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Exploring Chemistry Graduate Student Identity Development and the Intersection of Multiple Sub-Identities

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Mathematics and Science Education

by

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The Dissertation of Adriana Corrales is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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DEDICATION

To Katie and Laney- I couldn't have done this without you. Y'all are my rock and my safe place. You supported me through so much. Finishing a PhD in a pandemic is no joke and y'all got me through. I owe so much to you both, I love you so much. Thank you for being there.

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LIST OF ABBREVIATIONS

GTA	Graduate Teaching Assistant
STEM	Science, Technology, Engineering, and Mathematics
CoP	Community of Practice
RFU	Research Focused University
TFU	Teaching Focused University
HSI	Hispanic-Serving Institution
GSID	Graduate Student Identity Development
AFAB	Assigned Female at Birth
MTRS	Modified Teaching and Research Survey
OEQ	Open-Ended Question

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ABSTRACT OF THE DISSERTATION

Exploring Chemistry Graduate Student Identity Development and the Intersection of Multiple Sub-Identities
by

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Graduate education follows an apprenticeship model, primarily aimed at preparing students for academia; however, the inclusion of teaching within this apprenticeship is not always clear as faculty, students, and other stakeholders do not agree on the need for instructional training (Golde & Dore, 2001). Despite the variability in training, over half will be graduate teaching assistants (GTAs) at some point in their education. This number increases to 91% for chemistry graduate students. This discrepancy between hiring graduate students as GTAs and inconsistent inclusion of instructional training indicates a misalignment between the needs of graduate students and the support programs offer. In addition to this mismatch, there is a need to improve mentoring and support for graduate students as they navigate their programs (Harshman, 2021). In particular, graduate students spend a large portion of their time at work,

yet are not treated as full people as many students cite that they must leave parts of their identities behind in academic spaces (Brown, 2016; Tran, 2011).

To better support graduate students, we must first understand how graduate student identities develop. The foci of studies are generally placed either on teaching or research or identity, but not both simultaneously (Baker & Lattuca, 2010; Lane et al., 2018; Zotos et al., 2020). Graduate student identity has also been introduced as a lens for encompassing multiple sub-identities, however teaching identity is not emphasized. Through the collection of interviews from 18 chemistry graduate students and the administration of a modified survey across two institutions, this work expands upon the conceptualization of graduate student identity.

Sociocultural and identity theories were employed to understand graduate student identity development. Mixed methods analysis with an emphasis on qualitative theme generation revealed that graduate students' multiple identities often intersect, with research identity being the primary identity around which other identities develop. This includes teaching, student and personal identities such as socioeconomic status, international status, race, ethnicity, and gender. This works illustrates how multiple graduate student identities can develop and that supporting students as whole people including their personal identities and interests is important for a sense of belonging in the field.

Chapter 1: Introduction

Graduate students are said to inhabit an "ambiguous niche" in higher education (Park, 2004; Vaughn, 1998) as they take up multiple roles as employees, students, researchers, and teachers. However, the importance of each role varies widely among graduate programs (Weidman & DeAngelo, 2020) and are often perceived to conflict with each other (Brownell & Tanner, 2012; Gilmore et al., 2014; Lane et al., 2018). Hence, these roles do not exist in a vacuum and intersect with and influence each other as graduate students move between multiple roles throughout their education (Beijaard et al., 2004). The degree to which one identifies with a certain role and the extent to which that identity is valued by oneself and others is linked to learning and professional development (Abu-Alruz & Khasawneh, 2013; Baker & Lattuca, 2010; Wenger, 1998). Thus, development of particular identities indicates competence and commitment to a role.

This project aims to make sense of the types of identities chemistry graduate students develop in order to explore the types of roles graduate students tend to identify with and the intersections of those roles in context. Particularly, this work will provide an in-depth examination of how different sub-identities develop within the larger umbrella of graduate student identity and the ways these sub-identities may reinforce or constrain each other. This work spans chemistry departments at two universities with different programmatic requirements, institutional structures, and cultural environments. The results will provide a holistic view of graduate student identity development in different institutional and departmental settings and generate insight into how the institutional setting and programmatic expectations, supports, and culture influence identity development. On a larger scale this study will inform efforts to improve graduate student professional development programs and training in chemistry.

