to be like these are the state standards. These like Indiana Standards, which I'm sure are pretty similar to other states are like what is relevant to this information. This is why you need to know this. I feel like it would motivate us more to actually care to learn it."

Sarah looks down and starts examining her nails to soften her disagreement. She sighs, “Well, I like the elementary ed science courses just because all of the experiments have been designed so that you can use them in the classroom. I think it is really cool because if you are just taking the general one then you would not be able to apply that to our future careers. But I like how all of these can be adopted or changed or modified into a normal classroom, so I don't know. I feel like I am getting a lot out of it. Even though I am not like super sciency.” Margo winces a little and narrows her eyes at Sarah. Penny notices Margo’s anger and glances at Margo.

Penny motions to speak, “I will say that I totally agree. A lot of the labs can mostly be done in a class with limited resources. But, like, elementary schools focus mostly on English and Math. Those are the standards. My first TIP assignment was a special ed Math specific middle school classroom, so it had so much stacked against it because not only was it middle school, but it was also focusing on Math and nothing else. And it was also just terrifying because all of them were talking about the drama on the weekend and were like you broke up with so and so and I'm just like guys let's learn our Math and they all didn't care.”

Sarah starts playing with her sleeves trying to again soften her disagreement. She narrows her eyes at Penny and sighs. Sarah pulls her lips in and wrinkles her forehead. Sarah begins mouthing, but no words come out. She eventually finds some words, “Yeah, but I don't think that how we divide our time teaching should be based on what we're assessing as much. I'm sad that we're not teaching a lot of science. I think it's still a very important concept and there's a lot of different sciences and you use it a lot in daily life, so I think it's stuff you need to know in general, so I believe it's important and I was really surprised when I went into my classroom and they were only learning science for half of the year and I mean you do get tested on it for like the SAT and ACT or something, yeah ACT has science in it.”

Minjung agrees, “I have heard that, too. How would you then teach science as an elementary teacher? Err, like, why do you think it’s important to teach science?”

7.3.4 Story. Scene 3-Future

Sarah begins. Her voice is louder now that she feels Minjung supports her ideas, “As teachers, I mean my classroom teacher actually has like her schedule posted on the board and four of their, no five of their seven hours in class are devoted to math and reading and writing. So, I mean there's this much time to incorporate health and social studies and science and all of the other subjects you might want to teach, so like you have to incorporate it with the writing and those

kinds of things or else it's just not going to get done, or not going to get the attention that it needs. I am better at those subjects, so I can see how I can fit science into those."

Margo leans back and puts her hand on the back of Sarah's chair. Margo looks at Sarah apologetically and pockets the side of her mouth. Margo speaks softly, "Yeah, I actually think you are right. I was just saying that I think it's also hard because like when I was in elementary and middle school, we never really. or maybe we did touch upon it and I don't remember it, but we never talked about chemistry and physics in the way that we talk about it now. If there is anything for this course, I'd like to see more of that because it's like some of it I am like I don't know if I am having my students test acids and basicity' like experiments like that and like I want to keep trying to think of things that I can do and it's very great like Oobleck. Especially because science is inquisitive and you have to make observations to understand the world."

Penny chimes in "I am more concerned about being a good elementary teacher. I care about helping students with all the subjects regardless of how I feel about them. I mean it's not just science, like you know God I hate math. Ugh, I hate social studies. I hate English. But, it's because we're all tested on that stuff in the same way that we're not, I mean we're not tested like that in education. And, I think that's what makes it easy for us because education is what we do. So, if I were in a chemistry class and my final was teaching something to the class it might be a little easier for me because I'm a lot better at having a lesson plan and doing it and getting it over with is kind of what I feel like is how we think and it's not ask-a-question, answer-the-question type thing. Yeah, you just got to be able to go up there and get the students involved and engaged in what you are doing with a smile on your face. Like, if you're having a bad day, teachers have told us, if you're having a bad day tell your students because they're the ones that care. But, I never thought about teaching as being an acting job and then I got here and they're like fake-it-till-you-make-it. Like, you go in there with a smile on your face like you're the happiest person in the world and, I mean that's hard, but those little ones maybe don't like math and you got to act like it's the most fun thing for them and they'll like it because they love you—"

Sarah pulls her sleeves up and leans back in her chair. She tries to make her voice sound mischievous. "I have to say this now. I have a confession, guys. I actually did like science in elementary school. Shocking right? Um, growing up my dad was super into science, so we always had science kits where we made circuits. And we had like sciencey things in my house growing up. I just didn't necessarily like it. I think that, I know that personally science has made me

appreciate— science here has made me appreciate what I've learned in my elementary school science and I remember I had a fifth grade teacher and I absolutely hated her and I hated that class and I don't know, she did a lot of things with science and then I just didn't like it and every day that class was so bad and I got to college with biology and literally every single experiment that we did in that class was what I did in this fifth grade classroom and I was like dang it, she was right. So, I really appreciate my teachers, so I felt like I can now look at my students and say you will learn this someday."

Margo pretend-gasps as she lightly hits Sarah's shoulder. Penny joins in by throwing her hands in the air dramatically.

Sarah speaks again, "Yeah, this kind of relates to what Penny was saying earlier. This is sort of my problem with elementary science classes in general, not necessarily this class. I mean it's just kind of gets, it gets frustrating because I mean I know that my teaching experience classroom that I'm in, they alternate curriculum teaching units between science and social studies, so basically, they are only learning science for like half the year at most. They'll teach a unit of chemistry and then a unit of social studies and they just keep going back and forth for one-hour slot that they are allotted a day for like those two subjects. So, it's not being taught a lot and then you go here where they really, really, really value science a lot, and so we have to take seven, eight science courses and it's kind of frustrating because we are not going to use every single thing that we learn or probably maybe twenty percent of what we are learning in those classes combined, so it's just kind of there is a disconnect there and it's just kind of annoying from our perspective that we don't get to use what we are learning."

Margo responds, "And with that, too you said something Sarah…like...Oh! Okay, yeah because you were like you don't know if they didn't teach science or if it was just not called science. I was actually talking to a professor about this yesterday because we got on this topic about math and all the science classes you have to take and um it's true like in chem for chemistry, when I was in grade school I don't ever remember chemistry. I don't ever remember physics, but they do teach you...they just call it science that's what my elementary school called it. We just called it science, but I do remember learning about liquids, phases...err solids, liquids, gases and I remember learning about that. I remember learning about gravity, I remember learning about you know magnets and I remember doing a little experiment with that."

Penny hums in agreement, “Now, that you said that more things do come to mind. Like in third or fourth grade, we had a little garden that we would do and we would take care of that and learn more about that and why plants grow and what takes for them to grow and things like that, but I think you're right. We just don't call it that, we just kind of do it,” Penny takes a breath, “I actually thoroughly enjoyed this course. I thought, like I said I went into this with a bad taste in my mouth because of previous experiences, but it wasn't like I was expecting it to, like the beginning of the semester when I got my lab notebook, I was looking through it and I was like okay I can do this and I wasn't as bad as I thought it was going to be. But, I actually thoroughly enjoyed it and I liked that every week, we did something that was hands-on and we just did it instead of just learning about it. Because I know that more high school, you get a lecture and then you fill out a worksheet maybe and that's kind of it. But, with here we have a lab and then we have a lecture explaining like okay let's talk about what we did. I think we...like, I like the way it's set up, too where we do the lab first and then the lecture because I think if we did the lecture first, then it would be like okay what are we doing and then we do the lab and then it be like okay, how is this tie into this, how does this tie into this. But, having lab first we got to experience it hands-on even if we didn't fully understand what we were doing, but we still got to do it and then coming in to lecture and we gotta talk about it like okay let's talk about this, did someone not understand this part, let's talk about it on molecular level things like that, but yeah. I thoroughly enjoyed the class and I think a lot of other people did, too like I know other people went into the same mindset as me like I wasn't successful in previous chemistry courses, then maybe I'm not going to be successful now, but I actually did really well in this class, so…”

Sarah nods to Penny as she speaks. She catches the end of Penny’s sentence and continues, “Yeah, the chemistry in the class feels like something I can do. I feel like I can do this kind of science. I can do this in the classroom, too.”

Minjung chuckles to herself, “So, how did you decide to be elementary teachers?”

Penny jumps into the question enthusiastically, “I'm actually going into special ed and elementary ed and I think what really inspired me to become a special ed teacher was my brother has autism and that's something that's always been a big part of my life like me and my brother have always been like this and I have five other siblings, too, but me and my brother have always been the closest. And I think out of all of my siblings, I understood him more than anybody else and I think that's kind of what inspired me to continue doing that for other people and then tying

into education, a lot of students who do have disabilities are looked at as okay let's teach them the basics of living. Not an education and I think that's what I'm most passionate about, is I want these kids to not just learn about how to take of themselves and make it in the world, but also give them an education that other kids are getting and all the other students are getting in the world. But, I think that's my biggest thing is I want them to experience chemistry and I want them to experience writing and writing papers and all this stuff that all the other students are getting. And I feel like that's something that's decreasing in education today and the schools today. We just want them to...which is good, we do want them to learn life skills, but at the same time they're not getting the education that they should be getting, so I think that's my biggest thing."

Sarah exclaims, "That is awesome! That is honestly really inspiring."

Minjung smiles and lets the room fall silent. Minjung raises her head to look out the window. She notices the brown leaves stacked up against the window. "I think this is a good place to stop. Remember that it's Thanksgiving week next week, so we don't have class. Thank you everyone for sharing your stories. If you have any questions about the class or the interview, let me know."

"Yeah, this was kind of fun! Thanks…Mia" Sarah winks playfully at Minjung.

The students stand up and the room fills with sounds of shuffling. The red light blinks off.

7.4 Discussion

To situate the narrative, I wrote a composite story centered around Margo, Penny, and Sarah. The PSETs had a dislike/disinterest in science that stemmed from their experiences with high school science courses; however, I tried to create three different sub-plots for each of the characters that elucidate the ways they carried that dislike/disinterest/de-identification in science throughout their lives. For Margo, the PSETs that I drew from had strong backgrounds in Math because I wanted to show that not all PSETs who disliked science did so because they were "lacking" some prerequisite knowledge that is usually noted as being important for chemistry. In fact, Margo notes that she actually enjoyed the parts of chemistry and physics that dealt with Math. For Penny, the PSETs that I drew from had somewhat of a "fear" of science because they did not perceive themselves as being good at it. Penny's character was also meant to showcase the altruism that PSETs tend to have towards their students (i.e., the notion of doing anything for their students). Finally, for Sarah, the PSETs that I drew from had a strong dislike of science that is more familiar

to how the literature describes PSETs. Sarah's character is to show the nuance of disliking science that is somewhat lost using pre/post methods of analysis. Again, the themes were generated by looking across the Nvivo nodes and by referring to the analytical memo-profiles that were made for each student; for direct quotes see **Narrative Worksheet** in **Appendix B.** I chose three allegorical characters to show the complexity and variety of ways PSETs can be "not science people." Research question one will be addressed using Margo, Penny, and Sarah's narrative, which tells the discursive identities of these characters; this was generated by the stories from Barbie, Erin, Reagan, Sporty, Gina, Britany, Ally, Renae, Lilian, Jordan, Gretchen, and Taylor.

In scene one, the past practices that Margo and Sarah mentioned as salient to their science learning revolved around memorizing and going through worksheets. Margo even said that she was able to get an A in a science course, but that it was not very accessible for her to learn. In Margo's chemistry class, she did not perform well. Nevertheless, she did like a lot of the Math "parts" of the class in that she felt that was doable for her. Margo is a character who likes to push herself and finds that challenge important to her learning. Margo's past practices include memorizing science ideas, filling out worksheets, and doing math. These past practices influenced her dislike of science but affirmed her identity as a "Math-person." Sarah attributes most of her inability to do science to the setting that she was placed in and the teacher that she had. Sarah also briefly mentions how she did like science as a child (**see Scene 3. Future**.), but that it was never her "thing" even though her father introduced her to science from an early age. Sarah's practices include memorizing, filling out worksheets, and playing with circuits, which have influenced her strong disinterest with science and clear demarcation as "not a science person"; the reason she identifies as "not a science person," not exactly known. Penny's experience was similar, but she emphasizes how she never really did any hands-on activities or experiments in her class. She worked with the periodic table for the most part, which she contrasts with the *Fundamentals of Chemistry* course. Penny also had a mindset in high school that science was just too hard for her and that she did not do well because of her mindset. Penny's past practices are not explicitly defined, but I think it's important to acknowledge that Penny said working with the periodic table, struggling through the material, having a deficient mindset, and not doing experiments were what shaped her previous experiences in science.

In scene two, the present practices that Penny mentions as salient to her science learning revolved around the lab setting. Penny contrasts her lab experiences with her lack of lab

experiences in high school. Being in lab helped Penny reflect on her learning. She mentions that she wishes lecture was before lab to provide her with a baseline of what to do in lab, but then she acknowledges the importance of figuring out the process and being wrong to negotiate collaboratively the right answer. She mentions that collaboration, inquisition, and imagination are thus important for her to teach her future students because Penny learned the practices of collaboration, inquisition, and imagination are part of science. These moments affirmed Penny's identification as more of an altruistic teacher where science learning became a means for her to be a great future elementary teacher. Penny's practices include doing the labs situated using everyday materials, feeling overwhelmed by the reading material, asking the TA questions, collaborating in lab, and applying course materials to the classroom. In contrast, Margo feels that some of the labs are not necessarily helpful for her learning because she has no way to visualize the concepts, but that she learns by collaborating with her partner Sarah. Margo cares a lot about her grades and getting the right answer, which frustrates her during lab since she often feels like it's difficult for her to learn. Margo does say the class has broadened her idea of science from being concrete to more creative. To Margo, science has many right and wrong answers, which makes it frustrating for her because she wants there to be more of a clear right answer. Margo is motivated by grades and evaluation, so it is important for identity as a science person to have her work recognized as being "good." Margo's practices include collaborating with her lab partner, finding the right answer, and evaluating herself based on grades. In contrast to Sarah, Margo views the lab as both fun since she works with Sarah, but also frustrating because she does not feel she knows what is going on. For Sarah, she struggles with visualizing and doing chemistry, which she internalizes as her own problem with being a good student. Sarah laments not being able to understand the readings in the class and feeling overwhelmed such that she positions herself as not being a good [science] student. Sarah is the only character that strongly feels the class has helped her learn science aside from elementary teaching and has helped her think of science differently. Sarah, like Penny, has a mentality that she is not good at science; however, Penny is not as burdened as Sarah because Penny believes she can be a great elementary teacher without it. Sarah is more concerned with how the class affects her ability to understand science in her everyday life. Sarah's present practices include collaborating with her lab partner, reflecting on her past science experiences, feeling overwhelmed by the material, and being wrong.

In scene three, the future practices Penny, Margo, and Sarah mention as being salient to their science learning revolve around incorporating her strengths in other areas to teach science. To these characters, being a good science teacher looks different to each of them and the ways they felt about *Fundamentals of Chemistry* reflect that difference. For example, Penny and Margo felt there should be more activities that could be easily transferable to the class. In Penny's character, she emphasized a lot that she wanted to pass the experiences she had in the course to her students where she had students explore, be creative, and collaborate because she felt that was most beneficial to her own learning. Penny wants to be the best elementary teacher possible and for her that means prioritizing the subjects that have higher accountability testing. She still agrees teaching science is important, but in light of the standards. Margo wanted more activities that emphasized the implicit ideas about science (i.e., nature of science). She felt observations and investigations are important since she learned that science is about being inquisitive. Moreover, Margo notes that she does not really remember science because it was not taught as science; instead, students explored ideas and talked about them. Margo wants to teach science more implicitly because she thinks it will help students feel more capable in the future since she notes that science is such a scary word for elementary students. In Sarah's character, she believes that science is very important to teach even if she doesn't like it and she also feels that standards should not really dictate how they teach subjects. Sarah notes that she would want to incorporate science in other subjects like health and history so she can leverage more of what she is better at. Penny's present practices include adhering to state standards and using her experiences as models for students' learning. Margo's present practice includes providing activities that give students the sense that they are doing science. Finally, Sarah's present practice includes leveraging her strengths in other areas to teach science.

I have narratively constructed Margo, Penny, and Sarah by considering their individual past, present, and future practices in science. Although each character was crafted considering a different and salient factor that influenced their dislike/disinterest/de-identification with science, I did not want to present the characters as stagnant archetypes of each factor. In Margo's character, I wanted to emphasize that she was a "Math-person," who still struggled with sciences that had heavy math components like physics and chemistry. I also did not want to present Margo as having an easy time in the class because there is traditionally a lot of math in chemistry. Margo's reflection about not really understanding what a mole was even though she could do the math for it was to

acknowledge that she recognizes the importance of also visualizing in chemistry to learn; Margo finds this difficult to do. Margo is also a character who prefers to have a concrete, definitive answer like what she finds in Math, but the course has broadened her ideas surrounding definite answers and how science requires inquisition and creativity. To summarize Margo's experiences, Margo had a strong sense that she was a "Math-person," which she carried into the present *Fundamentals of Chemistry* course. She finds the course to be frustrating because there is not always definite answer and she feels uneasy about being unsure during the lab. However, she eventually understands that it is important that science is more open-ended because it allows for inquisition and creativity throughout the process. As a result, she wants to teach science more implicitly by having students do experiments that have them question what is happening.

In Penny's character, I wanted to showcase that Penny overcame her mindset of struggling in science being bad. Similarly to Margo, Penny did not initially understand that the process of being wrong was really helpful for her learning. I wanted to show this meta-growth in Penny: at first she perceived her struggle in science as meaning she was not a science person, but now in the class she has repurposed that struggle as a tool for her learning. Penny is a person who thinks the class has been a good science experience, but she would have preferred more materials that could be used easily in the elementary classroom. In addition, I wanted to emphasize Penny's strong sense of being a good elementary teacher. I had her be the only PSET to share her motivation of becoming an elementary teacher to highlight her exuberance for it. She wants to do anything that will benefit her future elementary students, which means considering Indiana State Standards and the current classroom structure of elementary education. In the past, Penny struggled with science and had the mentality that struggling was something negative, but in the class, she repurposes that struggling to make meaning out of incorrect answers. Now, she finds it more beneficial to be wrong so she can figure out how to make it right. As a result, she wants to teach science by having students go through similar opportunities for their learning that are aligned with the Indiana State Standards.

In Sarah's character, I wanted to elucidate how not having an innate interest in science does not necessarily mean she'll be a bad science learner. Sarah is the character who feels she has learned so much in the course. Sarah starts off saying how much she hated science in high school but then reflects in the course that she has actually learned more science in her undergrad than ever before, which she notes being proud of. Sarah's character also struggles with her mindset towards science in a similar way to Penny, but Sarah has broadened her perspective that she can actually

learn science and apply it to her everyday life. Even though she strongly does not consider herself a "science person," Sarah wants to incorporate science teaching wherever she can. The *Fundamentals of Chemistry* pushed Sarah to think about herself and what she was capable of learning in science. Moreover, Sarah was the only character that disagreed with teaching according the high-accountability testing requirements because she believes it is important that students receive a well-rounded education. I had Sarah's character at the end re-reflect on her science experiences and she noted that her earlier experiences were positive. In the past, Sarah struggled with science and even called it a "nightmare," but now in the course she has realized how much she has learned despite not grasping all the concepts fully. In the future, she wants to utilize her strengths in other areas like social studies to find opportunities to teach science in elementary schools.

CHAPTER 8. ANALYSIS AND "DISCUSSION" OF AMBIGUOUS

8.1 Overview

The nature of this chapter is different from the others. The first two sections have a similar format as the analytical chapters presented previously. However, the third section, "**Discussion**" describes how my choice of theoretical and methodological framework fall short of producing sound research claims about certain participants. The finale section describes my rationale for writing the chapter with this format.

8.2 Participant Subjects

The table below contains the PSET pseudonym that they self-selected during the interview. The first three participants have quotes that I used to group them under the banner of not necessarily "belonging" in elementary education. The other nine participants at the bottom listed in series do not have quotes to show that I could not group them based on common themes.

Table 3: PSETs' Science Experiences

PSET Pseudonym	Allegorical Character	Data Source
Annalee	(As Andrew)	[00:13:39.00]: AA: [We meet] Chinese students through the Chinese Association. But I have plenty of American friends because I lived in dorm for the first two years and the two neighbor dorms are elementary education, so I... before I know [Chinese roommates] I knew them and we know we are in the same course and same major. In total, there's 12 people and only 2 of them are Chinese including me.
Bailey		[00:16:13.04]: BB: It sucks. It sucks because a lot of my friends are in engineering and management major. Like the "Asian majors" and it was really hard for me to make friends because they have a lot of topics to talk about and then they can go to class together and they can review together and go to a review together because they have a date and then the schedule stuff, so when I first come here my freshman year they make friends through that experience and similar things, so it was really hard for me at least.
Evan		[00:35:09.07]: Ev: Hmm, I mean I don't think there's a specific time, well I guess like when I was growing up I always wanted to be on Sports Center, I was big on sports and like in high school I was a broadcaster for our radio station for sports, for basketball and football and it was something that I wanted to do. Junior year came around, and I took peer tutoring and I just went to my step dad's class and I just goof off and go to his class and hangout, and the students there got me really excited, like oh Evan is here. It's like, I don't know, this feeling of want that you get from their students that when you walk in the door, they want you there and as being a male in elementary education, I think you guys know, there's not many and that's one thing I wanted to change, too. Like, a lot of these kids don't have a father-figure either, so like just because you're their teacher that can kind of give them guidance into like being a good student or if they go off track, or like down the wrong path, you can kind of just sit them down and talk to them.
Amy, Annette, Cortney, Elizabeth, Julie, Koby, Liv, Mandy, Olivia, Patty, Ruthie (As Amber)		

8.3 Narrative Analysis

Drawing from Sfard and Prusak's (2005) model, ${}_{B}A_{C}$, the identified person who is the subjects of the story, A, are allegorically named Andrew; the author, B, is me; and C consists of Amber who represents the Ambiguous students and the readers who are acknowledging Andrew (i.e., Andrew is telling his story to *other* PSET named Amber, Minjung, and to *you*). The story is told from Andrew's third-person point of view and attempts to blend the essences of Annalee, Bailey, and Evan. Thematically, these students report having mixed feelings about science and

elementary education. The other character named Amber is used to represent the Ambiguous students whose science practice-linked identities were not knowable to me.

8.3.1 Exposition

The scene is a small, yellow room with a large window that extends to the top of the celling. Under the window is a table large enough for four people—there are three chairs around it. At the center of the table is a microphone and a box nearly empty of Halloween candy. On the other side of the wall with the window is a camera perched on a tripod. The interview room is ready. Minjung moves toward the camera and presses record. The red light blinks on.

8.3.2 Story. Scene 1-Past

"So, can you tell me about your science classes in high school?" Minjung asks as she quickly shuffles into her chair.

Amber nods, "Hmm, I took just the basic classes in high school like biology and chemistry. To be honest, I don't really remember what I did in those classes. I know biology had stuff about cells and chemistry had a lot of math. Actually, I do remember how my chemistry teacher would cover the whole board with notes—"

"Wow, the whole board," Minjung leans forward interested.

"Yeah, it was so much writing that my hand would hurt after! So, that's all I really remember from high school. I didn't like it, but I didn't necessarily hate it," Amber adds.

"That is a lot of writing. And what about you," Minjung pauses to read the name tag, "Andrew?"

Andrew looks up at Minjung and then turns his eyes down towards the table again to speak, "I took biology, chemistry, physics, and environmental science in high school. I did not like biology very much at all, but the other science classes were okay. I just remember science was very different from back home."

"Oh, where, wh—" Amber trails off, unsure of how to phrase her question. Minjung sits silently in her chair waiting for Amber to finish her thought.

"…Where am I from?" Andrew says with a smirk.

Ambers' cheeks turn red, "Yes, thank you! I didn't want to like ask, ask, but yeah, where are you from?"

Andrew sighs somewhat annoyed, “China. I’m from China.”

Minjung furrows her eyebrows and peers at the questions she wrote in her notebook. She takes a pen from her pencil case and places it inside the spine. She closes the notebook and turns her body towards Andrew as she speaks, “I thought school was kind of different, too when I came to the U.S. I did most of my schooling in Korea.”

Andrew pauses unsure of how to respond to Minjung. He takes a breath and starts, “Yeah, American teachers are mostly just fun. I don’t really feel like I learned anything. I took AP chemistry for my senior year and I really liked it because my chemistry teacher was really fun but she was also kind of strict too. So, it's kind of like Chinese teacher, but really balanced. I took AP chem with a lot of my best friends, so we worked together a lot of the time, so I had a really great year taking that class and environmental science was...didn't really like it,”

“What was taking classes with your friends like,” Minjung asks calmly.

Andrew continues more confidently now, “I had like two of my best friends and they were really good at science. I am not sure if I am a science or English person. I am not sure. I just need to like that class and as long as I get good grades in it, I can be whatever. And I remember in senior year we had study group every single week basically on weekends and then we would do homework together and then for exams and tests we would study the night before and the weekend before and basically sharing each other’s notes and then we look at each other’s quizzes and then see what they did wrong and what I did wrong. Since we were really close, it would be easy to study together.”

Amber jumps in decidedly, “Yeah, like studying with people is what I do to help with this class. It’s nice to talk to people and share ideas. I have found it really helpful”

8.3.3 Story. Scene 2-Present

“That is a great point. How do you use study groups for the class?” Minjung opens her notebook again.

Amber nods as she speaks, “Like, make outlines and share them with people. We have each person in the group like outline a lab and the PowerPoints.”

“Do you study with anyone in the class, Andrew,” Minjung asks.

“There's not many education majors that are Asian. I think the year I started college, I knew every Chinese person in my year. There are 4 people who were Chinese including me and I’m the only guy.”

Minjung glances at her open notebook again and takes the pen from inside. She twirls it around her fingers, “Can you say more about that?”

“Most people make friends with the same major, but like... So, most of my friends outside of school are Chinese. I have some Korean and American friends. Back in high school, I had mostly Chinese friends I could talk and make jokes with in class. I have mostly American friends and other nationality friends. So, it was a big change for me since there are not many Chinese people in this major. It sucks—”

“Yeah, that feels like it would be really tough not being able to relate to anyone in like… an easy way,” Amber says slowly. She smiles at Andrew to continue.

He blinks quickly and begins again, “It sucks because a lot of my friends are in engineering and management major, which are like the "Asian majors." It was really hard for me to make friends because the other Chinese students in the same major have a lot of topics to talk about and then they can go to class together and they can review together. The other Chinese students make friends through that experience and similar things. When I first came here my freshman year, there were a couple Asian people in the program, but they have changed their majors. So, now I am the only one. It’s really hard for me.”

Minjung feels Andrew is getting uncomfortable. She tries to think of a way to continue. Twirling her pen, Minjung asks, “Huh. What would you say are ‘Asian majors’? Like, what makes them ‘Asian?’”

Andrew laughs a little as he turns his head to look at Minjung, “Well, you know, like science majors. The ones with a lot of math. If you are good at math then you can be good at other chemistry, physics, or other things. But like, this class does science differently, so now I don’t know. Now, I think you also have to be imaginative to do science. Science has been going on for thousands of years so what can you think of that someone hasn't already thought of. For example, I never thought I was going to figure out a way to make a really good bouncy ball. The labs really changed my ideas about chemistry. Taking this class, chemistry is more than just the periodic table and numbers. There's so much more to chemistry. That's what I think is the crazy thing about science is that there's just so much.”

“Yeah and collaborating with people in the labs, even like the TAs make the whole experience so much better,” Amber adds.

“You know, I am really glad I stayed in elementary education though. Even if it is hard being the only Asian guy,” Andrew explains.

Minjung asks calmly, “How do you decide to do elementary education?”

Andrew begins, “I wanted to be a teacher since I was a little kid and that has not changed. I don't know because I think I like being with kids. I think teachers...you educate younger people and you help them grow up and gain that knowledge. I think it's something about being proud. I just like to be the person like that. And as you guys know, being a guy in elementary education, there’s not that many. That's one thing I wanted to change, too. Like, a lot of these kids don't have a father-figure either, so like just because you're their teacher that can kind of give them guidance into like being a good student or if they go off track, or like down the wrong path, you can kind of just sit them down and talk to them—”

Amber interrupts Andrew, “I just want to say that I think it’s really important that you are in this position and I think it’s really meaningful. I’m glad you stayed in elementary education. We need more people like you. I wanted to be an elementary teacher because growing up, I always got good grades, but I kind of flew under the radar because I wasn't really learning much, but I could get the good grades, but I wasn't excelling in my classes like I never felt like I was learning the material or whatever. I was always like a step behind, but my teachers never noticed because I was getting good grades and my parents didn't notice because on my report card, I got A's, so I really want to become a teacher to be able to catch those kids who aren't really like fully engaged in the lesson or aren't fully comprehending it even though they are getting a good grade or whatever it is.”

“Thank you, Amber,” Andrew smiles. There is a long pause. Minjung darts her eyes at Amber and then back at Andrew. She tries to keep the conversation going, “So, what about teaching science in elementary school?”

8.3.4 Story. Scene 3-Future

Amber starts, “I feel like it’s important because we teach English and Math, so they should learn science, too. It gives students the foundation they need.”

“Yeah, hmm, I think knowing science it just makes you really knowledgeable. Maybe kids will ask you a random question like, "Why does the sun shine or stuff." I will be really embarrassing if you knew nothing like "I don't know, go search the book." I agree with Amber, I think that science gives you a general idea and maybe you can give them like an interest and something given to them and then they maybe can find interest in it or that is about it and go find out themselves. They don't have to know every single thing. That is not possible. But learning science, I don't think that is necessary. It's necessary to be a teacher because you need to know how to handle these situations and its really fun.”

The pen Minjung is twirling falls from her fingers into the legs of the tri-pod. She bends into her lap and picks the pen off the floor. She lightly taps the camera.

Minjung stands startled from her chair to adjust the camera back into place. As she swivels it into position, she notices something… and her heart sinks a little—the lens was closed the entire time. Minjung turns around at Andrew and Amber. She looks out the window and she notices there is frost on it.

“It’s pretty cold out now. That means the semester is almost over,” Minjung offers.

“Yeah, that’s true,” Amber replies.

“The third exam is coming up soon. If you need anything for the class, let me know,” Minjung lifts her voice at the end trying to make the upcoming exam less scary.

Another long pause.

“Oh, is this it, Dr. Ryu” Amber asks a little confused.

Minjung speaks slowly, trying to appear collected, “Yeeeah, this was really helpful.”

“Um, I just want to say no one’s ever really asked me these questions before. They made me think,” Andrew says as he stands up to leave, “Thank you.”

Amber follows Andrew out and says, “Hey, if you want to study together for the last test, let me know.”

The red light blinks off.

8.4 “Discussion”

Foremost, I would like to discuss the themes presented in this narrative: 1) lack of focus on Amber throughout the interview; 2) Amber not necessarily saying her experiences but agreeing with Andrew; 3) Andrew discussing his status as a Chinese male student in elementary education;

and 4) Andrew wanting to change the lack of presence of Asian males in elementary education. Amber represents the Ambiguous students and example responses that were difficult for me to group. Many of the students did not really remember their experiences in high school science classes or said that it was "okay." Amber also "agreed" with Andrew, but I did not necessarily know how to interpret those utterances. I did not want to conflate agreement with having the same experiences. Agreement can also be used for encouragement, which is how I decided to utilize Amber throughout the interview. I had her character acquiesce interview time to allow Andrew to discuss his story. For Andrew's character, I was conflicted about how to present him. I chose to represent Andrew as an Asian male to expand on the different marginalizations presented in the data. The PSETs (i.e., Annalee and Bailey) who identified as being Chinese and discussed their [lack of] representation in elementary education referenced their Chinese background a lot during the interview. However, Andrew rarely referenced his male status being a large determent because the male PSET student (i.e., Evan) mentioned it in passing a couple times. This was why I chose to center the conversation mostly on Andrew's Asian status rather than his male status. I also wanted to showcase how well Minjung easily got Andrew to open up in the interview and share about himself, which she did by relating more to his Asian status. Moreover, Andrew [and the PSETs that inspired that character's composition] wanted to change the lack of representation. I felt it was meaningful to include why Andrew felt it was important to have other students that were "like him" in his major to show depth to the classic neoliberal argument surrounding representation—being that representation is important because it adds diversity (Kuntz, 2015). It affects his ability to relate and learn in his classes since he did not have an "easy" way to make friends.

Furthermore, I also wanted to this narrative to be shorter than the others to showcase that the data was somewhat incomplete and did not fully explore many of the questions that were asked in previous interviews. I wanted to convey that Minjung's character was somewhat uneasy and conflicted about the direction she wanted to take in the interview by opening and closing the notebook. I had her character choose to explore Andrew's feelings rather than keep asking similar questions from the previous because Minjung explored Annalee and Bailey's Asian status a lot during the interview. In that moment, Minjung's character cared more about making Andrew feel comfortable and feel heard rather than the interview protocol itself. The interview setting functioned as a platform for Andrew to tell his story. Even if it was not fully related to being in

science, I felt it was important to use this space to share this narrative. The narratives surrounding race, class, and gender are larger than science and are always in conflict and conversation with learning. The final scene when Minjung realizes the lens of the camera was closed for the entire interview was to symbolize the "theoretical" and "methodological" lenses that I had used are somewhat "closed" to this story, too. I will now discuss what I mean by "closed."

In terms of the data set, I wanted to present an Ambiguous science practice-linked identity to deconstruct the dichotomy between science people and non-science people since science is a philosophy of knowing and research has noted we can all "know" science in different, but equally valid ways (Basu & Barton, 2007). Looking through this data set again, I concluded that the students whose science practice-linked identity I labeled as Ambiguous were not necessarily Ambiguous to the PSET students themselves, but more so ambiguous to me as the researcher. I could argue that the science practice-linked identities are also ambiguous to the participants themselves, but since the focus-group interviews did not have a set question to probe for science identity, I cannot argue the claim that the participants had ambiguous science practice-linked identities onto themselves since they were never directly prompted to elaborate how they saw themselves; the self-identifications mentioned above emerged from the data set voluntarily. As Kuntz (2015) discusses, there were words participants left un*said* such that I cannot make sense of how to *say* them. Although narrative work aims to tell counter-stories that have not presented in the literature to show where the literature falls short, I felt presenting this section as if it were completed and the claims I made were finite would be inattentive to the participants. Most notably, I wanted to showcase the narrative of three PSETs who self-identified as not really belonging in elementary education and what that meant for their science practice-linked identity. However, I came to realize that the feeling of not belonging in elementary education was not necessarily predicated by their relationship with science. More egregiously, practice-linked identity does not have the theoretical underpinnings to unpack how gender, class, and race actuate practices that would have helped me understand the concept of not belonging to the community of elementary educators. I will now discuss the history of the framework to elaborate more on that point.

Drawing from funds of knowledge (Moll et al., 1992; Vélez-Ibáñez & Greenberg,1990), practice-linked identities (Basu & Barton, 2007; Carlone et al., 2015; Nasir & Hand, 2008) is a construct whose historical and political roots are grounded in sociocultural studies. Vélez-Ibáñez and Greenburg (1990) first coined the term "funds of knowledge" (p. 313) in their anthropological

study of households in the US-Mexican borderlands where they assert that households had strategic and cultural resources they could use to increase their social statuses, which was based on an economic organization of resources within communities. Therefore, funds of knowledge is more of an economic argument for power within community structures that tends to simplify power dynamics as "more resources" equals "more status." Power manifested through gender, race, and class are metaphysical and have associated value that is dictated by society (Yosso, 2005). Yosso (2005) explains that there are knowledges that 'count' and knowledges that are 'discounted' because of gender, race, and class politics that manifest in epistemological debates surrounding power. Yosso (2005) continues that funds of knowledge is a lens that is used to examine Latino families that is meant to empower and dismantle deficit, Bourdieuan capital arguments by centering the narrative around the wealth (i.e., funds) that people of color provide to spaces. Moll et at., (1992) extended this work into education as an attempt to disrupt deficit narratives and problematize teachers' beliefs and attitudes towards students where the construct has been taken and appropriated in a variety of ways. However, Esteban-Guitart and Moll (2014) note in *Funds of Identity* that the original operalization of funds of knowledge lacks a conceptualization of identity that is mediated by the distributed semiotic resources that arise from communities. Esteban-Guitart and Moll (2014) argue that, "identity can be viewed as the dynamic organization of various resources, socially, historically, created," (p. 37). Thus, the original funds of knowledge as a construct does not unpack how gender, race, and class influence those funds or how those funds are meditated in terms of identity.

Moreover, Oughton (2010) discusses how funds of knowledge has changed interpretation since it has been appropriated for educational research. Foremost, she writes that funds of knowledge was originally used to describe the macroscale organization of *community* resources, not *individual* resources. This perspective puts the onus of power on the individual and not in the social space in which power is theorized to reside. Moreover, resources themselves have shifted from being physical to being meta-cognitive and epistemological in nature. In the former form, resources are easily recognized, quantified, and exercised within communities whereas in the latter, meta-cognitive and epistemological resources are not easily recognized, quantified, and exercised. Finally, and most related, funds of knowledge is a construct that is within the province of the researcher in that it is the researcher who often decides what is a "fund" and what is not instead of the participant.

These critiques raise important implications for what science practice-linked identities even mean. Practice-linked identities are in reference to an individual, are often meta-cognitive and epistemological in nature, and are usually determined by the researcher during her analysis. As Basu and Barton (2007) acknowledge, practices that individuals perform originate from participating in other community spaces inside and outside the classroom that learners bring to a space. The funds of knowledge construct is used to qualify the origin of practice from communities outside and inside school. However, it is difficult to acknowledge a practice as such without knowing the community in which the practices emerged from. In a focus-group interview setting, I cannot explicitly state the community that a PSET draws a "practice" from, which makes it difficult to enact that awareness into the analysis; I can only *acknowledge* that the practices originate from community memberships inside and outside school. Looking at the individual and making direct claims that their practices are a result of funds of knowledge gathered from community memberships without explicitly examining the community is problematic. Communities are made up of more than one individual and are thus not representative of one individual. In accordance, the practices that [I am claiming] individuals participated in that link to a science identity are often not physical actions that can be easily categorized—they can include *thinking* like a scientist, *arguing* like a scientist, which makes drawing a proverbial boundary in the epistemological sand difficult. Operationalizing practice usually includes legitimizing them either through what the *curriculum* values or what the *researcher* values. When those practices develop gendered, classed, and/or racialized themes, making claims about how they contribute to identity can become essentialist in nature. The construct of practice-linked science identity therefore was not built with the tools to evaluate practice as a product of gendered, classed, and racialized community structures, rather it was built to acknowledge them.

In the context of narrative, I have defined the language PSETs used to be the analytical evidence of science practice-linked identities. Conflating practice with experience and experience with identity only reproduces structures that overemphasize linguistic renditions of experience over actual human experience itself (Kuntz, 2015). I realized that the PSETs I grouped as ambiguous either did not speak very much in the interview (lowest REF # 15) to properly explain past, present, or future practices that contribute to their science identity or mostly participated by sponsoring other PSETs' past, present, and future practices that contributed to their science identity. For the former consideration, focus group interviews are difficult to facilitate and moderate above

three participants since participants inadvertently compete for opportunities to speak (O.Nyumba, et al., 2018). The PSETs with smaller reference numbers tended to be in the larger focus-group interviews so it could have been a resulted in less opportunities to speak. In accordance, many other PSETs who did not have higher reference numbers tended to one-word "agree" or "disagree" with PSETs that were more vocal in the interview. Using narrative and grounding the data from a post-structuralist viewpoint privileges language as the dominant mode for analysis, I attended mostly to what and how PSETs *said* things rather than examining other modalities such as gesture, body language, and, tonality. This discrepancy is also a reflection of my underutilization of the focus-group space since I examined the data by individual PSET and not by how ideas were taken up by the group and supported. Using a methodological framework that could examine the *interactions* of different moments would have useful for accounting for participants who engaged more with the interview through non-verbal modalities.

8.5 Rationale for Chapter 8

I wanted to emphasize that this work was not all encompassing of the focus-group data and that I still have much to learn. I also came to realize that no matter how I "treated" the data, there were still questions I could not answer with the frameworks I have chosen. I am conceding to myself and to the data that there are some stories that I cannot tell and would be irresponsible for me to tell. In his essay, Martin Schwartz (2008) describes his stance on feeling ignorant throughout his doctoral program and the implications that this feeling had on his work in chemistry. He writes that feeling "stupid" is a normal part of the process because research is about trying to solve problems that have not been yet addressed whereby researchers are simply trying to muddle through the work as best they can with the tools that they have. However, he writes that being "productively stupid" (p. 1771) is about acknowledging that you do not have all the answers and working through that uncertainty to make meaning from that journey that can benefit ourselves and society is the research process. Throughout this process, I have tried to be "productively stupid" by iteratively making sense of the data by examining it with different research questions, frameworks, and methodologies. To expose how I failed in elaborating the constructs of practice-linked identity and narrative, I draw from Kuntz (2015), "The Responsible Methodologist."

Kuntz (2015) booms that "inquiry-for-social-justice inherently newly formed ethical questions," (p. 19). He asks that we consider what to do when "extractivist logic" (p. 52) leaves

behind pieces of participant data—pieces of participant stories. Extractivist logic is a neoliberal researcher mindset that privileges practices articulated with discourse as more certain than practices that are not [yet] articulated with discourse in that a researcher goes through the interview and pulls out the practices that are well articulated and acknowledged but leaves those unarticulated and unacknowledged practices behind. Methods like narrative theoretically consider experience to be irreducible (Bruner, 2004), but the act of turning words into actions that then become things that then stand in for the living is conceptually counterintuitive. Kuntz (2016) continues that 'experience-as-extracted-things' (p. 53) colonizes experience as a substitute for everyday life such that asking participants to speak on their experiences in interviews will somehow "capture" the humanist subject at its core (i.e., their identity). Following Desjarlais's (1997) critique of his own work, I would like to acknowledge how I am potentially framing PSET students who are ambiguous. When I call them Ambiguous, I am making that claim because I am privileging language in the ways in which PSETs reify their experiences. Simply because I say there is no unified consensus of their experiences does not mean these PSETs do not have science practice-linked identities, but rather I cannot understand them because of my theoretical and methodological choices. As I have mentioned in **Chapter 5**: **Positionality and Analytical Approach** section of this thesis, I am more concerned with the obligations to my participants than to adhering to a dogma of procedure. I chose not to write about these participants' stories as if they were coherent and definite and instead chose to use this chapter as an opportunity to discuss the shortcomings of the theories and why I think it is important to be forthcoming about data that does not fit. There is nothing wrong with the data; there is something incomplete about the research design and the theories I used to guide it.

CHAPTER 9. ANALYSIS AND DISCUSSION *OF FUNDAMENTALS OF CHEMISTRY*

9.1 Overview

The goal of this chapter is to understand how the science-content course *Fundamentals of Chemistry* affords identity-building resources that contribute to PSETs' science practice-linked identities. The first section will consist of the allegorical characters that will take part in "interview" and the quotes from the previous narrative that will be expanded upon in the narrative analysis of the course. The second section will consist of the narrative analysis that expands upon what the allegorical characters mentioned in the previous analytical chapters, specifically scene two. Scene two of the narratives in the previous analytical chapters elucidates PSETs' present practices. The third section will consist of the discussion of the narrative analysis to answer research question two. The theme of this chapter is *deconstruction* of the curriculum from the perspective of the allegorical characters based on the language that PSETs utilized in the interview setting (see Appendix B for **Narrative Worksheet**).

9.2 Allegorical Subjects

The table below contains the names of the allegorical characters that participated in the interviews for Chapters 6 and 7. I have not included the allegorical characters that participated in the interview for Chapter 8 because I could not distinguish how their science practice-linked identities contributed to how they saw themselves in relation to science (i.e., science person or not science person) or their attitudes toward science (i.e., I like or dislike science). The quotes I selected will serve as the basis for follow-up questions that Minjung will ask in this new interview context.

Table 4: Characters' Science Experiences

Allegorical Character	Quote from Previous Narrative
Lina	In this chemistry class, I find the labs are helpful to go back and study especially the wrap up questions and going through the activity because once you've done it, you can go back and read your notes, it's easier to understand it. Like I remember why that happened. I didn't really have that "why" understanding in high school. I was going to say like in science you are constantly asking question and then you are always like learning more and more. So, it's good to be asking questions and in science classes you are always in collabs and always working so you always need to collaborate with someone. Yeah, and like having real-life materials. Things...that's one of the biggest things because if you haven't had these experiences, it's so much harder to think about, so using materials we are familiar with, it makes it not only less intimidating but we are able to think about it on a deeper level because now we have had these experiences. Yeah, I google a lot, too. I just...basically like what she said...google keywords and sometimes it's really confusing because some websites will like go in a lot of detail and then we don't really necessarily go into that, so I look at the kid's websites and see all the things there.
Margo	Yeah, I agree with Sarah, sometimes the labs help and sometimes they don't. Like, I could solve equations in high school to find a mole, but I don't really know what a mole is. Like, I know how to find the moles for this and blah blah blah, but I was like...Even with that lab, I still don't really know what a mole is," Margo's voice raises changes a little, "But, I like working with Sarah in lab. Sarah pumps her hands in the air, "Yeahhhh, woooah! I don't think it would bother me nearly as bad if we could do it, explore it, and then maybe have our laptops and look it up really quick. And it's very helpful when the TAs are both in there because with just one of them in there, it's hard for them to come around and get to everybody because we all just shoot our hands up, but with both of them in there it's helpful because they are able to help everyone in lab more. And the homeworks, like the prelabs, are hard to do with our current class format. Since the lectures are after the labs, it's a little frustrating because you don't know. Then you look it up and you find out for yourself and you reteach it and they teach it in lab and I really think doing the homework before is actually helpful even though it's frustrating. Yeah, sometimes, I'll also go on the internet if I don't understand a topic like as in-depth as I want to know it. For example, polar and non-polar. Um, I kind of wanted to refresh my memory, so I googled polar and non-polar and I found a nice little activity thing that let you look at polarity and nonpolar things and why are they polar and why they are attracted. So yeah, sometimes I'll go on the internet and google it. Sometimes I'll go and look at YouTube videos, I love YouTube videos. I love it especially with chemistry because they show you, so I look at YouTube a lot when I am studying because it's nice to see it visually

Table 4 continued

Penny	So, in high school chemistry, I felt like it wasn't as...it was hands-on. It wasn't as relatable. But, here I think it makes it a little more relatable than my previous science because we are actually hands-on doing things with real products that we use every day. I guess, I can kind of get what you mean. That was also something I was going to say about our lab group like there's a lot of the time we have questions and our TA would come up and she'll say to collaborate with other groups and see what they got because there are lots of times we all got different answers and so we're like well what did we do wrong? And we got this answer right and this answer right and maybe we just came up with two different right answers or maybe they are both wrong or maybe one's right and one's wrong. Like, we had to figure it out. But, I think that was just a great learning experience. The TAs really make the lab better because they could have just easily been like, okay let's take a look at this instead of the rest of them and like hinting that was the one to look at, but instead she was like collaborate. Figure out what's going on like let's figure it out and get on the same page again. So, I appreciate that. Those are experiences I would want to have with my future students. I actually was going to say. I think being creative, collaborative, and inquisitive are important parts of science," Penny puts her hands spread out on the table, "Like, somewhere decided that they were going to figure out why this table is this table. Like, somebody one day was like I'm going to figure out what this table is besides that it's made out of wood. And even more than that you have to ask questions and work with people. There are scientists out there that have thought of something, but I mean like yeah where a lot of stuff has already been proven and stuff like that, but there's so many things being disproven nowadays. Like, this used to be amazing for you and now they're like this causes cancer. Yeah, everything causes cancer nowadays, but like I mean you have to imagine what you're going to look and then you have to experiment and you might collaborate with somebody on it because like if you have an idea of something, you almost want to share it with somebody because you just have to have that help of like thinking of like why would somebody take a kite out in a thunderstorm. Like, why would you do that? And he imagined that, that was going to happen and there's electricity now
Sarah	Yeah, I guess I would say that. But, it's still kind of hard. Like even without the math…" Sarah lowers her voice in a mimicking tone, "'How many moles are in this many particles?' Whatever, like it's just hard to grasp the wording. Like electronegativity is cool, but you can't like visualize it. Chemistry is just hard to visualize, but the labs help sometimes. It's not something that will help me understand moles by looking at clear water and putting a probe in it. That didn't really happen for me. I can even tell with other labs we are doing like the one where we are making ice cream, static electricity like the ball sticks to the wall kinds of things I can understand those better because I can see it, but when we are talking about molecular. Yeah, those kind of things, then I kind of am not as great in those. I like the visual experiments that we do. Because it was rough just going off the pre-lab just because I hadn't seen some of these concepts in so long and I know that I could email the TA, but when I was working on it, it was kind of late. And even the stuff we used to study, I just feel like it's a little bit overwhelming and a little bit over my head. Yeah, I can't fully grasp it all so it's just frustrating. As I read, it turns from intense reading to like skimming just because I get so overwhelmed by it. I am just not a very good student, I guess. For me, I thought science was like objective and there was a right or wrong answer and you have to find the right answer. But now, I think that sometimes it can be more memorable if you do it wrong because if you do something wrong like if you caught something on fire then you'd be like yeah… that's not how that works. I still think being right is important, but also I think exploring why something is wrong, you know?