Motivation

Over half of doctoral programs require students to serve as graduate student teaching assistants (GTAs); this is even more common for chemistry graduate programs where 83% of graduate students will be hired as GTAs while working on their degrees (Golde & Dore, 2001). At research intensive universities, chemistry GTAs also take responsibility for 88% of undergraduate chemistry lab instruction (Sundberg et al., 2005). Thus GTAs, particularly in chemistry, are responsible for a large portion of undergraduate education. The use of GTAs stems from the traditional structure of a graduate degree as an apprenticeship into an academic career as well as from financial and teaching labor needs (Hancock & Walsh, 2016). Graduate teaching assistantships often provide income for graduate students not supported by research funding and allow departments to address the growing need for more instructors as undergraduate populations increase (Kuniyoshi et al., 2021; Park, 2004). However, the role of teaching in the apprenticeship is unclear.

Currently, there are concerns that graduate programs do not adequately prepare graduate students for the multitude of professional opportunities available (Harshman, 2021; National Academies of Sciences, Engineering, and Medicine, 2018; Thiry et al., 2015), including providing instructional training for future teaching positions (Austin & McDaniels, 2006; Brownell & Tanner, 2012). This is clear through the overt emphasis on the Ph.D. as a research degree (Golde & Dore, 2001) as opposed to a multifaceted degree with applicability to a variety of career trajectories. While graduate programs are assumed to operate under an apprenticeship model (Hancock & Walsh, 2016; Thiry et al., 2015) in which students are mentored by more knowledgeable others in their field (i.e. faculty, postdocs, and experienced graduate students) there is often a lack of emphasis on mentorship in teaching (Keyser et al., 2008; Lane et al.,

2018). The absence of mentorship and modeling of quality instruction is not conducive to the development of instructional skills via an apprenticeship model. In addition, GTAs capable of fostering a positive classroom environment and communicating clear expectations and feedback are linked to undergraduate persistence in STEM majors, thus the lack of instructional training could be detrimental to undergraduate education as well (O'Neal et al., 2007).

The scarcity of adequate instructional training is particularly striking as research suggests that STEM faculty often do not receive formal pedagogical training outside of their GTA experiences (Tanner & Allen, 2006). While not all graduate students will become faculty members after graduation, almost half of STEM PhDs will teach at the college level within five years of completing their degree (Connolly et al., 2016). As well, instructional training and experience has also been linked to improvements in GTA communication and presentation skills (Gilmore et al., 2014), which are applicable to careers outside of teaching and academia. Consequently, adequate instructional training will more than likely be beneficial to most, if not all, graduate students in addition to potentially benefitting undergraduates.

In response to these issues, the National Academies of Sciences, Engineering, and Medicine (NASEM, 2018) have called for graduate education reform to include a larger emphasis on best practices in teaching and mentorship for faculty. This would include incentivizing faculty to demonstrate high-quality instruction and inclusive mentoring that incorporate known best practices. Faculty demonstrations of high-quality instruction and support through mentoring would benefit both GTAs who would have the opportunity to implement previously modeled instructional strategies and the undergraduate population that faculty and GTAs teach. Training through apprenticeship and inclusive mentoring will require faculty to better understand the educational needs of graduate students. Thus, in order to improve

instructional training for graduate students we must first understand the current state of the graduate student experience including the design and current best practices for instructional training programs.

The STEM Graduate Student Experience

The structure and function of graduate programs in the US vary across institutions and departments (Weidman & DeAngelo, 2020), however the main goal has been to become a competent researcher through apprenticeship (Golde & Dore, 2001). Teaching is often not explicitly named as a component of this apprenticeship; however, it is becoming more widely recognized as an integral part of graduate education and professional development (Kendall et al., 2013; Wulff & Austin, 2004). To date, improvements in such areas are still ongoing (Dragisich, Keller, Black, et al., 2016; Dragisich, Keller, & Zhao, 2016; Reeves et al., 2018; Rosales et al., 2013).

Graduate Student Roles

Throughout their degree programs, graduate students hold a variety of roles contemporaneously including those of researcher, student, and teacher, among others. Researchers often conceptualize graduate education as a series of stages within which students take up the aforementioned roles to varying degrees (VanValkenburg & Arnett, 2000). Weidman and colleagues (2020) describe the overall process as socialization into a graduate program and details the stages as "different states of identity and commitment that are overlapping rather than mutually exclusive" (p. 11). This means that graduate students develop multiple identities within each stage and these identities interact with each other. The four stages Weidman and colleagues propose are the 1) anticipatory, 2) formal, 3) informal, and 4) personal stages.