9.3 Narrative Analysis

Drawing from Sfard and Prusak's (2005) model, BAc, the identified person who are the subjects of the story, A, are allegorically named Lina, Margo, Penny, and Sarah; the author, B, is me; and C are Minjung and the reader who are acknowledging Lina, Margo, Penny, and Sarah (i.e., they are telling their story to Minjung the instructor and to *you*). The story is told from Lina, Margo, Penny, and Sarah's third-person point of view. The context of the narrative follows these four allegorical characters into a "fictional" second interview where Minjung asks questions specifically about the Fundamentals of Chemistry course logistics, their learning in the course, and what they think science is after taking the course. The narrative will not be broken into scenes as before because these topics are very interrelated.

9.3.1 Exposition

The scene is a small, yellow room with a large window that extends to the top of the celling. Under the window is a table large enough for four people—there are five chairs around it. At the center of the table is a microphone and a box empty of Halloween candy. On the other side of the wall with the window is a camera perched on a tripod. The interview room is ready. Minjung moves toward the camera and presses record. The red light blinks on. She checks the lens: it's open. Minjung sighs and shuffles into her seat.

"Hi," Minjung begins with an upward tone in her voice, "I am glad you all could come back for another interview. How is everyone?"

The room falls quiet.

"…Ehhh," Margo breaks the silence, "Just trying to survive finals week." Margo nudges Sarah, who is sitting to her left. Sarah barely notices in her big sweater. Margo decides to nudge Sarah again. Sarah perks up, "What… yeah… just trying to get through till the end of the semester. For sure."

Penny giggles to herself. She takes off her jacket and rests it on the back of the chair, but it falls. Lina leans over and picks it up for her.

"Oh, thanks… sorry, what is your name," Penny asks.

Lina grins, "It's Qu—."

"Uahhh," Minjung quickly interrupts, "Let's use our pseudonyms from the last interview or unless you want to make new ones."

Lina stares blankly, “What?” The room erupts in laughter.

Minjung grins, “Yeeahh, like I went by Mia and I think you went by Lina. Do you still want to go by Lina?”

“Oh, yeah, yeah! That’s okay. So, hi everyone I’m Lina, I guess.” Lina waves.

“Well, thank you for picking up my jacket, Lina. I’m…Penny.” Penny also decides to wave.

“Uh, so I’m Margo.” Margo flattens her hands under her chin to frame her face.

“And last, but never least, I’m Sarah.” Sarah puts her arms up in the shape of a V.

“Okay, great. Um, so I asked you guys back because I was very curious from your last interview. I think all of your inputs were interesting and I wanted to ask some more questions about it.

Margo whispers, “Uh oh.” Lina tries to hold in her laugh.

“So, anyway, I wanted to ask you very generally what you thought of the *Fundamentals of Chemistry* course,” Minjung says as she spins her pen around her fingers.

“Like…whether it was good or bad or…, Sarah asks.

Minjung hesitates before speaking, “Well, not like good or bad, but like what you thought about the course.”

Sarah begins still hesitant, “Uuhh, I’m not sure if this is what you mean, but I definitely feel like I learned a lot in your class. I think that, I know that personally science here has made me appreciate what I've learned in my elementary school science and I remember I had a fifth grade teacher and I absolutely hated her and I hated that class and I don't know, she did a lot of things with science and then I just didn't like it and every day that class was so bad and I got to college with biology and literally every single experiment that we did in that class was what I did in this fifth grade classroom and I was like dang it, she was right. I felt like I can now look at my students and say you will learn this someday. For this class, it's been really interesting being in this class because I am in my TIP right now for the college of education and I am in a 6th grade classroom and they just went over the phases of matter, so it was interesting going from in here and learning about how they are doing it too in the classroom.”

Margo follows up in agreement, “Yeah, like, I would say the class has made me see the difference between high school and college. At least in my high school, if you were able to memorize the answers and memorize the answers and then take your test, then you were good. But, in college you are forced to learn the information in-depth and understand why it happens rather

than memorizing it and throwing it out after the exam. Like in college, you are going to be doing this in your everyday life and you don't really have a choice. Like, you have to learn it to be successful in your career. I learned so much and my first year of college compared to my four years of high school combined just because it's a skill, it's more skills and everything is just like so much more in-depth rather than being right or wrong or knowing the answer. I think it's harder. Or it's easier in high school if you didn't get something because it was so many equations and conceptually based that if you missed a class or you didn't understand something, you could go in the next day and they are still practicing using equations. In the class, like you need a solid foundation before you go to the next step whereas in high school you can just pick off where you left off and like help yourself," Margo scrunches her face and lifts her voice, "You know what I mean?"

Lina answers Margo's question, "Kind of…so, I kind of enjoy it where I felt confident in the content because we were going through material I knew from high school. I'm not the best at Math, so I think I actually enjoy this chemistry class a little bit better because it's more conceptual. But, in terms of things to apply, I mean there were some things that we would apply like the Oobleck. Kids would love that. I mean there were some concepts from the class I could use, but there were some like moles that none of my fifth grade would ever understand. Some of the mole stuff, coming from being in elementary-ed, even if the student does ask a question just for their understanding of it, just to try and explain that to the student who is in fifth grade is…I feel like you'd have difficulty understanding that. I was in a fifth-grade classroom and a lot of the students I know couldn't understand that. I even struggle with how to do that in an eighth-grade class, so I feel like that material in the course wasn't really useful. I wouldn't spend more on that. I would focus on the experiments that would better me and my future classrooms. But, I also realized that if I could never do this they wouldn't have the resources to do it in school either. And worry less about material that I wouldn't teach, but it affects my grade now, so it is stressful."

"Yeah, I feel like Lina really captured what I wanted to say." Penny pauses to add a new idea, "I thought the class was helpful whenever it connected to material that I felt would be applicable to elementary education. I did think this class has been a lot more applicable than other courses, but it still…I don't know," She takes a deep breath and continues, "What I liked about the class is that it's related to everyday things. It's not like biology where you're going to teach the kids what the leaf outside is, so you can identify the tree based off the leaf. Like, it relates to everyday

things like a water bottle, we use that or plastic as well as like pressure and how heating and cooling and we use like everyday things. Like, it was more in-depth than what I'll ever teach an elementary student, but it was giving us the background knowledge which was nice. For example, making the bouncy balls. Kids would love that. It would be a little difficult. You'd have to do it with older grades, but something like that would be super easy and you can teach students doing that with fun. And Oobleck and stuff like that, but I'm not one to get my hands dirty. It's a weird thing, but you're teaching them with science and stuff like that, so that's good."

Minjung opens her mouth to speak, but Penny continues, "And in terms of the class, I thought it would have been better to have lecture and then lab, but some of them it was better to have lab and then lecture. So, it's just like I'm a little split because some of the stuff I wasn't understanding and then my lab happened to have the most questions and the TA was running around, but it was harder to get a good answer out of her because somebody would always be like TA, TA, TA like the whole time."

Minjung goes to speak but stops. She opens her notebook to a page with the upper corner flipped down. She takes a moment to read it.

Minjung starts again, "Yeeeah, I think you mentioned that last time, too, Penny. I'm trying to think about how to ask this question…," Minjung makes a small o with her mouth.

Sarah smiles at Minjung before speaking, "It's okay. You can ask. We already did the course evaluations last week." Sarah winks at Margo.

Minjung laughs a little nervously, "—I guess what I am trying to say is whether you learned anything from the lab or the class that wasn't just for applying to the elementary classroom. Like, Penny you had mentioned that the lab helped your learning when you collaborated with people."

"Ohhhh," Penny raises her voice, "Yeah, I think the class was pretty useful. I'm not really sure what you mean though—"

Lina interjects, "I'm not sure if this is what you meant…Mia, but I feel like for me, chemistry used to be stuff I saw on TV of people pouring things into a beaker and it explodes, so this class has definitely shown me how much chemistry could be."

"Yeah, that was kind of what I was trying to say. Thank you, Lina." Minjung continues, "What have you learned in the class about science?"

Margo starts, "Um, for me, I think science on the most basic level is questioning, so we should know how to question so we can teach our students how to question. Like with the Oobleck

experiment, we want students to try and understand how it behaves as a solid and a liquid and why. They have to question what solids and liquids are then."

"Noooo, I mean yes, I totally agree with you Margo, but I think Mia is asking like aside from elementary teaching, what have we learned in the class," Sarah says as she nudges Margo.

"Oh! I definitely think it's important. Like, it is a goal, but I think it's hard for people to want to learn that when it isn't applicable to their futures because you are always told that when you get to college the only things you'll do are things that will actually apply to your future," Margo offers.

"I agree with Margo," Penny sighs before continuing, "I think a lot of us in education are maybe not overachievers, but we are very passionate about doing well and you know it's just funny as we get into upper courses like this and our, one of our block four classes where we were like pretty much you are at the point of your career, your educational. Right now, this is about our learning and that's hard for us because our entire lives, our self-worth has been tied to thriving at school to be a great elementary teacher…at least for me. Sometimes, that's what I think like because we do need to know this like the in-depth content and like the particle, molecular level and all this stuff, but like sometimes I need a little dumbed down just because science isn't my strong suit and I can get the harder stuff if I have a grasp on the simple, dumbed down version. Like, sometimes during lecture we would literally write like osmosis for dummies and read it because then it makes a little bit more sense. I also feel like collaborating in lab. I think that when we have two different ideas, we almost build off of each other's ideas like we just sat and discussed and discussed and discussed until both out ideas made sense together. So, like we would take one concept and she would take her concept and it was like she would explain it to me what she meant and I would explain to her what I meant and then we kind of almost morphed them together to make one answer and I think that's how we succeeded in our answers. We, I mean we never did poorly on any of our labs because I think that helped us having somebody to collaborate with and make a larger answer out of like a smaller thing and if we did that, even if we did like okay you answer this one question and she had something in two that she was confused about then she would kind of asked me, or I would go to her. Like, I'm thinking about this, but I'm not positive. What do you think? That's how we would build off of each other."

Sarah breathes in to soften her disagreement, "Yeaaah, I get that. I don't know. I kind of see what Lina was saying. Like, the class made me change what I thought science was. For example,

I felt like the labs made me realize the importance of collaboration. And also think about how science can be imaginative. For being collaborative. Like working with other people. Because you know sometimes you can meet with other people and someone can have the other half of the experiment that you have been searching for your whole life to find. And by working with other people you might find that. Like being able to work with others. Like extensive knowledge too though. I think that helps you. Even though you are being inquisitive and trying to find out more and you already know a lot then that helps you to have something to draw on. I think with imagination, too. Well, I haven't actually tested this, but I bet this will work out. And I kind of just took the imagination and the creativity aspect as...so are you just making this up? Or are you actually doing experiments."

Lina murmurs, "Yeah, the inquisition thing especially when studying like keeping an eye on things and asking myself, 'Oh why' or like ask a question to try to better help myself understand or ask myself questions out of curiosity. I find that I make those connections like I know why we're doing what we're doing or like I know there is a purpose and through the experiment, I'll learn what, like what I'm supposed to learn. Whereas like in high school, I was just kind of like told this is what you're supposed to figure out, but like I never got to figure it out on my own or apply it. So, it's definitely better for me because I can make those connections. I feel like I'm oh this is why you're doing this."

"Hmm," Margo shrugs, "I don't know. I think I realized that chemistry isn't all Math like how I thought. There are other parts to it, too. Like, you have to be able to visualize and think of molecules in your head."

Sarah tries to keep the conversation going, "It's like funny because there are little things that like I've learned and I'm like oh I'm washing dishes and like oh the polar head is attaching to water and I try to tell like tell my friends something and they'll be like wow look at you or something. Because like I mean, like I said with chem we're actually learning how to like understanding of how things work and it's not like bio where you are just memorizing things and you forget about it like these are things I can actually remember because like you understand. I don't know. It was like the same thing in physics, so it was the same visualization so that was what I was using in my head to get through this lab like, that previous knowledge and that's how I knew the material that was going on because I'd seen that visual beforehand and then we watched the

same one, but I don't know. I couldn't really tell you what we learned besides that. Do you guys know what I mean?"

Lina adds excited, "Yeah! Yeah, like we were saying with the labs and having real-life materials. Things...that's one of the biggest things because if you haven't had these experiences, it's so much harder to think about, so using materials we are familiar with, it makes it not only less intimidating, but we are able to think about it on a deeper level because we have had experiences. For example, erosion. I know like the whole erosion unit and like landforms and stuff, um when I was kayaking over the summer, that's all I could think about the entire time. Like, I'm kayaking and like, 'Oh this is like sedimentation on the...like looking at the river. I really was because I had that background and so then I felt, you know, like it just became what you said a lot more aware of everything around me."

"So, what do you think science is," Minjung asks.

"We are always asking why?" Sarah pauses, "I don't really know. It's kind of feels like science is just like a perspective on the world. Like, seeing the world as a scientist would? Being curious, I guess. Why stuff happens or whatever," Sarah raises her hands sheepishly and looks around the room.

Penny clears her throat, "Yeah, I think that is important to pass onto kids. Like, that sense of being curious about the world. And also collaborating."

Lina jumps in, "True. I also feel like there is that level of you are setting the stage for their attitudes about school moving forward, whereas in the older grades or in high school, they already have this idea in their head about what school means to them. So, there are still those students who are still kind of excited about school, they like to go. But, then there are those kids who are like no I don't like this. I don't want to do this and it's hard to change their minds after that. Like, there's not much you can do. Like, you can try and you can.... like, I'm definitely not saying you shouldn't try, but at that age it's just really hard to change their mindset that they may have, so...That's the thing I love about elementary education."

"Yeeeeup," Margo nods her head emphatically.

The room falls silent. Sarah looks over at Minjung and tries to signal her. Minjung notices Sarah's eyes and grins kindly, "Whattt?"

"I'm kind of curious about you, Mia. Like, what is this for?"

Minjung pauses for a second, a little caught off guard. Margo jumps in, “Or like, we just want to know what you’re interested in finding out, I guess.”

“Oh…,” Minjung takes another moment, “Um, I am just curious about how you feel about science and what you have gotten from this course. I am always looking to improve the course in ways that are grounded in what students have said.”

Sarah nods in agreement, “That makes sense. That’s really cool. So, are you a chemist? Or a teacher? Or…?”

Minjung stops spinning her pen. She pushes her chair back nervously, “Uh, well, I did my undergraduate and master’s degree in chemistry. And then I taught middle school for about a year. Then I got my doctorate degree in education.”

“Wow!” Lina exclaims, “So, you worked in a lab and stuff? That’s awesome. What made you change to do education?”

“Um… It’s something that I really care about and I wanted to learn more how people learn science. What about you?” Minjung tries to redirect the conversation.

“I realized teaching was a very tangible way you can care for others and really make a difference in their lives and so I think so. I feel like I'm a natural teacher like I just love to help people and like instruct them when they don't know things and so…—,” Lina offers.

Margo jumps in, “I’m interested in the kids that are like challengers. People who are willing to challenge the teacher just like understanding the concepts and applying it to get a deeper meaning. They might come up with different ways to think about it like if we come across while we are teaching photosynthesis...maybe how the sun affects the leaves and they'll ask you like oh why do you do it like this? Like, I had a student in my class and he was like, ‘I love science’ and every single time we come, we read books and he goes, Ms. M I love science. I love science. So, I have been getting a ton of science books and trying to incorporate like space and all of this science into my literacy lessons and going off of that. It made me realize that I am going to have some kids and he literally said, ‘Ms. M I go home and do experiments at night.’ Like he just loves it and so I'm trying to reframe my mindset so that I don't hate science. I can teach science to the kids that love science and to everyone, but especially to those kids that excel in science, so I am slowly trying to change my mindset so that it's not, ‘that's my weakness’ it's not my interest, but I like it. You know?”

“Yeah,” Sarah nods at Margo, “You always have to be prepared because little kids will ask those questions.”

Minjung leans back in her chair, “Yeah, that’s true. They do ask. What was most helpful in the course?”

Sarah’s eyes brighten. She sits up straight and puts her hands on the table, “The TAs were great. I loved my TA. Like, if Candy was not a good listener and a good speaker then I wouldn't feel comfortable going to her with questions and I would do worse off. If she wasn't a good speaker then I would probably get board in lecture. She made me realize those things are important for science. Like she tries to apply it to us, so it's not just talking at us and it's not like, ‘Oh, I have two hours and 59 minutes of being in here.’ Like she's good. And even though my grade wasn't...like my grade right now probably isn't as good as it was in bio. I feel like I am way more confident and I am learning way more right now and like I feel way more confident in my skills since sophomore year of high school. And I don't know if it's just like going over it a second time has made me more mature, but like it is just coming a lot easier this time and I am more confident.”

“Oh my Gosh, yes! Candy is the best,” Lina offers, “Candy shares a lot with us like how the labs were created and how elementary students would think about it down to the little particles and she would make analogies of little communities and how these particles are like little people and it's so funny but I feel like that is huge concept that I really understand, I guess.”

Penny leans back in her chair. She leans forward again and motions to speak, “I think like going off of that, like in the beginning of the semesters, I thought my labs were going be rough. But Krissy, she’s my TA, but Krissy kind of just dove right into it and was like this is what you got to do this, this, and this. Just go and we look at each other and say like okay, let's get this going. But, it was really interesting because I actually did...I actually learned a lot that way and I feel like that time slot is hard to get students motivated to learn and I felt motivated to learn in the mornings and I think that's pretty awesome.”

“Yeah,” Minjung smiles, “Candy and Krissy are pretty great. I have really liked working with them over the past semester.”

Margo whispers, “Give them a raise.” Sarah, Lina, and Penny laugh together. Margo pauses and then starts laughing with them.

Minjung chuckles quietly, “I would if I could.”

The room falls silent again.

Sarah looks around the room. She leaves her gaze at the window and focuses her eyes to see through the window. Sarah exclaims, “Oh wow, it’s snowing!”

Margo looks up surprised, “It is!”

“Oh, boooo, that means I have to take the snow off my car,” Penny mumbles.

Lina puts her jacket on, “Yeah, I have to make sure I get to the bus in time then.”

Minjung sighs, “Um…I think this would be a great place to stop here then. Thank you all for coming back and I hope you have a great break.”

The red light blinks off.

9.4 Discussion

To situate the narrative, I wrote a composite story that expands upon the present practices that PSETs mentioned as being salient to their science learning. Although the previous analytical chapters discussed aspects of the course in “**Scene two. Present**,” I felt it would be clearer to discuss the identity-building resources of the course with one narrative; therefore, I had Minjung interview Lina, Margo, Penny, and Sarah again to learn more about their experiences within the course and how that impacted their learning; the follow-up interview from the first interview is fictional in that no PSET was interviewed again after an initial interview took place. To tell the story, I drew quotes from the PSETs that composed the allegorical characters such that the PSETs are speaking through the allegorical characters (see **Narrative Worksheet**). I choose not to have Andrew and Amber participate in the second interview because their science practice-linked identities were ambiguous to me. I cannot make claims about the class practices that contribute to their science practice-linked identity if I am not sure how the characters position themselves in relation to science. For the analysis of the dialogic between PSETs and curriculum, I draw from the theoretical construct of disciplinary identity (Van Horne & Bell, 2017). Disciplinary identity is an identity that curriculum designers either explicitly or implicitly anticipate when they are creating learning tasks and objectives that adhere to what is valued and important within a discipline; the disciplinary identity gives the curriculum a purpose (i.e., helping students learn what are important practices and knowledges of chemistry). These tasks and objectives often serve as identity-building resources that can be “material resources (physical artifacts in the setting), relational resources (interpersonal connections to learners in the setting), and ideational resources (ideas about herself and her relationship to and place in the practice and the world, as well as ideas

about what is valued and what is good)" (Nasir & Cooks, 2009, p. 44). Students utilize resources in different ways given that their lived experiences influence how they repurpose the resource as a tool for their learning. The ways in which students author tools become the practices that link to their sense of self within a discipline, which is known as a practice-linked identity. I will now discuss how different identity-building resources afforded by *Fundamentals of Chemistry* have shaped the practice-linked identities of the allegorical characters.

As mentioned in Chapter 6, Lina sees herself as a "science person." In terms of ideational resources, Lina mentions that she enjoyed how the class was more conceptual and less calculations, which reaffirmed her ability to do chemistry. She had mentioned that chemistry was not her strength in high school, so the conceptual nature of the class helped her view chemistry as something accessible, which contrasted to her high school experience. She realizes that chemistry is not just mixing chemicals and what is depicted on TV. Lina also valued that there were many concepts in the class that could be applied to an elementary classroom, which meant that she draws from her aspirations of being an elementary teacher to determine how she determines the importance of the course-content. She wants to help set students with positive attitudes and mindsets of science so they can have a better chance of doing something that is inspiring to them. In terms of relational resources, Lina decenters to what her fifth-grade students would be able to understand and learn from the class. She uses herself as a barometer for learning in that she focuses on the experiments that she could see herself successfully teaching in an elementary classroom. Lina implicitly defines success as whether students will grasp the concept and whether the lesson can be feasibly done considering the resources allotted by the school. Moreover, Lina views her TA Candy as a relational resource that models effective science teaching. Candy breaks down material in a way that is effective for Lina, which leads Lina to believe that model of teaching would be appropriate for elementary students. In terms of material resources, Lina utilizes PowerPoints and homeworks to study by drawing an aspect of the class that Lina has noted as being important for disciplinary knowing in science. Lina notes that the class focuses on "why" things happen, which has helped her frame science as an act of inquisition. As a result, Lina studies by asking herself why and trying to find the purpose of the experiments. She does not say specifically, but her purpose for doing the experiments can be both for her current understanding and for her future career. The everyday materials in the lab allow Lina to broaden her experiences

of sciences beyond the classroom and into her lived experiences where she mentions how she views landforms and erosion differently because of this new awareness.

As mentioned in Chapter 7, Margo, Penny, and Sarah see themselves as "not a science person." Margo sees herself as a Math-person and her high school experience with chemistry and physics went better than her other science courses, but because she was able to do the Math. In her previous interview, Margo noted that she used to think science had no creativity and that there was only one right way. In terms of ideational resources, Margo now sees that there is more value than just the right answer. She feels that it's more important to learn things in-depth even though it's more difficult and she feels that science at its level is questioning, which is what she wants to teach her students to do. In high school, she notes that she would practice equations if she missed something, but now it's more about trying to understand and visualize what the numbers mean. Margo's ideas about chemistry have changed, which have changed how she views science. Margo also strongly identifies as a future elementary teacher, so she relates most of her learning to what she believes would be valuable for elementary students. She wants students to learn similar ideas about science that she had learned in the class. In terms of relational resources, she mentions her current elementary students that like science. She acknowledges that there are students that do like science and that she is mindful not to convey negative ideas about science to her students. The students motivate her to a good science teacher because that is how she perceives that the students perceive her. She mentioned before the importance of learning material in-depth, which she relates to the students who are "challengers." She feels that she should learn these details for the challengers of the class who want to always know more.

For Penny, she is similar to Margo in that she views most of the learning from the class as being for her career as an elementary teacher. In terms of ideational resources, Penny says that she thought the class was helpful whenever it connected to material she felt could be taught in an elementary setting. In terms of material resources, Penny liked that the class related the content to everyday life because she felt the elementary students would be able to learn lessons more effectively that way. In contrast to Margo, Penny seems to be viewing the class as a space to find lessons that could be directly adaptable whereas Margo views the class as an opportunity to learn about science that she thinks would be useful for elementary students to learn about science. For example, Penny says that she likes to teach Oobleck because kids like fun things whereas Margo thinks Oobleck is important to get students to question what states of matter are. Penny views the

lecture and lab component to be somewhat disjointed. In some instances, she felt that it was good to have lab before the lecture to see the concepts they were going to explore. However, Penny mostly felt she needed some background information to actually answer the questions in the lab, which she utilized the TA for. She views the TA as a tool for helping get the answers and with motivating them in the early morning labs. In terms of relational resources, Penny often refers to herself as "we" as in elementary education majors. Penny often googles concepts like osmosis "for dummies." Here, she is using a material resource like google to help her simplify disciplinary ideas like osmosis, but the material is positioned relationally because she acknowledges she needs a "dumbed-down" version. She says that elementary education majors are very passionate about doing well so they can be good future teachers. She notes that the elementary education courses are evaluative of their self-worth in that doing badly in the course might presuppose being a poor elementary teacher. Penny struggles with the amount of depth that she would have to cover as an elementary education major and what would be appropriate for elementary students. Penny relationally views her classmates as resources to help refine her thinking about and building on ideas.

For Sarah, she was the character who strongly disliked science in the previous narrative but started reflecting on her experiences with science throughout the interview. Sarah realized that she has learned a lot in her undergraduate science courses, which allowed her to appreciate her science classes in elementary school. In terms of ideational resources, Sarah not only sees the goals of the course as being meaningful for her science development as a learner and future teacher, but also the interview setting itself because she has been able to reflect on her experiences. In the interview, Sarah realized that the goals of the course were to help her confront what science is. In terms of material resources, Sarah utilizes her TIP to compare how the science she is learning in *Fundamentals of Chemistry* is being actuated in practice. She uses that as motivation for learning. Sarah values the science in the class to help her think about her everyday surroundings with a new perspective. For example, while she's washing the dishes, she now reflects on how soap works. In terms of relational resources, I had Sarah serve as a character who is somewhat aware of what the interview is trying to accomplish. She clarifies Minjung's question for the group and also tries to position herself differently from Margo and Penny in the setting. She hedges her language by saying she understands what Penny and Margo are saying but usually offers a counter-point. This was also part of her character in the Chapter 7 narrative. For example, Sarah is like Lina in that

she sees the chemistry as being applicable to her everyday life. Sarah realizes that her views about science have changed as a result of the lab experiments and she learned the value of collaborating, inquiring, and imagining in science. Furthermore, Sarah views her TA as a good example of a science learner since she has skills that are good for communicating science. She notes that Candy is a great listener and speaker, which helps her learn and explain science effectively. Sarah regards those aspects as important to how she sees herself in science. She feels much more confident in the material now that she is guided by a caring teacher like Candy.

Overall, the allegorical characters utilize identity-building resources differently, but thematically the design features that they mentioned as being salient to their science learning were the TAs, the other PSETs in the course, and the lab experiments. For the TAs, Lina and Sarah viewed them as relational resources whereby Lina viewed her TA Candy as a great model of science instruction and Sarah viewed Candy as a great model for science learning. The TA acts relationally because Lina and Penny mention that Candy allows them to clarify how they feel about their science teaching or learning practice in relation to Candy. Penny viewed her TA as more of a material resource that acted as either a motivator a clarifier: Krissy was useful to interact with to accomplish lab activities, but Penny does not reflect how or why Krissy models certain practices differently from Penny. For the other PSETs, Penny uses them relationally when she says “we” in that Penny is showing that she is considering how she is part of the collective education majors and what she considers to be valuable in that community. Sarah within the focus group interview was also noticing how her sentiments were different from that of the other characters. She wanted to acknowledge what Penny and Margo were saying, but also trying to provide counter-points wherever possible. For the class, the experiments served as ideational and material resources for students. Lina, Margo, and Penny viewed the content as being valuable when they reflected upon how they could utilize the content in an elementary classroom. The experiments acted as opportunities for the characters to imagine themselves as future teachers who would need to teach their students the material. Sarah utilized the content more materially to enhance her learning. She actually felt the experiments and the course helped her become a better science learner and even think about science differently than she had before.

Table 5: Identity Resources Connected to Disciplinary Identity

Characters	Material	Relational	Ideational	Disciplinary Identity
Lina: "science person"	• PowerPoints • Homework • Lab experiments that used everyday materials	• Current elementary students • Candy	• Conceptual questions • Applicable labs to elementary classroom	Science can be conceptual and applicable to everyday life.
Margo: "not a science person"	N/A	• Current elementary students	• Questions that ask why • Applicable labs to elementary classroom	Science can be inquisitive and applicable to elementary school context.
Penny: "not a science person"	• Krissy • Lab experiments that used everyday materials	• Other elementary education majors • Classmates	• Applicable labs to elementary classroom	Science can be collaborative and applicable to elementary school context.
Sarah: "not a science person"	• Current elementary students • Lab experiments that used everyday materials	• Classmates • Candy • Lab experiments	• Goals of course • Interview setting	Science can be accessible and applicable to everyday life.

CHAPTER 10. CONCLUSION

10.1 Overview

The first section will describe the summary of the analytical chapters and how they answer the research questions. The second section will describe the implications of this work in terms of how this work adds to the standing body of literature on PSETs, which will describe the theoretical considerations and practical influences of this work on the PSET population and the curricula that are designed for these students. The third section will describe important reflections of the work in terms of the ensemble, inherent deficiencies, and academic outcomes.

10.2 Summary of Results

10.2.1 Research question one

The allegorical characters Lina, Andrew, Amber, Margo, Penny, and Sarah, represent the different ways that science practice-linked identities can manifest. For Lina, Margo, Penny, and Sarah the science practice-linked identities were clearer in terms of how the PSETs who composed these characters spoke through the allegorical characters. These PSETs tended to have strong feelings about science in a positive or negative way whereby the practices that contributed those positive or negative dispositions were discoverable in the interview. The practices that linked to their science learning and how they saw themselves were understood by organizing them into past, present, and future practices to emphasize where these practices originated. For Andrew and Amber, they do have science practice-linked identities; they were just not discoverable to me. Overall, the practices that influenced their science practice-linked identities mostly originated from high school experiences with science that students brought with them into the course. The students either reinforced, renegotiated, or reimagined these practices in the *Fundamentals of Chemistry* course while learning chemistry content. From there, the students noted how they projected these reinforced, renegotiated, or reimagined practices would translate into becoming an elementary teacher.

10.2.2 Research question two

The present practices of the allegorical characters, Lina, Margo, Penny, and Sarah were elaborated on in the second, fictional interview. The second, fictional interview was meant to highlight what practices the PSETs mentioned as being influential in how they saw themselves and how they viewed their science learning. The resources are not meant to be categorized as good or bad, but rather as simply contributing to how the allegorical characters described utilizing them. I analyzed the design features of the course that acted as identity-building resources to understand how the allegorical characters used them to construct their science practice-linked identities. The students mentioned that the TAs, the other PSET students, and the experiments were the main resources that the *Fundamentals of Chemistry* course afforded. The TAs and other PSETs acted often as relational resources for the allegorical characters while the experiments acted often as material and ideational resources for the allegorical characters.

10.2.3 Synthesis

Rather than promoting science-content courses dichotomize student identities as science learners and student teachers, practitioners should instead provide learning spaces where PSETs are able to understand their identities as *current science learners* and *future elementary teachers*. If PSETs are only legitimized when they have acquired skills that make them appear more as scientists and less like elementary teachers, it sends the message that those modes of being are mutually exclusive and counterproductive. The science content-courses that PSETs take can act as spaces to help reframe how students see science and see themselves doing science. From the data, allegorical characters like Margo and Penny have a strong identification to their future profession as an elementary teacher; therefore, it is important to note how PSETs may purpose materials from the course for their careers. Other allegorical characters like Sarah were able to reframe their perspective on science—not necessarily to say that she suddenly started to enjoy science, but rather she relearned the value of science in her everyday life. Finally, Lina was able to not only strengthen her identification with science that she has had early on, but also make new connections that are also meaningful to her everyday life and her future students' lives.

10.3 Implications

10.3.1 Intellectual merits

The goal of this work was to broaden the ways we theoretically frame and methodologically consider preservice elementary teachers. To broaden how we theoretically and methodologically examine PSETs, I will revisit important works from my literature. In response to more recent literature that examines PSETs' identities as science learners (Avraamidou, 2016; Carrier, Whitehead, Walkowiak, Luginbuhl & Thomson, 2017; & Chen & Mensah, 2018), I offer that my analytical chapters are composed of different ways that PSETs self-identified as a "science person" or "not a science person," that attempts to showcase the complexity of experiences that constitute those larger, self-identified groups. By presenting these analytical chapters using a narrative methodology, I positioned PSETs as complex learners for which essentializing them to constructs like content-knowledge, pedagogical content-knowledge, nature of science beliefs, attitudes towards science and science teaching, and self-efficacy in science and science teacher was not reasonable for my data set.

In terms of the second research question, my goal was to answer to Bergman and Morphew's (2015) literature review that examines the courses designed for PSETs. Using a disciplinary-identity frame to deconstruct the curriculum, I make explicit the implicit assumptions about the practices that constitute a curriculum and how students are impacted by those decisions. Moreover, deconstructing the curriculum and evaluating how students create tools from identity-building resources removes the impetus to market a "pre-packaged" curriculum targeted to teach PSETs chemistry-content. Rather, I hope that by elucidating the curricular elements that afford identity-building, I can empower instructors of these courses to evaluate their curricula practices and question how they can create opportunities for students to connect with the discipline's practices. In response to Beauchamp and Thomas (2007)'s extensive literature review on preservice teacher education, I offer that my work attempts to understand preservice teacher identity and how that identity is cultivated within a science content-course. Although I do not make claims about PSETs' identity-development directly, I believe that I have reflected their discursive identities complexly in creating the allegorical characters. The allegorical characters were animated by reconstructing what PSETs said in the interview setting in terms of their science experiences—past, present, and future—and their science learning in the content-course.

10.3.2 Broader impacts

Outside of improving preservice teacher education, I believe my work problematizes how science educators conceptualize science identity, how that contributes to a student's learning, and how curricula afford students opportunities for science learning and becoming. Using a practice-linked identity frame broadens how practices are conceived—rather than conflating practice with doing, I assert that practice is how participation brings someone closer to identifying with a community (Wenger, 1998). Analyzing the data with practice-linked identity and disciplinary identity affirms how these constructs are in dialogue with each other and how they cooperate to stabilize or disrupt science learning in the classroom. This is important because recent research and policy documents have explicated the need for students and teachers to engage in science practices (i.e., 'doing' science) in the classroom (Ford & Forman, 2006; Windschitl, Thompson, & Braaten, 2008). Windschitl and colleagues (2008) argue that practices conceptualized only as actions promote a stagnant view of science as rote performance that can be achieved by earning vague skills; instead, they offer that student engagement should consist of pairing skills with meaningful participation in scientific knowledge construction, evaluation, and refinement that contributes to the learning community. Moreover, Hammer and Elby (2003) support that the ways learners reflect or think about their practices can elucidate science norms, instructor's meta-messages, learner's feelings about the material, and learner's position about the disciplinary material; therefore, it is important to consider theoretically how a curriculum acts to position a learner within a discipline.

In accordance, Ford and Forman (2006) examined this "practice turn" in the context of disciplinary learning in the classroom. They argue that learning within a discipline is more than students procedurally performing science whereby students should be engaged in science knowledge construction and evaluation. Linking the performance of science procedure with reflection about the epistemological motivations surrounding what is considered a "scientific procedure" *together* constitute a practice. Disciplinary learning then becomes how students develop and use their learning as tools to make sense of themselves and the world around them. To design disciplinary learning that productively links practice with its epistemological origin, it is important to create classroom cultures that privilege scientific knowledge construction (Berland & Hammer, 2012). Berland and Hammer (2012) extend that although curricula can design productions of scientific practices (i.e., activities that simulate lab), it cannot be assumed that the

students will always interpret these productions as meaningful. Thus, curricula designers should view activities as opportunities to uncover student's existing sense-making tools and leverage these sense-making tools as productive for learning about and participating in the goal of becoming a science learner. Therefore, the activity is framed more of a means to creating a science community culture rather than the activity being the end itself.

Engaging in meaningful activities fosters a science community culture that develops the connection between epistemology and action (i.e., practice) where epistemology and action are viewed as mutually supportive rather than mutually exclusive. Given that the context of this work asks students to reflect on their practices within the *Fundamentals of Chemistry* course, future work in this area would consist of investigating the in-moment context of students engaging in activities that are structured around scientific practices through video-recorded classroom observations. Although it is useful to investigate students' reflections about their beliefs surrounding activities (Lederman, 1992), it is also meaningful to examine the activities when they happen in the class. As highlighted by sociocultural theories of learning from which the practice-based perspectives emerged (Bang & Medin, 2010; Calabrese Barton & Tan, 2010; Fortus & Vedder-Weiss, 2014), it is important to examine the actions that students are doing in conjunction with their epistemological reflections on those actions to understand the practice being enacted contributes to the stabilization or disruption of the science community culture that learning environment fosters.

10.4 Considerations

10.4.1 Expertise

At the time I was writing this work, I was a third-year, PhD. candidate in the chemistry education division under the advisement of Dr. Minjung Ryu. As mentioned in the **Positionality and Analytical Approach** section of the paper, I have been examining this data off-and-on since my first year in graduate school. Until this point, I have taken many classes and served on several other research projects that I believe have afforded me the resources necessary to shape the work into what it is becoming. Courses that I would like to acknowledge as contributing to this thesis include Qualitative Methods I, II, and Seminar in Identity. Qualitative Methods I and II provided me the opportunities to learn about thematic and narrative analyses that have inspired this work as

well as the Seminar in Identity class that guided how I understand identity as a theoretical structure. Projects that I have worked on that I would like to acknowledge as contributing to this thesis include my first research project with PSETs that inspired my appreciation for this population and the graduate teaching assistant project that helped me learn the importance of curriculum on students and student-teachers' performances in the classroom. Although I have learned a lot from this program, I still have much more to learn in terms of research analysis and writing. I hope this work serves as a stepping stone that furthers my ability to do work that meaningfully contributes to my community and social goals.

10.4.2 Limitations

Previous sections have highlighted the limitations of the methodology used and the study context. For brevity, I will summarize how these two sections relate to each other and how I have tried to intervene or justify research choices. In the study, the data consisted of focus-group interviews that took place once in the semester; therefore, there are limitations on the claims that can be made about students' identity development. The most well-known limitation in using narrative inquiry to examine identity describes identity as a discursive medium; however, identity can be theorized beyond discursive consideration (Wenger, 1998). Wenger (1998) argues that identity in its essence is not discursive or reflective given that identity is predominantly experience and stories can merely recount experiences. He writes: "We often think about our identities as self-images because we talk about ourselves and each other—and even think about ourselves and each other—in words. These words are important, no doubt, but they are not the full, lived experience of engagement in practice (p. 151). In terms of my study, this is important because I cannot make claims about the PSETs' identities directly. With this analytical approach, it would be irresponsible to argue that these are the PSETs' definitive [science] identities and that the curriculum directly influenced those identity constructions. Instead, I can make claims about the allegorical identities of the personas that I have animated in my analytical chapters. I can also make claims about the allegorical PSETs' perceived shifts in participation that contribute to the stabilization or disruption of science practice-linked identities as they recount their experiences doing scientific practices – which we take to be the way that identification unfolds in the narrative context (Wortham, 2009).

Moreover, the data sources are ten-focus group interviews which were done once and at different times of the semester. Meaning, the ways PSETs might recount their experiences in the

course could be different depending on when the interview was taken. For example, if the interview was done following the exam (as was the scenario for V001), PSETs might perceive their participation in the course as being "good" or "bad" depending on the scores they received on the exam. To mitigate this, I offer that my theoretical and methodological frameworks seek to acknowledge and capitalize on the co-constructed identity that is occurring in the moment. I am foregrounding that PSETs are making unconscious and conscious choices about how they want to present themselves in the setting. My allegorical characters were made to represent groups of PSETs that thematically shared experiences such that the allegorical characters might reflect complexity and depth. Students may have also felt an obligation to say positive things about the course since the instructor did the interviews with the students and may have felt embarrassed to discuss their participation in the course in front of their peers. To mitigate this, Minjung gave students an ice-breaker activity to create their own pseudonym and have students refer to one another in the interview using that name. Most students also opted to interview with people that they knew, so they were able to self-select who would be in the room. Interviewing with the focus-group rather than individual interviews have been shown to reduce the power of the interviewer (O.Nyumba, et al., 2018) and help participants feel more comfortable.

In terms of limitations I could not reconcile, I recognize that the constructs of practice-linked identity and disciplinary identity grounded through narrative were not enough to explain the ambiguous students. I acknowledge that my work relies on extractive processes that do not do enough to disrupt the normative ideas of data collection or the difficult learning position PSETs are in. Thus, my work is problematic especially in Andrew's narrative. Drawing from a framework that acknowledge power dynamics in race and gender but does not actually provide a mechanism for interpreting power dynamics in race and gender was irresponsible. The production of blending these participants together in a character under the guise of "protecting" their confidentiality does not excuse the colonizing reproductions at play such that even the name I chose for the participant to reflect his male status and Asian status was negligent. Since I am telling the story as a non-Asian man, I am drawing from normative ideas about what it means to be Asian and male in this context. However, I decided to tell pieces of this story because I believe it was important to showcase how dominant populations can still experience marginalization. Research that aims to transform is always "political risky and ethically responsible" (Kuntz, 2016, p. 123). I created my own rules for doing narrative analysis because I wanted to use the methodology to elucidate

counter-examples in the existing literature that challenge pre-existing notions about PSETs. I wanted to use the methodology to help readers sense the emotionality of these participants to showcase that we need more ways to understand these students and their learning needs.

10.4.3 Deliverables

Given the limitations summarized above, I intend to publish the literature of this work that argues for more utilization of asset-based frameworks in marginalized science student populations and the design features of the *Fundamentals of Chemistry* course that PSETs have described as being beneficial for their science learning. To operationalize the literature review for publication, I will describe my methodological approach to synthesizing the themes from the articles that I read and provide the research questions that guided my literature search. To make my review more robust, I will frame it as a critical literature review that not only seeks to elucidate the literature on PSETs, but also call into question the theoretical and practical ramifications that these papers conjure. I will also offer the positive ways that the literature has worked with PSETs and explain how those studies or elements of certain studies can be fruitful leveraging opportunities for researchers who want to continue serving this population.

In addition to the literature review, I will also publish content from the second research question that examines how PSETs reflect on their learning in the *Fundamentals of Chemistry* course and what materials contribute to relational and ideational identity-building opportunities. By exploring this topic in a publication, I believe it will help instructors realize that designing curricula involves attending to disciplinary identities in either implicit or explicit ways. By making this perspective known, I hope that instructors will be more mindful of who students are before the course, where students are during the course, and how students might be after the course such that instructs can cultivate a curriculum that contains identity-building resources students can use as tools long after these courses have been completed.

APPENDIX A. SAMPLE TRANSCRIPT

Decoded: Video 7 JN (Josie) analyzed and video 0070 MJR (Minjung) interviewed. Date: 02/17/18

Session Overview: The goal of the interview was to understand how preservice elementary teachers (hereafter, PSETs) undertaking a course called CHM 200 at Purdue University perceived science classes throughout their schooling (elementary, middle, and high school). The interview then moves into how these PSETs perceive the utility of science content classes at the undergraduate level by using CHM 200 as an example and moving into courses that PSETs take such as BIOL 205, 206, EAPS 102, and PHYS 215. The way science classes are conceptualized at the undergraduate level has also influenced the way they foresee themselves teaching science as in-service teachers. Notions of what science is and who can do science are elucidated by using Carlone's (2012) methodology for studying identities in school science. The data for this is not complete given that it was not possible to see how the students organized the cards. Finally, students were asked to brainstorm what they thought about how heat transfers between two objects that have the same temperature. Student participants interviewed in this segment by Minjung (MJR) include Karen (Ka), Koby (Ko), and Liz (Elizabeth).

Segment 1: PSETs' perceptions of science classes in high and elementary school

Cam 1: [00:00:05.00] - [00:08:04.10]; [00:44:01.14] - [00:48:50.10]; [00:52:34.24] - [00:56:23.02]

Note: There are 3 participants in frame and they are sitting (starting from the left of the screen): Karen (Ka) is sitting at the left and Koby (Ko) is sitting on the right of Ka, and then Elizabeth (Liz). Minjung (MJR) is sitting at the head of the able facing the PSETs (she is out of frame).

(TQ1) MJR [00:00:18.00]: What kinds of science classes did you take in high school and how were they?

(SQ2) MJR [00:04:58.11]: What do you remember from your chemistry class that you took?

(SQ22) MJR [00:43:55.15]: How do you feel like you've grown throughout your college?

(SQ23) MJR [00:45:55.21]: How did the transition from grade-focused to learning-focused happen?

(TQ26) MJR [00:52:27.16]: In terms of general learning, how do you feel?

(SQ27) MJR [00:54:19.13]: Is there anything you'd like to talk about more of the class?

Segment 2: PSETs discuss how they think they will teach science and the value of teaching science to elementary students

Cam 1: [00:14:57.04] - [00:22:27.13]; [00:32:10.01] - [00:38:26.07]; [00:56:20.13] - [01:06:29.24]

Note: There are 3 participants in frame and they are sitting (starting from the left of the screen): Karen (Ka) is sitting at the left and Koby (Ko) is sitting on the right of Ka, and then Elizabeth (Liz). Minjung (MJR) is sitting at the head of the able facing the PSETs (she is out of frame).