The anticipatory stage refers to the preconceived notions of new or novice students entering a field. New students have preliminary ideas of what the program will be like and the tasks and roles in which they will be required to engage. These notions are short lived as graduate students enter the formal stage. This is when graduate students receive formal instruction regarding the roles they will take up and the skills they will need to acquire. This information is communicated via faculty and other more experienced members of a program through course materials and engagement in apprenticeship. The informal stage is when graduate students form community support systems within which they communicate the informal or unofficial expectations of the program. In the personal stage, students form a professional identity that integrates the knowledge and experiences from the previous stages. Students also realize that at this point that their professionalization is ongoing and constantly developing and will develop further beyond the graduate program. While socialization can be described in stages, the process of becoming a member of graduate program is flexible as is the negotiation of one's role in it.

In practice, the perception of graduate student roles varies as faculty see graduate students as research apprentices, graduate students often see themselves as students with teaching responsibilities, and undergraduates see graduate students as a combination of students and academics (Muzaka, 2009; Park, 2002). Graduate students seem to be more aware of their roles as teachers than faculty (Park, 2002; Muzaka, 2009) likely because they are aware of the time commitments associated with serving as a GTA; however, that does not mean graduate students formally consider themselves teachers (Zotos et la., 2020). This is reinforced through institutional norms as excellence in teaching is generally not emphasized in the faculty reward structure (Austin & McDaniels, 2006). In turn, faculty may not value or reward graduate students

who excel in teaching, thus discouraging the pursuit of teaching interests. This mentality is echoed by both faculty and graduate students as teaching is repeatedly considered to be of lesser value than scientific research (Beath et al., 2012; Brownell & Tanner, 2012). Despite perceived negative attitudes toward teaching roles, the widespread need for better trained GTAs and faculty has strengthened the call, from education researchers, for the explicit inclusion of teaching in graduate apprenticeship (Kendall et al., 2013; NASEM, 2018). Instructional training for graduate students does exist to some degree in graduate education. However, with a more formal inclusion of teaching in the apprenticeship model, graduate students may be able to identify with and better understand the importance of and utility in developing skills in teaching.

GTA Training

While some programs already provide instructional training, the content of these trainings is not standard across programs and could be improved upon through the incorporation of current knowledge of GTA training best practices and researched-based teaching best practices (Luft et al., 2004). Often graduate students are only instructed on what to teach, but not how to teach (Jensen et al., 2005). Current GTA training program formats include shorter workshops and bootcamp style training sessions (VanValkenburg & Arnett, 2000) as well as longer quarter- or semester-length courses (Estrada & Tafliovich, 2017; Marbach-Ad et al., 2012; Marincovich et al., 1998; Marshman et al., 2016). Programs vary from institution to institution and often department to department (DeChenne et al., 2012). As well, the evaluation of existing GTA training programs varies widely to include informal feedback from graduate students and instructors (Patitsas, 2013), undergraduate student evaluations (Estrada & Tafliovich, 2017), and quantitative surveys of self-efficacy (Boman, 2013; Dechenne et al., 2012; Young & Bippus,

2008; Shannon et al., 1998; Prieto & Altmaier, 1994). Thus, the efficacy of GTA training programs is often unclear and it is difficult to compare existing training programs.

While comparison of programs is difficult due to the lack of program evaluation standards, similar themes for best practices have emerged from GTA training program studies (Bond-Robinson & Rodriques, 2006; Marbach-Ad et al., 2012; Park, 2004; Rosales et al., 2013). Best practices in GTA training identified in these works include: a) providing ongoing support, feedback, and reflection for teaching, b) encouraging community support from faculty, staff, and peers, c) explicitly addressing GTA roles, d) modeling teaching using evidence-based techniques, and e) respecting and accounting for time constraints between teaching, research, and other responsibilities. These practices encourage a respectful community of graduate students, faculty, and staff who value all aspects of the graduate experience and mindfully provide support as graduate students develop professional expertise.

One way to understand the efficacy of instructional training programs and the use of current best practices is to study graduate student identity development. Through the lens of identity, we can better understand the impacts of changes in instructional training programs as graduate students develop as researchers, students, and teachers in context. The following chapter will expound the theoretical underpinnings of identity development. Presented below are narrative examples of graduate student lived-experiences to illustrate the current state of the graduate education and the importance of explicit instructional training as a part of that experience.