(TQ8) MJR [00:14:37.04]: Do you think there is connection from this class to what they'll be teaching in elementary?

(SQ9) MJR [00:18:27.13]: Do you feel happy when you learn new things in chemistry?

(SQ10) MJR [00:19:49.26]: Is that something you want to transfer to your students?

(SQ11) MJR [00:20:42.08]: When did you decide to become an elementary teacher?

(SQ12) MJR [00:23:00.08]: Why elementary in particular?

(SQ13) MJR [00:25:23.10]: All of you like it so far?

(TQ16) MJR [00:32:10.01]: Pick two or three cards that are most relevant to doing science.

(SQ17) MJR [00:33:14.28]: Can you say more about your choices?

(SQ18) MJR [00:34:56.19]: Are there people who are naturally inquisitive?

(TQ28) MJR [00:56:23.02]: How would you like to teach your students science?

(SQ29) MJR [00:59:47.23]: What would you teach for chemistry to elementary students?

(SQ30) MJR [01:04:04.08]: What is chemistry?

(SQ31) MJR [01:05:06.29]: Did your understanding of what chemistry is change by taking this class?

Segment 3: PSETs' perceptions of CHM 200 lab and lecture (class materials, resources, and assignments)

Cam 1: [00:08:04.00] - [00:14:57.04]; [00:38:25.09] - [00:44:01.14]; [00:48:50.10] - [00:52:34.24]

Note: There are 3 participants in frame and they are sitting (starting from the left of the screen): Karen (Ka) is sitting at the left and Koby (Ko) is sitting on the right of Ka, and then Elizabeth (Liz). Minjung (MJR) is sitting at the head of the able facing the PSETs (she is out of frame).

(TQ3) MJR [00:08:04.10]: How was the class today?

(SQ4) MJR [00:09:10.01]: Do you feel like a lot of things in lecture are repeating what you did in the lab?

(SQ5) MJR [00:09:54.16]: How was it?

(SQ6) MJR [00:10:32.21]: So, how is the chemistry class you are taking is different from or similar to what you learned in high school chemistry?

(SQ7) MJR [00:13:25.02]: Do you talk a lot about those things in the lab?

(TQ19) MJR [00:38:26.07]: Do you experience these things in the class?

(SQ20) MJR [00:40:18.03]: Is there anything different from this class than other classes you have taken so far?

(SQ21) MJR [00:42:45.10]: Are you frustrated not to know the answer?

(TQ24) MJR [00:48:39.06]: How are your grades and performances in this class?

(SQ25) MJR [00:50:56.08]: How do you feel when you are taking the exam?

Segment 4: PSETs classify cards about what they believe science is

Cam 1: [00:25:24.04] - [00:32:10.01]

Note: There are 3 participants in frame and they are sitting (starting from the left of the screen): Karen (Ka) is sitting at the left and Koby (Ko) is sitting on the right of Ka, and then Elizabeth (Liz). Minjung (MJR) is sitting at the head of the able facing the PSETs (she is out of frame).

(TQ14) MJR [00:25:24.04]: Categorize these cards *Data missing*

(SQ15) MJR [00:29:30.27]: Can you explain your categories?

References

Carlone, H. (2012). Methodological considerations for studying identities in school science: An anthropological approach. In M. Varelas (Ed.), *Identity construction and science education research: Learning, teaching, and being in multiple contexts* (pp. 9-16). Rotterdam: Sense Publishers.

APPENDIX B. NARRATIVE WORKSHEETS

Chapter 6: "I am a Science Person"

The chart is organized by individual PSET with related quotes that I felt best captured the science experiences of these students. The Ref# refers to the number of quotes that were catalogued for each student in Nvivo.

PSET Pseudonym (Ref #)	Quotes
Amanda (44)	*I was always really unsure because I wanted to be a marine biologist ohh that's why I really liked bio. I loved that. and then I wanted to go into forensics for like a long time. I wanted to be a crime scene investigator so I wanted to do a lot of things and this still appealed to me, but like education was always on my mind and like senior year of high school I was a peer tutor, so I worked in a special needs classroom and I take them to lunch and I work with them and ever since then I knew it was the most amazing.* *I enjoyed chemistry a lot, but I took physics. I took like an earth space class my junior year and I really liked that one. I like space a lot, so I think it's really cool learning about planets even earth like the different formations and stuff. I think that is cool, too. And then I enjoyed physics, but it was definitely tough. I remember people struggled with that.* *I think that was like...not having to memorize it all but I remember having to memorize the periodic table and like a lot of equations. That's what I remember from chemistry.* *I'm not a math person at all. Like with equations like yeah, they show you how to do it but it's like okay I know how to do that but okay now explain why you did that or how you go to that and you're like I cannot tell you anything.* *I remember strictly formulas and the periodic table and I just remember really what I remember from and so coming in here, it's definitely more of like a foundation for it and a lot of concepts more abstract thinking which is what I really like because it's kind of like yeah we are looking at some of those equations like the same thing mole. I remember doing that. But now I know what a mole is, why we are using it, so things just more so go from formulas to like actually putting them into use and being able to explain why you are doing it.* *I think inquisitive too especially when studying like keeping an eye on things and asking myself, "Oh why" or like ask a question to try to better help myself understand or ask myself questions out of curiosity. I think that's why I always enjoyed science because it such a bigger concept and like that really motivates me to like. How important is this to know even though like the little concepts and just how later in life. It's just like life. Everything around you is science and everything you do effects it so I just think it's cool to incorporate those bigger concepts and this is why you are learning the little things so you can see the bigger picture.* *I was going to say like science in general like you are constantly asking question and then you are always like learning more and more. So, it's good to be asking questions and in science classes you are always in collabs and always working so you always need to collaborate with someone and like experimental like yeah.*

	It's used to understand instead of looking at it and being like, "That's cool" like to be able to explain it to them and they are at the point where they know why that happens. If it's like in simpler terms because as they go on, even with us. Now we learn more and we can explain it more. But just like give them that basis of like I at least have an idea of that's why that's doing it and even for the kids that are really interested in it. To have that interest that I'm going to even know more and I have that foundation, so now I can build upon that foundation. *I just feel like these are more for students to have a positive outlook because I know for me I like to describe myself through our study habits. Like I work hard to get good grades. I wouldn't say like, "Oh things come easy to me like I get that. but I am persistent" Like I have to work so hard in order to get that and I feel like looking at a student You are so smart especially when they are so young, gives them that. Places that seed in them that I am smart and everything comes so easy to me that I don't have to try.*
Ashley (41)	*I've always enjoyed building things, so that's kind of like why I wanted to do that. Like, that aspect so this is perfect and then I could do that. And then I did an Engineering-ship. It was a mission trip, but it was an internship company and we would build homes for families in Mexico and I would have really liked it, but I wasn't in love with it and so I was like I love little kids like I always...I guess teaching was always in the back of my head, bt it wasn't what I thought I wanted to do and so that summer, I'd love to hang out with the kids and I loved like talking to them and I just like being around them and I don't know.* *I feel like the goop...what was it the [Oobleck]. Oobleck was really cool like to do [I'm going to do that over winter break with my kids because I'm a nanny] Yeah because it's an easy concept like solid, liquid, gas like just talk about that and then have them make it and then be like well which one is it, it's a liquid now, but it's a solid so maybe they might get a little confused, but be like it's both.* *I think moles is just...I mean maybe because I'm really overwhelmed with it right now, but I just don't think [I don't think there is any way you would do that in elementary] I think I learned that in high school like when I was in chemistry in high school and I still struggle with it to this day so I could never see like even fifth graders. I don't really know. I think...* *Well, I picked imaginative just because for example with moles you have to think about it because you can't think about...I mean you can obviously think of molarity, but like imagine what's going on because you can't always see what we are talking about. This one I thought because different scientist always build off what one says and they have to work well with each other.* *I don't know when I think of science people I feel like they are very smart and I feel like they have all this knowledge that not everyone necessarily knows about and so.* *In the bubbles. The bubbles I thought...I think it was a homework...I never saw a bubble or like I don't know I just thought it was so cool how it could pop and talking about the different layers of the bubbles.* *But for me, I feel like science you either get it or you don't. But when you said that then it kind of makes sense because like I know there are some concepts in science that are either this way or not. But then there's other concepts where you can have a better answer.*

	Well, I have a really good friend. She's a chem major and so I ask her questions, especially for...I think it was the pre-lab...when we did moles. Like, not this pre-lab but last week's. So, I ask her and then I look through the PowerPoints and the lab and I google a lot, too. I just...basically like what she said...google keywords and sometimes it's really confusing because some websites will like go in a lot of detail and then we don't really necessarily go into that, so I look at the kid's websites and see all the things there *Definitely imaginative because we don't always see what we talk about in class. And then in lecture we have those groups where we talk about questions where you ask us and this one kind of...I feel like this is kind of a personal thing like you can't just be like you guys need to need knowledge, but if there is a topic someone if really interested in and we can do more research about it and do more research with it in the classroom.*
Bethany (46)	*That was really fun. I enjoyed biology and I enjoyed biology here when I took it last year* *than like calculation and like the math part. I think that the science part...the science part of chemistry...it's all science. Um, I think that the math part and the calculations and the abstract thinking um...it was really, really tough.*
Denise (84)	*Okay, I guess I kind of come from a science background just because I originally wanted to go into the medical field. My sophomore year of high school I took chemistry and I really enjoyed chemistry. It seemed to come really easy.* *I mean to me, it's a lot of exploring and figuring out for yourself. Because like I was saying, remember how we did a lot of math and like yes there is a lot of math in science but as I am now learning that just because I can do that math doesn't mean that I understand what is going on. It's more so the concepts and being able to apply those in real life, so I mean like even just learning about the different phases of gases and liquids, being able to look at that and say like how is that going to change at different altitudes. It's actually usable.* *And like you said about the awareness. I think if you are teaching children specifically with science, having them aware leads to them being curious [Yeah] because kids are naturally curious where they know the deeper questions they are going to have, which means they are potentially going to learn or experiment.* *Or that science is constantly changing, too. And so, it's kind of like one of those where I know that I am learning this stuff, but fifty years from now a lot of this can be way different which is kind of crazy to think about as you are learning. I mean absolutely, yeah if you don't understand like the world around you then you're just here and you're just kind of...things are falling and you're like it just happens... I don't know.* *I would agree because a lot of the science I remember doing in elementary school wasn't even presented as science. So, a lot of times it was like let's look at a bean seed and like I didn't see that as science it was like playing with plants. You know? I was just lucky enough to have a dad who was really nerdy with science and was like hey we are going to do this and we're going to find this out and we're going to we did science experiments without me knowing it, but that's kind of what sparked it for me, but I feel like elementary schools really do lack.* *Well, when it's pulled into Pedialyte and Gatorade and things like that, like okay I get why we are learning this, like that makes way more sense than if we just went*

	[Now, I get why my Gatorade bottle has a lightning bolt on it]. Yeah, so it's that idea of can I take this into my real life and manipulate it to my benefit or understand it so that I'm not just doing something. *To me, science is no longer flasks and Bunsen burners and beakers. It's what is happening at all times and I think that's the one thing that I'm fortunate for science and like kids don't get exposed to it at a younger age and they just automatically picture like Albert Einstein or like really complex things going on and they don't realize that science is what they are constantly doing.* *"Okay, I think this was kind of like the scenario that they are talking about, so that I could visualize it." I think that's kind of my biggest problem with this, with science in general is so much of it is half looking at the molecular level or like way off where we can't see it and without that visualization because I'm such a visual learner [And it's hard to picture, figure out]. It's really hard to figure out exactly what. Yeah [I agree]. And then throughout the lab, I feel like you are learning those concepts, but then when you come to actual lecture, you are learning the why more so behind the concepts. You are learning those pieces you didn't fully get to see. Because we are coming from lecture saying okay we know this happens and we saw what happened, now we learn why.* *Yeah, like we were saying with the labs and having real-life materials. Things...that's one of the biggest things because if you haven't had these experiences, it's so much harder to think about, so using materials we are familiar with, it makes it not only less intimidating but we are able to think about it on a deeper level because we have had experiences* *Yeah, it's a lot of teamwork. Even if they're not, like you said building off of each other, even if they are not directly sitting there next to each other collaborating, it can be I read so and so's research and that made me question this and so I'm going to do this.*
Erika (42)	*Yeah, I liked it too, like I kind of felt in high school you knew that you had to take it, so I think it was harder to enjoy because everyone just wanted to get a good grade in the class and everyone just wanted...everyone knew they had to take it, so it felt like you weren't choosing, "Like, oh I get to take biology." Everyone was more like, "Oh I have to take this class, so..." And it was also neat to like see the different areas of science that you like because it's all science, but also different. Like, I was more of a biology person. I don't know I just loved biology whereas chemistry I found more difficult and physics I loved, but I felt it was difficult. But um...it's just interesting to see the different sciences that people find easier or more difficult because I had friends who thought biology was so much harder and they understand chemistry better, so you just need to see which one people find easier. [So, people have different difficulties?] Exactly.* *Yeah, I've also taken bio XXX and XXX and um one thing I loved about it was that (kind of similar to chemistry), the labs are really applicable to elementary school classrooms as well. So even though they are not easy by any means, you can do elementary school labs, but you can take any part from the different labs we do in chemistry and biology and you could like adapt to fit to a younger classroom which I think is really neat because it gets us a lot of ideas so it's like one thing when we are teaching. I don't know a third-grade classroom something about...phase change you could think back to chemistry when you were doing the Oobleck and that is something you can implement in like younger classroom and they can explain. Like there are a lot of labs that we do that you could implement in your classrooms. [Can you give me a few more examples?] Making the ice cream. I thought that was a neat*

	one because that explains a lot of...chemistry related material but in such a neat way for students to understand and also doing the pH. *Oh! I would say the different properties of water. Almost all of those you could do like surface tension and the...I remember putting the drops of water onto the pennies and seeing the dome shape versus the... [rubbing alcohol] and how that just slipped right off and you can relate to the properties of water and also when you put the detergent into the water and all the salt...or pepper went away... that was really cool. And I think that is something that can be easily done in a younger classroom, too. So, all the ones with properties of water* *And since they are younger, they may not know all the correct terms like intermolecular forces or polar versus nonpolar, but they'll remember that. Those basic concepts and as they continue their chemistry education throughout the rest of middle school to high school and then college. Those are things that will stick in their head and then they'll learn all the terms that go along with it. Because I feel like in elementary school I didn't actually do that much chemistry or like lab. Like an actual hands-on chemistry assignment. It was more like writing stuff done and things like that so...but I think that integrating experiments and labs into elementary schools is becoming a lot more done. Like more teachers are doing it, which is really awesome.* *Um, I guess I love kids and I love the effect that an elementary teacher can have on younger students because that's when you are really teaching them the fundamentals, so if you have a strong elementary school teacher who teaches you how to add really well, how to multiple really well or just like those fine mental skills, that's what you carry on the rest of your life.* *"Why...why you are studying elementary education...like why are you taking physics. You know you're never going to teach them that" But like you do teach elements of physics to elementary students. Maybe it's not as complex and you are not doing the math involved, but you are definitely in science are teaching physics and they just don't know the terms physics yet and by having us trained in all the different sciences and trained really well in it just makes us more qualified to be able to explain it to them because the more you understand something the more you can explain it to someone else and sorry that's just something that* *In this chemistry class, I find the labs are helpful to go back and study that especially the wrap up questions and going through the activity because once you've done it, you can go back and read your notes, it's easier to understand it. Like I remember why that happened. So, I find it most useful to do that. And then once I go through all the labs then I go over the PowerPoints and then relate the PowerPoints back to the lab because the PowerPoints are more information detail, whereas the labs are more the concepts and so I'll connect the two and yeah, that's how I study for chemistry.* *Yeah, I was going to say inquisitive because you are because when you are doing the lab like you are watching the experiments and a lot of times you are like why does that happen there and thinking questions in your head and then you go to lab and you answer the question right now. So, it's like while you are doing it, you are thinking of question. Like inquisitive is like the reason you said for when you teach science in elementary you have to be constantly curious and asking questions. It's like asking questions and questioning why things happen.*

	No, does make sense. Though I'd say also collaborative because it's not like reading where you read your book indecently quietly. A lot of sciences deals with working with other people and helping them with concepts.
Karen (46)	*Well, growing up it was something that I wanted to do and then I had my advisors keeping tell me stuff like oh you do really well in biology, you should pursue something in biology, so I was like okay, maybe I should. I didn't know what I wanted to do, so I like went in as a bio major and took it like a semester doing that stuff and I was like I don't want to do this for the rest of my life. I was decent at it and I liked it, but the options for when I graduated, I didn't want to med school* *I think a lot of it for me was that like I could not, I didn't know enough to connect our experiments to what we were doing, so I would just do stuff because she told us to do it, but I never know why we were doing it or what the purpose behind it was, so I think that's why I have such a hard time remembering what it was because I never reviewed the purpose behind it.* *Yeah, like I'm going to be teaching for thirty years and not...like no, it's going to be the material from this course and what I got, took from the class. That's what's going to matter so...* *That's like if I were to sit down and talk to someone about it, I feel like I could explain it no problem like, but I don't know so...I just feel like my test score isn't reflecting my knowledge if that makes sense [Yeah, I get what you're saying]. Yeah, I mean generally the tests are hard and I am not the best test-taker like I get test anxiety and all that stuff. It's been something that I've always had to deal with my whole life and I needed to like come to terms with the fact that I am not going to do as well on tests as I know I am really capable of and so, but I do notice a bigger difference in like these tests like it's not just my normal test anxiety. It's like I know this, I don't know..* *And I think another disconnect might be that the material that we're going through it much more in-depth. Like we're not going to talk about molecules and things like that with our kids, but I do think it's important that we understand how it works because then we're going to be able to explain it this does. But like I do think it's important for us to know, so I think a lot of the times people are kind of like I'm not going to teach my kids about molecules. Why do I need to know about them? But, like it is still important for us to know about them.* *I also feel like there is that level of you are setting the stage for their attitudes about school moving forward, whereas in the older grades or in high school, they already have this idea in their head about what school means to them. So, there are still those students who are still kind of excited about school, they like to go. But, then there are those kids who are like no I don't like this. I don't want to do this and it's hard to change their minds after that. Like, there's not much you can do. Like, you can try and you can.... like, I'm definitely not saying you shouldn't try, but at that age it's just really hard to change their mindset that they may have, so...That's the thing I love about elementary educations. I don't know, I feel like this kind of goes with that in terms of chemistry because we have to think when we're doing stuff, we have to think about how this would apply to other aspects of our lives or how could we teach it or how could, like what activities could we do for it so I think that kind of gets us thinking about yeah this is my experiment, but how else could we modify. Like, what else could we do? How else could we apply it? Type of thing for that.*

	But, I think inquisitive is important just because like if you're faced with a problem in a science contest or context or a chemistry whatever. If you don't have that desire to figure it out, there's no reason for you to do it. You know? If you don't have that natural drive to be like why does this happen or what would happen if this whatever. I feel like that's just kind of a natural thing because if people weren't inquisitive, there wouldn't be any research on anything or like any development of anything because nobody would be like oh what happens if I try this. So, I feel like that's just kind of a natural and really important aspect to anything science related. *I think it's important to not be stuck...I know this might sound, I've heard stories of different scientists who made break-throughs because of something completely un-science related that they observed and were like oh...like thinking in a different context will like put them somewhere else or like made something click in their minds, so I just feel like it's important to not be so stuck in your head like I like math, so I'm going to focus on math and you can do something based on math, but if you read some literature or something, it could set something off. So, I just think that's important to just like not focus it on one thing and to be open to other subjects or like applications and stuff like that* *Chemistry used to be in my head like in a beaker pouring things in there like watching it explode, like that's what I'd seen on TV when people are in chem labs and like that was in my head what it was, so here's definitely shown me how much. Like, how many more different ways it can be applied, like it could be applied like everything like in life basically. And so, it's really...I mean when you look at clouds you're like oh I know clouds are formed because blah. I don't know it's an understanding of, like a deeper understanding about it and I really thought to apply it to everyday things so...* *No, I think I find that I make those connections like I know why we're doing what we're doing or like I know there is a purpose and through the experiment, I'll learn what, like what I'm supposed to learn. Whereas like in high school, I was just kind of like told this is what you're supposed to figure out, but like I never got to figure it out on my own or apply it. So, it's definitely better for me because I can make those connections. I feel like I'm oh this is why you're doing this*
Quincy (45)	*I had the best chemistry teacher. She won awards and the stuff we were learning up until the first exam, she went over everything with that so it was kind of just review for me, but I took bio in high school, physical science. Yeah, I agree. I know that especially with chemistry, it's more just like okay, you are looking at this paper. What molecule is in the paper. I can't see that and obviously like I start to overthink it like is that even true what people are telling me? Like, how can you see that with a microscope and stuff like that, but really? I start to questions things over and overthink it and then that throws me off a lot* *I don't think I know enough about the periodic table to start thinking of ideas for students to start engaging with it. You know what I mean? Like, I don't know enough background about the periodic table to be able to think of ways to teach the students how to learn the periodic table. I just don't know enough to get it which I feel like I don't know enough because the curriculum really ever, but I am sure they have to do something with the periodic table* *Yeah, like I agree with you. Some of the mole stuff, coming from being in L-ed, even if the student does ask a question just for their understanding of it, just to try and explain that to that to the student who is maximum teaching sixth grade, I feel like you'd have difficulty understanding that. I was in a sixth-grade classroom and a lot of the students I know couldn't understand that and it's more because I think I struggled with how to do that in eighth grade, beginning of my freshman year and*

	so I feel like that wasn't really useful, so by the time I wouldn't spend more on that, but more on once again the experiments that would better me and my future classrooms even though it affects my grade now. *I definitely think the activities are great with what we do like almost all of the activities I could sub, like even making a band, maybe not making rubber bands with my class, but just the depth we go in. I feel like we go in too much depth for...not coming from a chemistry backgrounds which I mean it's not really any excuse, but we're like.... coming from an educator, like wanting to get my degree to be the best educator I can, I can't put all my focus on something that won't be using. I feel like going too much in depth is preventing me from focusing on what I need to be to be the best educator* *I know if you do think about going in depth, I almost want to, this is from my classes, I want the professors to prove to me okay we are going this much in-depth, how much is...will students actually ask me this in my classroom. Where's the proof that this will benefit me in my classroom instead of just saying you're learning this just as background, just to get the credits. I want proof like this will help me, so...that's what I want if professors choose to go that in-depth. I want proof of why this is helping me.* *But, at the same time, they shouldn't be my only source of information. Like, if they weren't there or one of them left, I wouldn't have a clue what's happening. But, when I do ask they explain it very detailed and I eventually understand it, but I feel like there should be another reference to go to and once again there's lecture, the PowerPoints, at that time the questions that will eventually be graded, I can't just have them as my source, my one source to use and then phones which we're not supposed to have, computer which we're not supposed to have. A lot of it relies on the TA, which isn't reliable because there are so many students.* *And this might sound a little harsh, but I'm out of state paying so much money and I shouldn't be using google to help my answers. I'm paying money for Purdue to help me, either a book or a teacher. Not from google. So, I feel like in terms of my money's worth or something... Just coming from experience, I don't honestly think a textbook would be best coming from bio with the lab manual where our course coordinator specifically made that and she has like the standards on it and I think that's useful for us. I feel like that's the best thing to do.* *I feel like it's justified to be knit-picky with like atoms and molecules if we were chemistry people. If this is what we are majoring in, then this is what I want chemistry people to know an atom and molecule and to an extent, I expect us to know that, too but that is not our purpose at Purdue and so to be knit-picky is not going to benefit us too much* *I feel like the way we do it now is okay with us exploring, if in lecture then you specifically go over what is happening in each experiment. I know that we do that at the end of the lab, but in lecture then reiterate like this is what happened, this is what happened and this is why and explain it as a whole we're grading this based off your reasoning, now I know what to study and how to study. If you didn't tell me that, I wouldn't know. I didn't know, I was confused so..*

Chapter 7: "I am not a Science Person"

The chart is organized by individual PSET with related quotes that I felt best captured the science experiences of these students. The Ref# refers to the number of quotes that were catalogued for each student in Nvivo.

PSET Pseudonym (Ref #)	Quotes
Barbie (38)	*Sometimes I'll go on the internet if I don't understand a topic like as in-depth as I want to know it like polar and non-polar I kind of had a before the exam last week because it was so long after we talked about that, um I kind of wanted to refresh my memory, so I googled it and I found a nice little, a nice little activity thing that let you look at polarity and nonpolar things and why are they polar and why they are attracted. So yeah, sometimes I'll go on the internet and google it. Sometimes I'll go and look at YouTube videos, I love YouTube videos. I love it [especially with chemistry because they show you], so I look at YouTube a lot when I am studying because it's nice to see it visually. So yeah.* *No, you said something like...Oh! Okay, yeah because you were like we don't teach them and they don't know physics. I was actually talking to a professor about this yesterday because we got on this topic about math and all the science classes you have to take and um it's true like in chem for chemistry, when I was in grade school I don't ever remember chemistry. I don't ever remember physics, but they do teach you...they just call it science that's what my elementary school called it. We just called it science, but I do remember learning about liquids, phases...err solids, liquids, gases and I remember learning about that. I remember learning about gravity, I remember learning about you know magnets and I remember doing a little experiment with that.*
Erin (55)	*I agree with that like I remember in high school I would always do equations and I can solve them like I got A's but I would like to know why I was doing it. Like I know how to find the moles for this and blah blah blah, but I was like...I didn't even know what a mole was when I was in high school. I was like, "I know what a mole was" and seeing how many particles are made up and it switches to this, "we use this thing called moles and you do the equation of moles.* *Yeah, I actually think you are right. I was just saying that I think it's also hard because like when I was in elementary and middle school, we never really. or maybe we did touch upon it and I don't remember it, but we never talked about chemistry and physics in the way that we talk about it now. If there is anything for this course, I'd like to see more of that because it's like some of it I am like, "I don't know if I am having my 4th graders test acids and basicity' like experiments like that and like I want to keep trying to think of things that I can do and it's very great like Oobleck.*
Reagan (53)	*I should have probably failed it as hard as he made it. And then he curved and to have to curve all the way to get a C from an F probably is a big curb and that means it wasn't taught very well and I know it was a lot and I remember when we just started doing moles last week in class I remember thinking that was the death of my high school career was moles, but I think it's getting explained a lot better in labs and class than it was in high school because once we didn't get it the whole rest of the class just went over my head and so it was awful.* *I don't think it would bother me nearly as bad if we could do it, explore it, and then maybe have our laptops and look it up really quick. And it's very helpful when Hannah and Kathleen are both in there because with just one of them in there, it's*

	hard for them to come around and get to everybody because we all just shoot our hands up, but with both of them in there it's helpful because they are able to help everyone in lab more *And the homeworks, like t like the homework is hard to do with our current class format. Since the lectures are after the labs, it's a little frustrating because you don't know. Then you look it up and you find out for yourself and you reteach it and they teach it in lab and I really think doing the homework before is actually helpful even though it's frustrating* *And I at first was skeptical about having lecture after lab and now I really like it because you get to explore, explore and then come to you and get it put into words for you.*
Sporty (36)	*I didn't like it, but looking back I feel like I knew what was expected of me like I knew what I had to do to get an A. I just felt like the information was just out there for me and it was up to me to know it, but like sometimes I feel like with science classes the information is not really as accessible. Like, I really have to dig for it. I have to use google and like...* *I think it's different because it involves a lot of math and I know physics has a lot of math, too. But, like chemistry math makes sense to me. It's all about balance, so like that's what I remember. Like, I still remember so yeah.* *I remember hearing about it and we asked her this and we were like imagination doesn't count in science because they are very concrete. I remember this now.* *I feel like we learn the theories behind things and like why kids need to be able to do things, but then it's very much like all application [Applying] and like they want us to understand the theories behind it, but it's a lot just because that's what we do in the classroom. We just apply, apply, apply, so it's a lot more application and here are different ways you can do this. Brainstorm with your group like creative ways that aren't like a worksheet that you could have kids learn about this.*
Gina (65)	*I like Math, but like science is not my forte, but I like to push myself, so I took honors chem, which was terrifyingly difficult* *Just study really hard. I am not one to give up on grades. For me, grades are everything. I get really upset when I get a bad grade. I just read through materials, google like it's my job, I figure out ways to memorize the material, I mean it's just a lot of extra effort on my part in those classes, but it's funny that I'll put three times as much effort in like chemistry and get a 70 on the exam while like in my other English class, I'll put in not even half the effort and get an A really easily, so....*
Britany (30)	*Yeah, I felt like in high school, there was a lot more balancing equations and stuff than we do in our chemistry now.* *Well, my first TIP assignment was a special ed Math specific middle school classroom, so it had so much stacked against it because not only was it middle school, but it was also focusing on Math and nothing else. And it was just terrifying and all of them were talking about the drama on the weekend and were like you broke up with so and so and I'm just like guys let's learn our Math and they all didn't care. I can deal with high schoolers, but not middle school.*

Ally (30)	*We didn't do hands-on like stuff we are doing in our lab, we didn't do like experiments or anything like that. We just worked worksheets* *I feel like that's my biggest thing about science classes have always been really hard for me. I think I just have that mindset that started back in high school because I didn't do very well in my chemistry class. I kind of set that for myself and I shouldn't have, but I think that's the biggest thing for me is that I struggle with them. Same with math, but those topics I have just told myself that I'm not good at that, so now I've just not been successful as I could have been, and I think that's my biggest thing* *That was also something I was going to say about our lab group like there's a lot of the time we have questions and our TA would come up and say oh, did you talk to another lab bench here. Like, collaborate with other groups and see what they got because there are lots of times where we all got, like between three groups, we all got different answers and so we're like well what did we do wrong and we got this answer right and this answer right and maybe we just came up with two different right answers or maybe they are both wrong or maybe one's right and one's wrong. Like, we had to figure it out and I think that was just a great learning experience because she could have just easily been like okay let's take a look at this instead of the rest of them and like hinting that was the one to look at, but instead she was like collaborate. Figure out what's going on like let's figure it out and get on the same page again. So, I appreciate that.* *I'm actually going into special ed and elementary ed and I think what really inspired me to become a special ed teacher was my brother has autism and that's something that's always been a big part of my life like me and my brother have always been like this *fingers crossed* and I have five other siblings, too, but me and my brother have always been the closest. And I think out of all of my siblings, I understood him more than anybody else and I think that's kind of what inspired me to continue doing that for other people and then tying into education, a lot of students who do have disabilities are looked at as okay let's teach them the basics of living. Not an education and I think that's what I'm most passionate about, is I want these kids to not just learn about how to take of themselves and make it in the world, but also give them an education that other kids are getting and all the other students are getting in the world. But, I think that's my biggest thing is I want them to experience chemistry and I want them to experience writing and writing papers and all this stuff that all the other students are getting. And I feel like that's something that's decreasing in education today and the schools today. We just want them to...which is good, we do want them to learn life skills, but at the same time they're not getting the education that they should be getting, so I think that's my biggest thing*
Renae (80)	*I think it makes it a little more relatable then my previous science because we are actually hands-on doing things with real products that we use every day* *At least like sometimes I really feel like having lecture lab would have been a little bit easier during lab. [Yeah] I feel like it would have, not like sped up the process, that's not what's important, but I wouldn't have had a little more of a knowledge base.*
Lilian (42)	*I mean it's not just science, like you know god I hate math. Ugh, I hate social studies. I hate English. But, it's because we're all tested on that stuff in the same way that we're not, I mean we're not tested like that in education. And, I think that's what makes it easy for us because education is what we do and I mean like if somebody is like I really love science, it's really easy for me and then they get*

	tested on it and if they can do it, great power to them because I have to teach it to understand it. So, if I were in a chemistry class and I had to, my final was you know teaching something to the class, might be a little easier for me because I'm a lot better at having a lesson plan and doing it and getting it over with is kind of what I feel like is how we think and it's not ask-a-question, answer-the-question type thing.
Jordan (81)	*Here are the answers. here are your notes. here is the exam." She gave us everything and it was just memorizing. Like if you could memorize all the answers then you did fine and we had these big coloring books and we just had to color in for a ton of points. But it was almost harder because I didn't have to learn it myself. Since it was already there, I just had to commit it all to memory* *Yeah, like I am not really seeing anything because [the water] was just clear. Like electronegativity is cool, but you can't like visualize. It's not something that will help me understand moles by looking at clear water and putting a probe in it. That didn't really happen for me. Like it was a neat experiment and it was cool to see, but it didn't really help me* *I think that sometimes they can be more memorable if you do it wrong because if you do something wrong like if you caught something on fire then you'd be like yeah… that's not how that works*
Gretchen (59)	*I can even tell with the labs we are doing like the one where we are making ice cream, static electricity like the ball sticks to the wall kinds of things* *I can understand those better because I can see it, but when we are talking about molecular, [The intermolecular forces] Yeah, those kind of things, then I kind of am not as great in those. I like the visual experiments that we do.* *Maybe, sort of. I feel like I learned more science in my years at Purdue than my whole entire life. Pretty much probably because it's just like a lot at one time and I had to take physics and I had never taken physics before in my life, so that was kind of opening like a whole new world to me. Like, my brain never thought that way and so I had to like train my brain to think in the science way of how things work like electricity and also there's stuff that I've never thought about and I just, it just happened and I just think about it extensively and so I kind of look at the world with a different perspective, I guess.* *I don't think that how we divide our time teaching should be based on what we're assessing as much as I'm not sadden that we're not teaching a lot of science, I think it's still a very important concept and there's a lot of different sciences and you use it a lot in daily life, so I think it's stuff you need to know in general, so I believe it's important and I was really surprised when I went into my classroom and they were only learning science for half of the year and I mean you do get tested on it for like the SAT and ACT or something, yeah ACT has science in it. As teachers, I mean my classroom teacher actually has like her schedule posted on the board and four of their, no five of their seven hours in class are devoted to math and reading and writing. So, I mean there's this much time to incorporate health and social studies and science and all of the other subjects you might want to teach, so like you have to incorporate it with the writing and those kinds of things or else it's just not going to get done, or not going to get the attention that it needs.* *Yeah, I mean it's just kind of gets, it gets frustrating because I mean I know that my teaching experience classroom that I'm in, they alternate curriculum teaching units between science and social studies, so basically, they are only learning*

	science for like half the year at most. They'll teach a unit of chemistry and then a unit of social studies and they just keep going back and forth for one-hour slot that they are allotted a day for like those two subjects. So, it's not being taught a lot and then you go to Purdue where they really, really, really value science a lot, and so we have to take seven, eight science courses and it's kind of frustrating because we are not going to use every single thing that we learn or probably maybe twenty percent of what we are learning in those classes combined, so it's just kind of there is a disconnect there and it's just kind of annoying from our perspective that we don't get to use what we are learning.
Taylor (78)	*Then I got to the class and within the first 3 days I knew I was going to do terrible in the class. The room didn't have any windows. It was all dark and it was a depressing environment and the teacher wasn't very nice* *Growing up my dad was super into science, so we always had science kits (do you guys know the snap circuit things where you know how to make circuits?). And we had like sciencey things in my house growing up.* *I just feel like it's a little bit overwhelming and a little bit over my head [the readings]. Yeah, I can't fully grasp it all so it's just frustrating. As I read, it turns from intense reading to like skimming just because I get so overwhelmed by it. I am just not a very good student.* *Well, I like the elementary ed science courses just because all of the experiments have been designed so that you can use them in the classroom. I think it is really cool because if you are just taking the general one then you would not be able to apply that to our future careers. But I like how all of these can be adopted or changed or modified into a normal classroom, so I don't know. I feel like I am getting a lot out of it. Even though... (I don't know) I like it a lot so...*

Chapter 8: Ambiguous

The chart is organized by individual PSET with related quotes that I felt best captured the science experiences of these students. The Ref# refers to the number of quotes that were catalogued for each student in Nvivo.

PSET Pseudonym (Ref #)	Quotes
Annalee (46)	*To be honest, I'm really not too good at biology and even the biology class I took in college. Yeah, there are two biologies and I did really bad on both of those and I don't want to take any of those. Even the second one.* *I think...I'm not really interested in like, "how's the weather going? Or some young kids ask parents about why the water is boiling or something, but my mom said that I really don't pay attention to those things. She sometimes said I was curious, but I just don't ask those questions.* *I just don't know why. I can work on it during class, but I can't do well on tests or...It seems like I just forgot everything after the class. I think physics is fine.* *I just don't know why. I can work on it during class, but I can't do well on tests or...It seems like I just forgot everything after the class. I think physics is fine.* *I wanted to be a teacher since I was a little kid and that has not changed. I don't know because I think I like being with kids. I think teachers...you educate younger people and they then become a famous person or. You help them grow up and gain that knowledge. I think it's something about being proud. I just like to be the person like that.* *I think my memory, I think there is less science class in elementary schools in China. Well in [Kati? I am from Kati]. And it's just called science. It's not like a real class where you read the book and you do the homework and things.* *Biology has two labs. And each is 2 and a half hours. Almost 5 hours and it's separate lab exams. and they always...they may crush together. Like you have both lecture and lab. The lab will take the whole lab even if it's not enough and the lecture is the same. So, you have a lot of things to review more of.* *This one! You should do a lot of experiments* *Help others. You should be able to help others, too. To maybe make others interested. If you can explain clearly to others about the chemistry things, then it is also a good way for you to learn the things.* *It makes lab a lot more interesting and the timing goes like a year. So, it makes working and class discussion helps to understand them. Makes the time goes well.* *I think I am not a person to really want to ask during the time she is speaking, but I ask a lot of questions when she walks by.* *You can have both, but it's a small possibility. If you are both then you are a perfect person. I think so. [I think math and science person] are the same for me.*
Bailey (21)	*Oh I think I did half a semester of physics, but I think I dropped that class because I didn't really like physics. I'd rather choose chemistry.*

	I really liked it [because] my chemistry teacher was really fun but she's also kind of strict too, so it's kind of like Chinese teacher, but really balanced not like most American teachers who are mostly just fun. *I had like two of my best friends and my exboyfriend, so he is really good at science, but I am not sure if I am a science or English person. I am not sure. I just need to like that class and as long as I get good grades in it, I can whatever. And I remember in senior year we had study group every single week basically on weekends and then we would do homeworks together and then for exams and tests we would study the night before and the weekend before and basically sharing each other's notes and then we look at each other's quizzes and then see what they did wrong and what I did wrong and then basically a study group. And then since we are really close, it would be easy to study together and then yeah...it went pretty good. Study group was 2-3 people.* *It sucks. It sucks because a lot of my friends are in engineering and management major. Like the "Asian majors" and it was really hard for me to make friends because they have a lot of topics to talk about and then they can go to class together and they can review together and go to a review together because they have a date and then the schedule stuff, so when I first come here my freshman year they make friends through that experience and similar things, so it was really hard for me at least.* *Maybe the kids will ask you random question like, "Why does the sun shine or stuff." I will be really embarrassed if you knew nothing like "I don't know, go search the book" But I think that science gives you a general idea and maybe you can give them like an interest and something given to them and then they maybe can find interest in it or that is about it and go find out themselves.* *I was kind of frustrated about it because I didn't do. That's the first reason I don't want to get into Math or management major. Like I don't really prefer science classes. You just have to get through them* *I think this one. Imaginative. In basic life, a lot of the people just don't think. Like a lot of people can't think of the little things, so you have to be really curious about things to research more and just keep learning the things you don't know. I think inquisitive then you kind of have to be curious.* *And also collaborative. I think like you can do lab by yourself, but it would be so much fun and easier if you do it with a partner, so you kind of need to learn the skills to get along with each other* *I hated that class for biology. Like the lab it's too long. Like it's 2 hours or something. In chemistry lab, it kind of gets by really fast. I don't know why. But in biology lab, it's a struggle. Like two hours seems like a yearlong. and Every time before I go into the lab I'd be like "Just kill me now" And then we cannot miss any of them. In chemistry lab, it gets better really fast and then we get to do thing and we have a goal. So, like okay finish this lab and we can leave early or stuff like that and we have a mission.* *Yeah, I think so...no not really. I feel like math is more strict. More black and white kind of to me, but chemistry and biology. We talk about there is a different explanation for the mercury stuff. It's not black and white. We can do our own search or talk about what we think about, but Math is the function and stuff. You draw and it's like 1 or 2. Right or Wrong, but chemistry and biology are more open.*

Evan (39)	*I just took biology freshman year and then I went to chemistry, which I mean my biology was all the same. It was just like a big overlay of everything and then coming here was more focused and then, I'm trying to remember, chemistry was kind of math like moles and stuff like that, but less than this class I mean we went over, it went into more depth with it and what we're doing with it and then junior year, I took zoology, which was like a, I don't know, I knew the teacher and I liked him and it was a fun class, too. But, I don't know it was just like every other science class I took. And the physics senior year, and I also tried to take astronomy, but it was senior year and I just didn't need astronomy, but I needed physics, so I cut loses with that one and just took another humanities. But other than that, that's about it.* *Mine was, mine was...one of the baseball coaches and he was really cool, really good teacher. We...he was very knowledgeable about the topic, but just how he teaches it was...I don't know it's not student-directed I guess. But, I mean we had labs and then basically our worksheets just like clockwork so like math and trying to figure out how much mass you burned off, and we'd always add our percent error is and it's always more math work. These labs here are more observations and thinking, so I feel like it makes you think about the topic more and get you more interested instead of doing the same thing like every other day and just filling out a worksheet.* *Elementary school is kind of blurry, but I remember like my favorite time for science was seventh and eighth grade, which wasn't a specific class. It was just called science like seventh grade science class, eighth grade science class. And like seventh grade you do the RG project where you had to make the bouncy ball into the cup or something. That was just more interesting to me because you could do so many different things to get that ball in the cup, so it gives you really a huge domain with what you want to do with the project. And then eighth grade, I remember vaguely that we make dance, dance revolution mats and it was more about electricity and like going from different signals and like we actually took them over here to XXX and tried them out and tried to play a dance, dance revolution game with our mats that we created, so that was pretty cool, too.* *On the topic of lesson plans, my stepdad is a sixth-grade math and science teacher and when I, when we had these projects that we had to do with lesson plans like last week, it's so not what "teaching's about." Like, yeah you got to make lesson plans, but when you get into teaching, like a year in you'll never use them again because you already know what you are doing, it's always about changing how your students react to what you are teaching them, so it's not about...it's about going to your desk and making twenty lesson plans for the week or something like that. It's you try to change your lesson plan, but you don't have to sit there and write it all out like just focus on the actual teaching part instead of desk work.* *Well, when you think about biology, the basics of biology is life, so I think about it as you're teaching science...not like our life, but biology is about life of like animals and plants and when you see that, I mean it pertains to science. I mean you're not going to walk in the everyday world and be like what is E=mc2 or some Calculus equation or something. You're not going to use that, but [my Calculus teacher told me that I would] That's a lie, they just say that to get you through it, but like with science every day science occurs. Even if you are not paying attention, there's always something that you can see or you can sit down and look at it, there's science. It's always occurring. I mean math...it's not always occurring like around you. So, I think it's like a big point. I mean you don't have to teach them, you know, chemistry or stuff like that in elementary school, but you can at least like you hit your*

	standards and you get those out of the way and then like I kind of want to open it up to get more student-directed like what do you guys know and what do you have questions about science and you can learn together. Like, even if I don't know it because I'm not going to know everything, let's be honest like I'm not going to know everything about science, but if they ask a question then we can research it and we can figure it out and I kind of want it to be like, especially that young of age you don't have set standards of what to teach them like you don't have to get chemistry, physics like in high school, so I kind of want to open it up as what questions do you have about science *I never thought I was going to make a bouncy ball [Yeah, like ice cream. Was not expecting that]. A lot of the labs really changed my ideas about chemistry.Taking this class, it's what I think is you now think more about chemistry than just the periodic table and numbers like there's so much more to chemistry. Like, it kind of like leads kind of into biology because science I mean they all play off each other because you can talk about chemistry and you can tie it into like biology and zoology and tons of other different classes. That's what I think is the crazy thing about science is that there's just so much.* *I think like in lab, basically there is more than one right answer, so like I don't know with us, we'd wait and wait and just think about...like, we talk now and usually she would say one thing and I would say another thing and more likely she was right most of the time, but I don't know I think it's important to have a partner that challenges you because it makes you question it and makes sure you get it right, so we'd ask her the question and sometimes like we noticed the trend that like when we asked...so, like on the first one, we never asked questions and we got like a 22 and then the next one, we asked questions and we got like a 29. So, like we took that as a trend of we want to ask her questions so we know what to write on the lab to get the right answer to get the points because that's mostly what we're there for to get that to happen. So, anyway we'd ask a question and then we'd get the answer from her, we'd write it down but the next one I'd be like well I don't know and I look at her and she's like I don't know and so I'm like alright, I'll raise my hand. I don't know, the questions are very tough because you want to get it right, so you question yourself kind of what you think it is. So, you double think about it like I don't know if that's right, so like you just want the points so it's tough to like and you're mostly just worried about what's on the lab and it's kind of nice to like take a step back and like talk about and I know it's like seven-thirty and not everyone is going to be very talkative, but it's nice*
Elizabeth (44)	*I don't remember that much from chemistry. I remember that we watched a lot of videos of reactions and stuff, but I don't really remember any of the...I know we did labs because I know we had lab space. And I remember going back there, but I don't remember anything that we really did. Just because it was...maybe because it was so long ago and I have such bad memory. It was just something that didn't stick.*
Amy (90)	*you would watch YouTube videos about it and you would take notes, but you weren't allowed to go to the exam for the chapter until you passed a certain number of quizzes and worksheets. It just basically turned into a cheating game where people would pass answers around for the worksheet.*