Lived Experiences

The following excerpts from Lane et al. (2018) depict a departmental culture in which graduate students are discouraged from becoming interested in and devoting extensive time to

teaching. There is a clear norm of valuing research over teaching, which in turn obscures professional development opportunities in teaching and often steers students away from their teaching interests or makes pursuing those interests more difficult. As a result, graduate students in this type of environment may not participate in activities that support the development of a teaching identity and as such may not recognize teaching as a part of one's graduate student identity.

The graduate students interviewed in this study were recruited from four life sciences departments at one university. Participants were recruited at various stages in their graduate education and had varying career aspirations. The goal of the interviews and qualitative analysis were to identify factors that enable or constrain the development of a teaching identity as a part of the overall professional identity of graduate students. Researchers found that participants fell into three categories along a continuum: salient and stable teaching identity, nascent or emerging teaching identity, and no noticeable teaching identity. Of the 33 participants, 12 have a salient and stable teaching identity, seven had an emerging teaching identity and 14 had no noticeable teaching identity. Within these classifications researchers found that the salient and stable group had a high degree of interest in teaching, which is consistent with other identity studies in which interest in the subject matter is a major component of identity development (Carlone & Johnson, 2007; Hazari et al., 2010). Even so, interest was not always enough as students reported a "cold" response from mentors regarding their teaching interests. One student, Andrew, shared a difficult internal struggle he faced due to the negative perceptions faculty conveyed about teaching interests:

> So that's something that kind of makes you want to—when you worry about whether you're weird, or you're wrong, or you're just not good at actual science? And maybe that's why you're into teaching...So I must've been bad at what I'm

> doing because I like doing this other thing, so it must mean that I'm not good at research. Certainly I've felt that. (Lane et al., 2018, p. 150)

He perceived, based on his interactions in the department, that teaching was for people who were not good at research and that a teaching interest is not welcome if one plans to become a successful researcher. Another student, Julia, reported that teaching "…is secondary. That's somethings that we have to do, but it's not what we are supposed to do" (p. 150). Another student, Catherine, was told that pursuing teaching interests alongside research was "PhD suicide" (p. 152). Departmental cultures fostered negative attitudes toward teaching that seemed to influence the graduate students in a way that conveyed that teaching is not important. A majority of graduate students in this study did not develop a salient and stable teaching identity as a part of their professional graduate student identity. The group that did were able to do so through a high level of interest and persistence. This begs the question: if we were able to remove the barriers that hinder the pursuit of teaching, would we see an uptick in the development of salient and stable teaching identities? Furthermore, would the development of a teaching identity conflict with the development of researcher identities or potentially enrich that development?

Research shows that pursing teaching interests in graduate school does not have a negative effect on the time to degree completion (Connolly et al., 2016) or publication number (Shortlidge & Eddy, 2018). There have also been modest connections between the ability to communicate research and participation in teaching professional development activities (Gilmore et al., 2014; Shortlidge & Eddy, 2018). As well, graduate students in a study from Gilmore et al. (2014) described connections between teaching and research and that the two activities may have a synergistic effect. The population of this study was broad and included both masters and doctoral students across all departments. One student reported that "each activity [research and

teaching] informs each other—it is a reciprocal relationship" (p. 29). In addition, many respondents explained that teaching and research have shared skillsets including communication skills, organization skills, creativity, and critical thinking. While 90.9% of students surveyed perceived a connection between research and teaching, only about 11.8% saw a bidirectional relationship. The remaining 79.1% showed unidirectional connections in which research influences teaching or teaching influences research only. Though not all respondents reported a bidirectional connection between research and teaching, the reporting of any connection indicates that some graduate students are aware of the shared skillsets needed to perform both roles and that there is space to explore the nature of those connections. It is often assumed that there is a teaching and research trade-off such that one cannot excel at both (Brownell & Tanner, 2012; Shortlidge & Eddy, 2018); however, the two pursuits do share a common goal of advancing knowledge and learning (Light & Calkins, 2015). The acknowledgement of this connection can help garner a holistic view of a professional graduate student identity that includes teaching as a legitimate component that works synergistically with other sub-identities, including research identity.