Annette (36)	*My background is that my mother is a biology major and she teaches all the science courses, so growing up it was always "let's do these labs. They will be fun" and things like that and I enjoyed it. It's not my favorite thing though. I love social studies and things like that so I enjoyed learning new things about anatomy and physiology was really cool to apply. Biology was interesting, but chemistry was a struggle for me sophomore year, so my experiences were pretty positive overall. Nothing to really complain about just not my favorite thing, but not my least favorite thing.*
Courtney (37)	*I was very behind in science, but I was able to catch up because they were able to catch me up on my private school didn't have like any funding, so I never used like a scale before or any of that and I, they were able to teach me without using the stuff, but it would have been more beneficial if they had money to buy science equipment, but when I got to eighth grade I was behind in science, but then by freshman year I did fine in biology. So, I think them having to accommodate and put more emphasis in middle schools, so they can get caught up on school because we don't teach it in elementary levels.*
Julie (15)	*I can't even really remember what the concept was, but it was a bunch of...it was kind of like our molarity and molality and the things we learned in lab or you had to put this here and this here so they can cancel and all that stuff, but these were like this fraction times this fraction times this fraction and like you have to get all these things to cancel and I don't know it was just really bad and my teacher, he really liked chemistry, so you know I understood what he was saying, but I just couldn't grasp the concept and he wasn't one to be very patient with his students and stuff and he wasn't really willing to help, so I would take a test and not do well because I didn't understand it in class, so I really got nowhere obviously because I couldn't even tell you what it was called, but yeah.*
Koby (27)	*I took the general in high school too: biology, then chemistry that you had to take. Kind of the same thing, we did a lot of labs in biology that I remember (a lot with cells), but that is really all that I remember from that class and I don't really remember a whole lot from chemistry.*
Liv (43)	*Well, like when I got to high school everybody seemed to have a better base knowledge than me and I would always have to study extra hard and like it just kind of piled on top of itself like yeah I could get by fourth grade, but then you get into fifth grade and we're building off what you were supposed to learn in fourth grade, and I'd never really learn that, so I'd have to relearn it and like, once you moved into sixth grade, like I always felt I was a little bit behind and always try to catch up, so I really want to empower my students to move forward and be ahead.*
Mandy (23)	*I think that this class is a lot better than my high school class because like I said I only remember that one balancing equations or like memorizing the periodic table and stuff like that [We did have to do that]. But, this one is more like real-life experiences and it's more hands-on, too*
Olivia (28)	*I remember a lot of PowerPoints and videos. And I don't remember doing... [and worksheets. So much worksheets out of the book].* *I don't remember a lot, but I do remember my senior year of high school we had a choice of taking biology II or chemistry I and I decided to take chemistry*

Patty (33)	*If it's hard to understand it like our kids aren't going, like it's not going to be something that we are going to be teaching our kids like we don't even understand it. You know what I mean? So, I think it's about relevance.*
Ruthie (94)	*I couldn't tell you what I learned in high school. I don't know anything we did a lot of calculations.*

Chapter 9: *Fundamentals of Chemistry*

Allegorical Character	Quotes from Previous Interview
Lina	*In this chemistry class, I find the labs are helpful to go back and study especially the wrap up questions and going through the activity because once you've done it, you can go back and read your notes, it's easier to understand it. Like I remember why that happened. I didn't really have that "why" understanding in high school," Lina explains. The other student offers, "Yeah, I really like the labs and talking to other students. That's really cool and it helps me understand."* *I was going to say like in science you are constantly asking question and then you are always like learning more and more. So, it's good to be asking questions and in science classes you are always in collabs and always working so you always need to collaborate with someone. Yeah, and like having real-life materials. Things...that's one of the biggest things because if you haven't had these experiences, it's so much harder to think about, so using materials we are familiar with, it makes it not only less intimidating but we are able to think about it on a deeper level because now we have had these experiences* *I go through all the labs then I go over the PowerPoints and then relate the PowerPoints back to the lab because the PowerPoints are more information detail, whereas the labs are more the concepts and so I'll connect the two. It's also a lot of teamwork. Even if they're not, like you said building off of each other. I have a really good friend. She's a chem major and so I ask her questions, especially for...I think it was the pre-lab...when we did moles. Like, not this pre-lab but last week's. So, I ask her and then I look through the PowerPoints and the lab* *Yeah, I google a lot, too. I just...basically like what she said...google keywords and sometimes it's really confusing because some websites will like go in a lot of detail and then we don't really necessarily go into that, so I look at the kid's websites and see all the things there* *Well…and this might sound a little harsh, but I'm out of state paying so much money and I shouldn't be using google to help my answers. I'm paying money for Purdue to help me, either a book or a teacher. Not from google. So, I feel like in terms of my money's worth or something...* ***(Bethany):** So, I kind of enjoy that where I feel confident and at times in the content when we are going through. I think I actually enjoy this chemistry class a little bit better because it's more conceptual.* ***(Ashley):** I mean there were some things that we would apply like we had a tank of like organisms and we talked about the ecosystem are related together, so I guess you could do that in your class like I can bring animals. Kids would love that. I mean there were some concepts, but there were some that were just like none of my fifth grade would ever understand this. I realized that if I could never do this they wouldn't have the resources to do it in school either* ***(Quincy):** Yeah, like I agree with you. Some of the mole stuff, coming from being in L-ed, even if the student does ask a question just for their understanding of it, just to try and explain that to that to the student who is maximum teaching sixth grade, I feel like you'd have difficulty understanding*

	that. I was in a sixth-grade classroom and a lot of the students I know couldn't understand that and it's more because I think I struggled with how to do that in eighth grade, beginning of my freshman year and so I feel like that wasn't really useful, so by the time I wouldn't spend more on that, but more on once again the experiments that would better me and my future classrooms even though it affects my grade now. ***(Amanda):*** *I think inquisitive too especially when studying like keeping an eye on things and asking myself, "Oh why" or like ask a question to try to better help myself understand or ask myself questions out of curiosity.* ***(Karen):*** *Oh, I find that I make those connections like I know why we're doing what we're doing or like I know there is a purpose and through the experiment, I'll learn what, like what I'm supposed to learn. Whereas like in high school, I was just kind of like told this is what you're supposed to figure out, but like I never got to figure it out on my own or apply it. So, it's definitely better for me because I can make those connections. I feel like I'm oh this is why you're doing this.* ***(Denise):*** *Yeah, like we were saying with the labs and having real-life materials. Things...that's one of the biggest things because if you haven't had these experiences, it's so much harder to think about, so using materials we are familiar with, it makes it not only less intimidating but we are able to think about it on a deeper level because we have had experiences. Erosion. I know like the whole erosion unit and like landforms and stuff, um when I was kayaking over the summer, that's all I could think about the entire time. Like, I'm kayaking and like, "Oh this is like sedimentation on the...like looking at the river" [And the meander] Yeah, exactly, I really was because I had that background and so then I felt, you know, like it just became what you said a lot more aware of everything around me.* ***(Karen):*** *I also feel like there is that level of you are setting the stage for their attitudes about school moving forward, whereas in the older grades or in high school, they already have this idea in their head about what school means to them. So, there are still those students who are still kind of excited about school, they like to go. But, then there are those kids who are like no I don't like this. I don't want to do this and it's hard to change their minds after that. Like, there's not much you can do. Like, you can try and you can.... like, I'm definitely not saying you shouldn't try, but at that age it's just really hard to change their mindset that they may have, so...That's the thing I love about elementary educations.* ***(Bethany):*** *I realized that teaching and caring for others and teaching was a very tangible way you can care for others and really make a difference in their lives and so I think so. I feel like I'm a natural teacher like I just love to help people and like instruct them when they don't know things and so* ***(Denise)****: never thought about these little particles and how elementary students would they can understand like Kathleen shares a lot about her research because she is doing how elementary students how they process science and she shares a lot with us like how the labs and how elementary students would think about it down to the little particles and she would make analogies of little communities and how these particles are like little people and it's so funny but I feel like that is huge concept that I really understand I guess.*
Margo	*Yeah, I agree with Sarah, sometimes the labs help and sometimes they don't. Like, I could solve equations in high school to find a mole, but I don't really*

know what a mole is. Like, I know how to find the moles for this and blah blah blah, but I was like...Even with that lab, I still don't really know what a mole is," Margo's voice raises changes a little, "But, I like working with Sarah in lab. Sarah pumps her hands in the air, "Yeahhhh, woooah!

And, it sucks when you are being assessed on something, but you don't really know what it is or you do know it, but not in the way you wanted it. I get really upset when I get a bad grade. I am not one to give up on grades. For me, grades are everything. I just read through materials, google like it's my job.

I don't think it would bother me nearly as bad if we could do it, explore it, and then maybe have our laptops and look it up really quick. And it's very helpful when the TAs are both in there because with just one of them in there, it's hard for them to come around and get to everybody because we all just shoot our hands up, but with both of them in there it's helpful because they are able to help everyone in lab more. And the homeworks, like the prelabs, are hard to do with our current class format. Since the lectures are after the labs, it's a little frustrating because you don't know. Then you look it up and you find out for yourself and you reteach it and they teach it in lab and I really think doing the homework before is actually helpful even though it's frustrating.

Yeah, sometimes, I'll also go on the internet if I don't understand a topic like as in-depth as I want to know it. For example, polar and non-polar. Um, I kind of wanted to refresh my memory, so I googled polar and non-polar and I found a nice little activity thing that let you look at polarity and nonpolar things and why are they polar and why they are attracted. So yeah, sometimes I'll go on the internet and google it. Sometimes I'll go and look at YouTube videos, I love YouTube videos. I love it especially with chemistry because they show you, so I look at YouTube a lot when I am studying because it's nice to see it visually

(Barbie)*:** *And this reminds me of like high school versus college and in high school, at least in my high school, if you were able to memorize the answers and memorize the answers and then take your test, then you were good but in college you are forced to learn the information in-depth and understand why it happens rather than just learning it, not even learning it but rather than memorizing it and throwing it out after the exam. Like in college, you are going to be doing this in your everyday life and you don't really have a choice, like you have to learn it to be successful in your career, so I feel like yeah those are all what you learn in college because I feel like going from high school to college, I was like wow. I learned so much and my first year of college compared to my four years of high school combined just because it's a skill, it's more skills and everything is just like so much more in-depth rather than being right or wrong or knowing the answer. You have to know the answer and you have to know why. You know what I mean?* ***(Erin): *I think it's harder. Or it's easier in high school if you didn't get something because it was so many equations and conceptually based that if you missed a class or you didn't understand something, you could go in the next day and they are still practicing using equations. like you need a solid foundation before you go to the next step and in high school you can just pick off where you left off and like help yourself, but here you have to have such a solid foundation of every topic that you get the conceptual stuff.*

	(Reagan): *And I think science on the most basic level is questioning, so we should know how to question so we can teach our students how to question.* ***(Gina)****: I definitely think it's important. Like, it is a goal, but I think it's hard for people to want to learn that when it isn't applicable to their futures because you are always told that when you get to college the only things you'll do are things that will actually apply to your future.* ***(Gina):*** *That's like challengers. People who are willing to challenge the teacher [just like understanding the concepts and applying it to get a deeper meaning]. They might come up with different ways to think about it like if we come across while we are teaching photosynthesis...maybe how the sun affects the leaves and they'll ask you like oh why do they that.* ***(Erin):*** *but he goes, "I love science" and every single time we come, we read books and he goes, Ms. E I love science. I love science. So, I have been getting a ton of science books and trying to incorporate like space and all of this science into my literacy lessons and going off of that. It made me realize that I am going to have some kids and he literally said, "Ms. E I go home and do experiments at night." Like he just loves it and so I'm trying to reframe my mindset so that I don't hate science. I can teach science to the kids that love science and to everyone, but especially to those kids that excel in science, so I am slowly trying to change my mindset so that it's not, "that's my weakness" it's not my interest, but I like it. You know?*
Penny	*So, in high school chemistry, I felt like it wasn't as...it was hands-on. It wasn't as relatable. But, here I think it makes it a little more relatable than my previous science because we are actually hands-on doing things with real products that we use every day.* *I guess, I can kind of get what you mean. That was also something I was going to say about our lab group like there's a lot of the time we have questions and our TA would come up and she'll say to collaborate with other groups and see what they got because there are lots of times we all got different answers and so we're like well what did we do wrong? And we got this answer right and this answer right and maybe we just came up with two different right answers or maybe they are both wrong or maybe one's right and one's wrong. Like, we had to figure it out. But, I think that was just a great learning experience. The TAs really make the lab better because they could have just easily been like, okay let's take a look at this instead of the rest of them and like hinting that was the one to look at, but instead she was like collaborate. Figure out what's going on like let's figure it out and get on the same page again. So, I appreciate that. Those are experiences I would want to have with my future students.* *I actually was going to say. I think being creative, collaborative, and inquisitive are important parts of science," Penny puts her hands spread out on the table, "Like, somewhere decided that they were going to figure out why this table is this table. Like, somebody one day was like I'm going to figure out what this table is besides that it's made out of wood. And even more than that you have to ask questions and work with people. There are scientists out there that have thought of something, but I mean like yeah where a lot of stuff has already been proven and stuff like that, but there's so many things being disproven nowadays. Like, this used to be amazing for you and now they're like this causes cancer. Yeah, everything causes cancer nowadays, but like I mean you have to imagine what you're going to look and then you have to experiment and you might collaborate with somebody on it because like if you have an idea of something, you almost want to share it with*

somebody because you just have to have that help of like thinking of like why would somebody take a kite out in a thunderstorm. Like, why would you do that? And he imagined that, that was going to happen and there's electricity now.

(Lilian): *What I liked about the class is that it's related to everyday things. It's not like biology where you're going to teach the kids what the leaf outside is, so you can identify the tree based off the leaf. No. I'm never, ever going to teach an elementary student to go get a leaf and identify it using a chart. [Well, you can go to the park. Better than sitting in a classroom] No. But, like it relates to everyday things like a water bottle, we use that or plastic as well as like pressure and how heating and cooling and we use like everyday things. We didn't go crazy and learn something that I'm never, never going to be able to teach. Like, it was more in-depth than what I'll ever teach an elementary student, but it was giving us the background knowledge which was nice, but it's something that...all of it was easily done with these students. Like, making the bouncy balls. Kids would love that. It would be a little difficult. You'd have to do it with older grades, but something like that would be super easy and you can teach students doing that with fun and Oobleck and stuff like that, but I'm not one to get my hands dirty. It's a weird thing, but like kids love ooy, gooey things that you're teaching them with science and stuff like that, so that's good. But, then that's like I'm just...perhaps it would have been better to have lecture and then lab, but some of them it was better to have lab and then lecture. So, it's just like I'm a little split because some of the stuff I wasn't understanding and then my lab happened to have the most questions and Hannah was running around like chickens with our heads cut off and answering questions, but it was harder to get a good answer out of her because somebody would always be like Hannah, Hannah, Hannah like the whole time. So, she was like everywhere, so most of the time it was like we would get her, but then she'd have to go to somebody else and we couldn't ask like all of the questions. But, she was pretty good at coming on her own and helping people. There were just somethings...like, I just learn better learning and then doing. Because like I have the background knowledge, but for somethings it was learning and then doing and then learning more. Does that makes sense? [Yeah].*

(Britany): *I think a lot of us in education are maybe not overachievers, but are [type A] yeah and very passionate about doing well and you know it's just funny as we get into upper courses like this and our, one of our block four classes, where they are like [Grades don't matter] yeah, they were like pretty much you are at the point of your career, your educational career [Grades don't matter], yeah grades don't matter. This is about you are learning and that's hard for us because our entire lives, our self-worth has been tied to thriving at school, you know? At least for me. [Me definitely]. You know? Like this is what I want you to know [Like, osmosis for dummies]. Sometimes, that's what I think like because we do need to know this like the in-depth content and like the particle, molecular level and all this stuff, but like sometimes I need a little dumbed down just because science isn't my strong suit and I can get the harder stuff if I have a grasp on the simple, dumbed down version. Like, sometimes during lecture we would literally write like osmosis for dummies and read it because then it makes a little bit more sense, so.*

(Ally): *I think like going off of that, like in the beginning of the semesters, these Mondays at 7:30 are going to be rough, but then I go into class and like the first day, I forget what we did, but the second day we just...our TA kind of just dove right into it and was like this is what you got to do this, this, and*

	this. Just go and we look at each other and say like okay, let's get this going. But, it was really interesting because I actually did...I actually learned a lot that way and I feel like that 7:30 spot is hard to get students motivated to learn and I felt motivated to learn on Monday mornings and I think that's pretty awesome. So...
Sarah	*Yeah, I guess I would say that. But, it's still kind of hard. Like even without the math…" Sarah lowers her voice in a mimicking tone, "'How many moles are in this many particles?' Whatever, like it's just hard to grasp the wording. Like electronegativity is cool, but you can't like visualize it. Chemistry is just hard to visualize, but the labs help sometimes. It's not something that will help me understand moles by looking at clear water and putting a probe in it. That didn't really happen for me. I can even tell with other labs we are doing like the one where we are making ice cream, static electricity like the ball sticks to the wall kinds of things I can understand those better because I can see it, but when we are talking about molecular. Yeah, those kind of things, then I kind of am not as great in those. I like the visual experiments that we do.* *Because it was rough just going off the pre-lab just because I hadn't seen some of these concepts in so long and I know that I could email the TA, but when I was working on it, it was kind of late. And even the stuff we used to study, I just feel like it's a little bit overwhelming and a little bit over my head. Yeah, I can't fully grasp it all so it's just frustrating. As I read, it turns from intense reading to like skimming just because I get so overwhelmed by it. I am just not a very good student, I guess.* *For me, I thought science was like objective and there was a right or wrong answer and you have to find the right answer. But now, I think that sometimes it can be more memorable if you do it wrong because if you do something wrong like if you caught something on fire then you'd be like yeah… that's not how that works. I still think being right is important, but also I think exploring why something is wrong, you know?* ***(Gretchen)*: *I think that, I know that personally science has made me appreciate, science here has made me appreciate what I've learned in my elementary school science and I remember I had a fifth grade teacher and I absolutely hated her and I hated that class and I don't know, she did a lot of things with science and then I just didn't like it and every day that class was so bad and I got to college with biology and literally every single experiment that we did in that class was what I did in this fifth grade classroom and I was like dang it, she was right. So, I really appreciate my teachers so I felt like I can now look at my students and say you will learn this someday.* ***(Taylor):** It was really cool and also it's been really interesting being in this class because I am in my TIP right now for the college of education and I am in a 6th grade classroom and they just went over the phases of matter, so it was interesting going from in here [CHM 200] learning about how they are doing it too [6th graders].* ***(Jordan):** I think being collaborative. Like working with other people. Because you know sometimes you can meet with other people and someone can have the other half of the experiment that you have been searching for your whole life to find. And by working with other people you might find that. Like being able to work with others. Like extensive knowledge too though. I think that helps you. Even though you are being inquisitive and trying to find*

	out more and you already know a lot then that helps you to have something to draw on. I think with imagination, too. Well, I haven't actually tested this, but I bet this will work out. And I kind of just took the imagination and the creativity aspect as...so are you just making this up? Or are you actually doing experiments. ***(Jordan):*** *Basically, all of these. Like, if Kathleen was not a good listener and a good speaker then I wouldn't feel comfortable going to with questions and I would do worse off and she wasn't a good speaker then I would probably get board in lecture. Like she tries to apply it to us, so it's not just talking at us and it's not like, "Oh, I have two hours and 59 minutes of being in here." Like she's good.* ***(Taylor):*** *And even though my grade wasn't...like my grade right now probably isn't as good as it was in bio. I feel like I am way more confident and I am learning way more right now and like I feel way more confident in my skills since sophomore year of high school. And I don't know if it's just like going over it a second time has made me more mature, but like it is just coming a lot easier this time and I am more confident.*

REFERENCES

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science education*, *82*(4), 417-436.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International journal of science education*, *22*(7), 665-701.

Abell, S. K., & Smith, D. C. (1994). What is science?: Preservice elementary teachers' conceptions of the nature of science. *International journal of science education*, *16*(4), 475-487.

Ahtee, M., & Asunta, T. (1995). Finnish lower secondary pupils' and teacher trainees' ideas on burning. Research in Chemical Education and its influence on teaching chemistry at school. *Proceedings of the 3rd ECRICE*, 112-116.

Akerson, V. L., Pongsanon, K., Weiland, I. S., & Nargund-Joshi, V. (2014). Developing a professional identity as an elementary teacher of nature of science: A self-study of becoming an elementary teacher. *International Journal of Science Education*, *36*(12), 2055-2082.

Avraamidou, L. (2014). Studying science teacher identity: Current insights and future research directions. *Studies in Science Education*, *50*(2), 145-179.

Avraamidou, L. (2016). Studying science teacher identity. In *Studying Science Teacher Identity* (pp. 1-14). SensePublishers, Rotterdam.

Avery, L. M., & Meyer, D. Z. (2012). Teaching science as science is practiced: Opportunities and limits for enhancing preservice elementary teachers' self-efficacy for science and science teaching. *School Science and Mathematics*, *112*(7), 395-409.

Aydin, Y. C., & Hoy, A. W. (2005). What predicts student teacher self-efficacy?. *Academic Exchange Quarterly*, *9*(4), 123-128.

Ball, S. J. 1993. "Self-doubt and soft data: social and technical trajectories in ethnographic fieldwork". In *Educational research: current issues*, Edited by: Hammersley, M. London: Paul Chapman.

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform?. *Educational researcher*, *25*(9), 6-14.

Bandura, A. (1997). *Self-efficacy: The exercise of control* (pp. 3-604). New York: wH Freeman.

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education*, *94*(6), 1008-1026.

Bang, M., Warren, B., Rosebery, A. S., & Medin, D. (2012). Desettling expectations in science education. *Human Development*, *55*(5-6), 302-318.

Banks, J., Au, K., Ball, A. F., Bell, P., Gordon, E., Gutierrez, K., ... Zhou, M. (2007). Learning in and out of school in diverse environments: Life-Long, Life-Wide, Life-Deep. *The LIFE Center (University of Washington, Stanford University and SRI) & the Center for Multicultural Education, University of Washington*.

Barnett, J. (2003). Examining pedagogical content knowledge: The construct and its implications for science education. *Science Education*, *87*(4), 615-618.

Barone, T., & Eisner, E. (1997). Arts-based educational research. *Complementary methods for research in education*, *2*, 75-116.

Barton, A. C., & O'Neill, T. (2008). Counter-storytelling in science: authoring a place in the worlds of science and community. *Creative encounters: New conversations in science education and the arts*, 138-158.

Basu, S. J., & Barton, A. C. (2007). Developing a sustained interest in science among urban minority youth. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *44*(3), 466-489.

Baxter, J. A., & Lederman, N. G. (1999). Assessment and measurement of pedagogical content knowledge. In *Examining pedagogical content knowledge* (pp. 147-161). Springer, Dordrecht.

Beauchamp, C., & Thomas, L. (2009). Understanding teacher identity: An overview of issues in the literature and implications for teacher education. *Cambridge journal of education*, *39*(2), 175-189.

Beijaard, D., Meijer, P. C., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and teacher education*, *20*(2), 107-128.

Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (1998). Implicit versus Explicit Nature of Science Instruction: An Explicit Response to Palmquist and Finley. *Journal of Research in Science Teaching*, *35*(9), 1057-61.

Bell, R. L., Matkins, J. J., & Gansneder, B. M. (2011). Impacts of contextual and explicit instruction on preservice elementary teachers' understandings of the nature of science. *Journal of Research in Science Teaching*, *48*(4), 414-436.

Bergman, D. J., & Morphew, J. (2015). Effects of a science content course on elementary preservice teachers' self-efficacy of teaching science. *Journal of College Science Teaching*, *44*(3), 73-81.

Berland, L. K., & Hammer, D. (2012). Framing for scientific argumentation. *Journal of research in science teaching*, *49*(1), 68-94.

Beyer, C. J., & Davis, E. A. (2012). Learning to critique and adapt science curriculum materials: Examining the development of preservice elementary teachers' pedagogical content knowledge. *Science Education*, *96*(1), 130-157.

Blackwood, P. E. (1964). Science teaching in the elementary school. *Science and Children*, 21-25.

Brandt, C. B. (2008). Discursive geographies in science: Space, identity, and scientific discourse among indigenous women in higher education. *Cultural Studies of Science Education*, *3*(3), 703-730.

Brenneman, K. (2011). Assessment for Preschool Science Learning and Learning Environments. *Early Childhood Research & Practice*, *13*(1), n1.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of teacher education*, *41*(3), 53-62.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *37*(5), 441-458.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *43*(5), 485-499.

Britzman, D. P. (1989). Who has the floor? Curriculum, teaching, and the English student teacher's struggle for voice. *Curriculum Inquiry*, *19*(2), 143-162.

Bruner, J. S. (1990). *Acts of meaning* (Vol. 3). Harvard University Press.

Bruner, J. (2004). Life as narrative. *Social research: An international quarterly*, *71*(3), 691-710.

Bullough, R. V. (1989). *First-year teacher: A case study*. Teachers College Press.

Bursal, M., & Paznokas, L. (2006). Mathematics anxiety and preservice elementary teachers' confidence to teach mathematics and science. *School Science and Mathematics*, *106*(4), 173-180.

Calabrese Barton, A., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls' identity work over time and space. *American Educational Research Journal*, *50*(1), 37-75.

Çam, A., & Geban, Ö. (2017). Effectiveness of case-based learning instruction on pre-service teachers' chemistry motivation and attitudes toward chemistry. *Research in Science & Technological Education*, *35*(1), 74-87.

Canagarajah, A. S. (1996). “Nondiscursive” requirements in academic publishing, material resources of periphery scholars, and the politics of knowledge production. *Written communication*, *13*(4), 435-472.

Capraro, M. Capraro, R. M., & Helfeldt, J. (2010). Do differing types of field experiences make a difference in teacher candidates’ perceived level of competence? Teacher Education Quarterly, 37(1), 131-154.

Carrier, S. J. (2009). The effects of outdoor science lessons with elementary school students on preservice teachers’ self-efficacy. *Journal of Elementary Science Education*, *21*(2), 35-48.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of research in science teaching*, *44*(8), 1187-1218.

Carlone, H. B., Johnson, A., & Scott, C. M. (2015). Agency amidst formidable structures: How girls perform gender in science class. *Journal of Research in Science Teaching*, *52*(4), 474-488.

Carlson, J., Stokes, L., Helms, J., Gess-Newsome, J., & Gardner, A. (2015). The PCK summit: A process and structure for challenging current ideas, provoking future work, and considering new directions. In *Re-examining pedagogical content knowledge in science education* (pp. 24-37). Routledge.

Carr, D. (1986). Narrative and the real world: An argument for continuity. *History and Theory*, *25*(2), 117-131.

Carrier, S. J. (2009). The effects of outdoor science lessons with elementary school students on preservice teachers’ self-efficacy. *Journal of Elementary Science Education*, *21*(2), 35-48.

Carrier, S. J., Whitehead, A. N., Walkowiak, T. A., Luginbuhl, S. C., & Thomson, M. M. (2017). The development of elementary teacher identities as teachers of science. *International Journal of Science Education*, *39*(13), 1733-1754.

Chen, J. L., & Mensah, F. M. (2018). Teaching contexts that influence elementary preservice teachers’ teacher and science teacher identity development. *Journal of Science Teacher Education*, *29*(5), 420-439.

Chinn, C. A., Buckland, L. A., & Samarapungavan, A. L. A. (2011). Expanding the dimensions of epistemic cognition: Arguments from philosophy and psychology. *Educational Psychologist*, *46*(3), 141-167.

Collopy, R. (2003). Curriculum materials as a professional development tool: How a mathematics textbook affected two teachers' learning. *The elementary school journal*, *103*(3), 287-311.

Clandinin, D. J., & Connelly, F. M. (2000). Narrative inquiry: Experience and story in qualitative research.

Clandinin, D. J., & Rosiek, J. (2006). Borders, tensions and borderlands in narrative inquiry. *Handbook of narrative inquiry: Mapping a methodology*, 35-76.

Connelly, F. M., & Clandinin, D. J. (1990). Stories of experience and narrative inquiry. *Educational researcher*, *19*(5), 2-14.

Costa, V. B. (1997). How teacher and students study 'all that matters' in high school chemistry. *International Journal of Science Education*, *19*(9), 1005-1023.

Cooks, J. (2009). Becoming a hurdler: How learning settings afford identities. *Anthropology & Education Quarterly*, *40*(1), 41-61.

Cooper, M. M., Stieff, M., & DeSutter, D. (2017). Sketching the invisible to predict the visible: from drawing to modeling in chemistry. *Topics in cognitive science*, *9*(4), 902-920.

Dall'Alba, G. (2009). Learning professional ways of being: Ambiguities of becoming. Educational Philosophy and Theory, 41(1), 34-45.

Davies, B., & Harre, R. (2000). Positioning: Conversation and the production of selves. *Journal for the Theory of Social Behavior*, *20*(1).

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational researcher*, *34*(3), 3-14.

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of educational research*, *76*(4), 607-651.

De Jong, O., Veal, W. R., & Van Driel, J. H. (2002). Exploring chemistry teachers' knowledge base. In *Chemical education: Towards research-based practice* (pp. 369-390). Springer, Dordrecht.

Derrida, J. (1998). *Monolingualism of the Other, or, the Prosthesis of Origin*. Stanford University Press.

Desjarlais, R. (1999). The Makings of Personhood in a Shelter for People Considered Homeless and Mentally III. Ethos, 27(4), 466-489.

Drake, C., & Sherin, M. G. (2009). Developing curriculum vision and trust. *Mathematics teachers at work: Connecting curriculum materials and classroom instruction*, 321-337.

Drake, C., Spillane, J. P., & Hufferd-Ackles, K. (2001). Storied identities: Teacher learning and subject-matter context. *Journal of Curriculum Studies*, *33*(1), 1-23.

Duschl, R. A., & Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. *Journal of research in science teaching*, *26*(6), 467-501.

Edwards, K., & Loveridge, J. (2011). The inside story: Looking into early childhood teachers' support of children's scientific learning. *Australasian Journal of Early Childhood*, *36*(2), 28.

Elbow, P. (1986). *Embracing contraries: Explorations in learning and teaching*. Oxford University Press, USA.

Enyedy, N., & Goldberg, J. (2004). Inquiry in interaction: How local adaptations of curricula shape classroom communities. *Journal of Research in Science Teaching*, *41*(9), 905-935.

Enyedy, N., Goldberg, J., & Welsh, K. M. (2006). Complex dilemmas of identity and practice. *Science Education*, *90*(1), 68-93.

Esteban-Guitart, M., & Moll, L. C. (2014). Funds of identity: A new concept based on the funds of knowledge approach. Culture & Psychology, 20(1), 31-48.

Fairclough, N. (1992). *Discourse and social change* (Vol. 10). Cambridge: Polity press.

Forbes, C. T., & Davis, E. A. (2008). The development of preservice elementary teachers' curricular role identity for science teaching. *Science Education*, *92*(5), 909-940.

Ford, M. J., & Forman, E. A. (2006). Chapter 1: Redefining disciplinary learning in classroom contexts. *Review of research in education*, *30*(1), 1-32.

Fortus, D., & Vedder-Weiss, D. (2014). Measuring students' continuing motivation for science learning. *Journal of Research in Science Teaching*, *51*(4), 497-522.

Freese, A. R. (2006). Reframing one's teaching: Discovering our teacher selves through reflection and inquiry. *Teaching and teacher education*, *22*(1), 100-119.

Gee, J. P. (2000). Chapter 3: Identity as an analytic lens for research in education. *Review of research in education*, *25*(1), 99-125.

Gencer, A. S., & Cakiroglu, J. (2007). Turkish preservice science teachers' efficacy beliefs regarding science teaching and their beliefs about classroom management. *Teaching and Teacher education*, *23*(5), 664-675.

Gilbert, A., & Yerrick, R. (2001). Same school, separate worlds: A sociocultural study of identity, resistance, and negotiation in a rural, lower track science classroom. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *38*(5), 574-598.

Ginns, I. S., & Watters, J. J. (1995). An analysis of scientific understandings of preservice elementary teacher education students. *Journal of Research in Science Teaching*, *32*(2), 205-222.

González, N., Moll, L. C., & Amanti, C. (Eds.). (2006). *Funds of knowledge: Theorizing practices in households, communities, and classrooms*. Routledge.

Greenfield, D. B., Jirout, J., Dominguez, X., Greenberg, A., Maier, M., & Fuccillo, J. (2009). Science in the preschool classroom: A programmatic research agenda to improve science readiness. *Early Education and Development*, *20*(2), 238-264.

Grosslight, L., Unger, C., Jay, E., & Smith, C. L. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of Research in Science teaching*, *28*(9), 799-822.

Grossman, P., & Thompson, C. (2008). Learning from curriculum materials: Scaffolds for new teachers?. *Teaching and teacher education*, *24*(8), 2014-2026.

Grumet, M. R. (1987). The politics of personal knowledge. *Curriculum inquiry*, *17*(3), 319-329.

Grumet, M. R. 1990. Retrospective autobiography and the analysis of educational experience. *Cambridge Journal of Education*, 20(3): 321–325.

Goodson, I. F. 1995. The story so far: personal knowledge and the political. *Qualitative Studies in Education*, 8(1): 89–98.

Gorski, P. C., Davis, S. N., & Reiter, A. (2012). Self-efficacy and multicultural teacher education in the United States: The factors that influence who feels qualified to be a multicultural teacher educator. *Multicultural Perspectives*, *14*(4), 220-228.

Gunning, A. M., & Mensah, F. M. (2011). Preservice elementary teachers' development of self-efficacy and confidence to teach science: A case study. *Journal of Science Teacher Education*, *22*(2), 171-185.

Hammer, D., & Elby, A. (2003). Tapping epistemological resources for learning physics. *The Journal of the Learning Sciences*, *12*(1), 53-90.

Hoban, G. F. (2007). Using slowmation to engage preservice elementary teachers in understanding science content knowledge. Contemporary Issues in Technology and Teacher Education, 7(2), 75-91.

Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental and Science Education*, *4*(3), 275-288.

Gubrium, J. F., & Holstein, J. A. (1998). Narrative practice and the coherence of personal stories. *Sociological quarterly*, *39*(1), 163-187.

Hogan, R. (1991). Engendered autobiographies: The diary as a feminine form.

Holstein, J. A., & Gubrium, J. F. (2000). The self we live by: Narrative identity in a postmodern world.

Holton, G. (1978). *The scientific imagination: Case studies*. CUP Archive.

Ivanič, R. (1998). *Writing and identity*. John Benjamins.

Jackson, P. A., & Seiler, G. (2013). Science identity trajectories of latecomers to science in college. *Journal of Research in Science Teaching*, *50*(7), 826-857.

Jensen, C., & Lauritsen, P. (2005). Qualitative research as partial connection: bypassing the power-knowledge nexus. *Qualitative Research*, *5*(1), 59-77.

Josselson, R. (2004). The hermeneutics of faith and the hermeneutics of suspicion. *Narrative inquiry*, *14*(1), 1-28.

Juzwik, M. M. (2006). Situating Narrative-Minded Research: A Commentary on Anna Sfard and Anna Prusak's" Telling Identities". *Educational Researcher*, *35*(9), 13-21.

Kagan, D. M. (1990). Ways of evaluating teacher cognition: Inferences concerning the Goldilocks principle. *Review of educational research*, *60*(3), 419-469.

Kane, A. A., & Rink, F. (2016). When and how groups utilize dissenting newcomer knowledge: Newcomers' future prospects condition the effect of language-based identity strategies. *Group Processes & Intergroup Relations*, *19*(5), 591-607.

Kazempour, M., & Sadler, T. D. (2015). Pre-service teachers' science beliefs, attitudes, and self-efficacy: a multi-case study. *Teaching Education*, *26*(3), 247-271.

Kim, J. H. (2015). Understanding narrative inquiry: The crafting and analysis of stories as research. Sage publications.

Koballa Jr, T. R., & Crawley, F. E. (1985). The influence of attitude on science teaching and learning. *School Science and mathematics*, *85*(3), 222-232.

Kokkotas, P., & Hatzinikita, V. (1994). The concept of the molecule in fourth year primary education students of the University of Athens. In *Proceedings of ATTI and European Conference on Research in Chemical Education (2nd ECRICE)*.

Kuntz, A. M. (2016). *The responsible methodologist: Inquiry, truth-telling, and social justice*. Routledge.

Kruger, C., & Summers, M. (1988). Primary school teachers' understanding of science concepts. *Journal of Education for Teaching*, *14*(3), 259-265.

Kvale, S. (2006). Dominance through interviews and dialogues. *Qualitative inquiry*, *12*(3), 480-500.

Lather, P. (2000). Reading the image of Rigoberta Menchu: Undecidability and language lessons. *International Journal of Qualitative Studies in Education*, *13*(2), 153-162.

Lave, J. (1988). Cognition in practice: Mind, mathematics and culture in everyday life. Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.

Lederman, N. G., & Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behavior?. *Science Education*, *71*(5), 721-734.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of research in science teaching*, *29*(4), 331-359.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Ablex Publishing Corporation, 355 Chestnut Street, Norwood, NJ 07648 (hardback: ISBN-0-89391-565-3; paperback: ISBN-0-89391-566-1)..

Lemke, J. L. (2008). Identity, development and desire: Critical questions. In *Identity trouble* (pp. 17-42). Palgrave Macmillan, London.

Lincoln, Y. S., & Guba, E. G. (2003). Ethics: The failure of positivist science. *Turning points in qualitative research: Tying knots in a handkerchief*, 219-238.

Martin, D. B. (2007). Beyond missionaries or cannibals: Who should teach mathematics to African American children?. *The High School Journal*, *91*(1), 6-28.

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science in science education. In *The nature of science in science education* (pp. 3-39). Springer, Dordrecht.

McDonnough, J. T., & Matkins, J. J. (2010). The role of field experience in elementary preservice teachers' self-efficacy and ability to connect research to practice. *School Science and Mathematics*, *110*(1), 13-23.

McRobbie, C., & Tobin, K. (1995). Restraints to reform: The congruence of teacher and student actions in a chemistry classroom. *Journal of Research in Science Teaching*, *32*(4), 373-385.

Mensah, F. M. (2016). Positional Identity as a Framework to Studying Science Teacher Identity. In *Studying science teacher identity* (pp. 49-69). SensePublishers, Rotterdam.

Munro, P. (1998). *Subject to fiction: Women teachers' life history narratives and the cultural politics of resistance*. McGraw-Hill Education (UK).

Nasir, N. I. S., & Hand, V. (2008). From the court to the classroom: Opportunities for engagement, learning, and identity in basketball and classroom mathematics. *The Journal of the Learning Sciences*, *17*(2), 143-179.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Nilsson, P., & Vikström, A. (2015). Making PCK explicit—Capturing science teachers' pedagogical content knowledge (PCK) in the science classroom. *International Journal of Science Education*, *37*(17), 2836-2857.

Olson, G. (2003). Reconsidering unreliability: Fallible and untrustworthy narrators. *Narrative*, *11*(1), 93-109.

Oughton, H. (2010). Funds of knowledge—A conceptual critique. *Studies in the Education of Adults*, *42*(1), 63-78.

Palmquist, B. C., & Finley, F. N. (1997). Preservice teachers' views of the nature of science during a postbaccalaureate science teaching program. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *34*(6), 595-615.

Palmer, D., Dixon, J., & Archer, J. (2015). Changes in Science Teaching Self-Efficacy among Primary Teacher Education Students. *Australian Journal of Teacher Education*, *40*(12), n12.

Papageorgiou, G., & Sakka, d. (2000). Primary school teachers' views on fundamental chemical concepts. *Chemistry Education Research and Practice*, *1*(2), 237-247.

Pendergast, E., Lieberman-Betz, R. G., & Vail, C. O. (2017). Attitudes and beliefs of prekindergarten teachers toward teaching science to young children. *Early Childhood Education Journal*, *45*(1), 43-52.

Pinar, W. (Ed.). (1975). *Curriculum theorizing: The reconceptualists*. McCutchan Publishing Corporation.

Polkinghorne, D. E. (1995). Narrative configuration in qualitative analysis. *International journal of qualitative studies in education*, *8*(1), 5-23.

Olitsky, S., Flohr, L. L., Gardner, J., & Billups, M. (2010). Coherence, contradiction, and the development of school science identities. *Journal of Research in Science Teaching*, *47*(10), 1209-1228.

O.Nyumba, T., Wilson, K., Derrick, C. J., & Mukherjee, N. (2018). The use of focus group discussion methodology: Insights from two decades of application in conservation. *Methods in Ecology and Evolution*, *9*(1), 20-32.

Olsen, B. (2008). How reasons for entry into the profession illuminate teacher identity development. *Teacher education quarterly*, *35*(3), 23-40.

Ramey-Gassert, L., & Shroyer, M. G. (1992). Enhancing science teaching self-efficacy in preservice elementary teachers. Journal of Elementary Science Education, 4(1), 26-34.

Rapley, T. J. (2001). The art (fulness) of open-ended interviewing: some considerations on analysing interviews. *Qualitative research*, *1*(3), 303-323.

Riessman, C. K. (2008). *Narrative methods for the human sciences*. Sage.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. Review of Educational Research, 75(2), 211–246

Richardson, V. (2003). Constructivist pedagogy. *Teachers college record*, *105*(9), 1623-1640.

Riegle-Crumb, C., Morton, K., Moore, C., Chimonidou, A., Labrake, C., & Kopp, S. (2015). Do inquiring minds have positive attitudes? The science education of preservice elementary teachers. *Science education*, *99*(5), 819-836.

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, *74*(6), 625-637.

Roth, K. J., Anderson, C. W., & Smith, E. L. (1987). Curriculum materials, teacher talk and student learning: Case studies in fifth grade science teaching. *Journal of Curriculum Studies*, *19*(6), 527-548.

Roth, W. M., & Lee, S. (2016). Scientific literacy as collective praxis. *Public understanding of Science*.

Rotter, J. B. (1966). Generalized expectancies for internal versus external control of reinforcement. *Psychological monographs: General and applied*, *80*(1), 1.

Scheurich, J. J. (1993). Toward a white discourse on white racism. *Educational Researcher*, *22*(8), 5-10.

Schwartz, M. A. (2008). The importance of stupidity in scientific research. *Journal of Cell Science*, *121*(11), 1771-1771.

Şenocak, E., Y. Taşkesenligil, and M. Sözbilir. 2007. "A Study on Teaching Gases to Prospective Primary Science Teachers through Problem-based Learning." *Research in Science Education* 37: 279–290.10.1007/s11165-006-9026-5

Sevian, H., & Talanquer, V. (2014). Rethinking chemistry: a learning progression on chemical thinking. *Chemistry Education Research and Practice*, *15*(1), 10-23.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher*, *15*(2), 4-14.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review*, *57*(1), 1-23.

Siegel, M. A., & Ranney, M. A. (2003). Developing the changes in attitude about the relevance of science (CARS) questionnaire and assessing two high school science classes. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *40*(8), 757-775.

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D., ... & Brunkhorst, H. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *36*(8), 930-954.

Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational researcher*, *34*(4), 14-22.

Southerland, S. A., & Gess-Newsome, J. (1999). Preservice teachers' views of inclusive science teaching as shaped by images of teaching, learning, and knowledge. *Science Education*, *83*(2), 131-150.

Spence, D. P. (1986). Narrative smoothing and clinical wisdom.

Stake, R. E. (1988). Case study methods in educational research: seeking sweet water. Complementary methods for research in education, 253-278.

Stollberg, R. (1969). The task before us—1962. The education of elementary school teachers in science. *Reading on Teaching Children Science. Belmont, CA: Wadsworth Publishing Company*.

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education*, *49*(1), 1-34.

Tisher, R. (1986). New directions for Australian research on science teacher education. *Research in Science Education*, *16*(1), 125-134.

Upadhyay, B. (2009). Negotiating identity and science teaching in a high-stakes testing environment: An elementary teacher's perceptions. *Cultural Studies of Science Education*, *4*(3), 569-586.

Van Aalderen-Smeets, S. I., Walma van der Molen, J. H., & Asma, L. J. (2012). Primary teachers' attitudes toward science: A new theoretical framework. *Science education*, *96*(1), 158-182.

Van Driel, J. H., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *35*(6), 673-695.

Van Horne, K., & Bell, P. (2017). Youth disciplinary identification during participation in contemporary project-based science investigations in school. *Journal of the Learning Sciences*, *26*(3), 437-476.

Vanhoozer, K., & Wood, D. (1991). On Paul Ricoeur: Narrative and Interpretation.

Varelas, M., Kane, J. M., & Wylie, C. D. (2012). Young black children and science: Chronotopes of narratives around their science journals. *Journal of Research in Science Teaching*, *49*(5), 568-596.

Wagler, R., & Wagler, A. (2011). Arthropods: Attitude and incorporation in preservice elementary teachers. *International Journal of Environmental and Science Education*, *6*(3), 229-250.

Washton, N. S. (1971). Creativity in science teaching. *Science Education*, *55*(2), 147-150.

Waterhouse, J. (2007). From narratives to portraits: Methodology and methods to portray leadership. *The Curriculum Journal*, *18*(3), 271-286.

Watson, C. (2006). Unreliable narrators?'Inconsistency'(and some inconstancy) in interviews. *Qualitative Research*, *6*(3), 367-384.

Wenger, E. (1999). *Communities of practice: Learning, meaning, and identity*. Cambridge university press.

Wilson, S. M., Shulman, L. S., & Richert, E. R. (1988). 150 different ways' of knowing: Representations of knowledge in teaching, in (ed.) J. Calderhead Exploring Teachers' Thinking.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science education*, *92*(5), 941-967.

Wingfield, M. E., Freeman, L., & Ramsey, J. (2000). Science Teaching Self-Efficacy of First Year Elementary Teachers Trained in a Site Based Program.

Wittgenstein, L. (2003). *Public and Private Occasions*. Rowman and Littlefield.

Wolfe, L. F. 1989. Analysing science lessons: a case study with gifted children. *Science Education*, 73: 87–100.

Wolfson, N. (1997). Speech events and natural speech. In *Sociolinguistics* (pp. 116-125). Palgrave, London.

Wortham, S. (2004). From good student to outcast: The emergence of a classroom identity. *ethos*, *32*(2), 164-187.

Yager, R. E. (1991). The constructivist learning model. *The science teacher*, *58*(6), 52.

Yoon, H. G., & Kim, B. S. (2016). Preservice Elementary Teachers' Beliefs about Nature of Science and Constructivist Teaching in the Content-specific Context. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(3).

Yoon, J., & Onchwari, J. A. (2006). Teaching young children science: Three key points. *Early Childhood Education Journal*, *33*(6), 419-423.

Yosso*, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. Race ethnicity and education, 8(1), 69-91.

VITA

We are never doing enough to make the world a better place, but education is the foundation for making large-scale positive changes within people and society: with knowledge comes the power to destroy modern injustices and institutionalized disenfranchisement. I acknowledge that I am not part of the community I am studying, and I am not privy to the experiences of these preservice elementary teachers simply because I had access to their stories. I believe in doing research that "breaks your heart and moves you." I decided to turn this work into a master's thesis because I believe that the ways in which research has been done with these students has been an inappropriate and unethical exploitation of participant trust. I offer my work as a call for researchers in science and chemistry education to think about how their theoretical and methodological frameworks situate the knowledge the participants provide as being a *privileged* resource that researchers *may* use to test learning theories.

I also offer the limitations of my work (see "**Limitations of Study Context**") as a reminder that there are always ways we can better serve our participants in-moment. My personal research philosophy is to do research that will help the population that I am studying and have my research do service for them. I do not believe in doing work that simply "fills the gap in the literature" regarding the academic enterprise's archived understanding of what a certain phenomenon is. Research that does not directly benefit the participants with which we work does not benefit anybody. I consider research to be a living body of knowledge, whose texts bleed with the dissection of decontextualized information. In essence, literature serves as an artifact of academia's philosophical endeavor to forever "search" for knowing— it is thus our job as researchers to "(re)form" what is known.