Beyond Roles as Workers

In addition to being researchers and teachers, graduate students are people. Scholars have begun to call for the consideration of graduate students as multifaceted humans and that they should be treated as such (Brown, 2016; Tran, 2011). This includes recommendations to use a whole-person approach to mentoring, which has been implemented in an undergraduate liberal arts college environment (Gross et al., 2015). This is particularly important, as institutions of higher education consider the diversity of their student populations and the types of students current institutional structures are built to support. Recent literature has shown the importance of

supporting graduate students personal backgrounds such as race, ethnicity, and gender and how this impacts persistence in graduate programs (Wilkins-Yel et al., 2021). As well, recent work (Stachl et al., 2021; Stachl & Baranger, 2020) has shown that community-driven transformation of chemistry departmental culture to a more inclusive environment that values the whole person has shown positive changes in perceptions of the academic climate. These positive changes in climate reflect an academic environment that is more conducive to student belonging and persistence.

Research Goals

In the abstract, graduate students' multiple identities have the potential to coexist and even bolster one another. Therefore, the way we train and support graduate students in practice should be structured to support the multitude of sub-identities that graduate students develop. However, in order to design and implement this type of support we need to understand where graduate students are currently in identity development and how development can be supported. In response to these needs, this study will address the following goals:

1. Understand graduate student identity development as scientists, teachers, and students throughout their graduate career.
2. Understand the relationships between graduate students' multiple sub-identities in the context of particular institutional environments.
3. Redesign an existing GTA training course using best practices from the literature such as feedback and reflection and evaluate the impact of the course on graduate student identity development.

Addressing these goals will provide an in-depth description of the nature of graduate student identity development and the impacts of a redesigned GTA training course incorporating best practices from the research literature.

Roadmap of the Manuscript

Chapter 2, *Literature Review and Theoretical Perspective,* provides an in depth overview of the theoretical positioning of the study and the previous work in the field of graduate student identity. This includes a broad overview of sociocultural learning theories and an in depth discussion of Wenger's Social Theory of Learning and identity. Finally, the theory is linked to the research goals and questions.

Chapter 3, *Methodology*, outlines the data collection and analysis procedures for the study. The study uses mixed-methods and case study approaches with an emphasis on qualitative data collection and analysis.

Chapter 4, *Graduate Student Identity Development,* characterizes the types of identities graduate students develop, the intersections between them, and the resources graduate students access through development and reconciliation of multiple identities.

Chapter 5, *TFU Case Study Results*, describes the impact of a graduate student training course on research and teaching identity development and lesson learned from the course.

Chapter 6, *Conclusion and Implications*, summarizes the overall findings, recommendations for graduate programs based on this work and future research related to and beyond this study.

Chapter 2: Literature Review and Theoretical Perspective

Introduction

The purpose of this study is to understand the experiences of chemistry graduate students as they take on various roles and responsibilities throughout their graduate education and how these experiences contribute to identity development. In particular, this study aims to make sense of the current state of graduate student identity development in order to understand which sub-identities are developed and which would benefit from additional supports. Through the exploration of graduate students' multiple sub-identities such as research and teaching identity, among others, we will be able to better understand how to support these identities simultaneously as graduate students take on multiple responsibilities. As well, this study will provide information regarding how different sub-identities may conflict, which will aid in addressing how to prevent this conflict and promote mutual and harmonious sub-identity development.

The sociocultural perspective, communities of practice (CoP), and theories of identity will frame this study. While CoPs are not emphasized in current work on graduate student identity development, other sociocultural theories surrounding identity have been used to analyze the graduate student experience (Baker & Lattuca, 2010; Hopwood, 2010; Sweitzer, 2009). However, the foci of such studies are generally placed either on teaching identity (Zotos et al., 2019; Lane et al., 2019), or research identity (Castelló et al. 2021; Murakami-Ramalho et al., 2013), but not both simultaneously. Doctoral student identity has also been introduced as a lens for encompassing multiple identities (Baker & Pifer, 2011, 2014; Foot et al., 2014; Sweitzer, 2009), however teaching identity is not emphasized in this work, nor is the nature of the overlap or intersection of such identities. In addition, doctoral identity excludes the experiences of master's students who also grapple with similar struggles in identity development.

Teaching identity is of distinct interest in this study due to the historical lack of inclusion of teaching in the apprenticeship model of graduate education (Kendall et al., 2013; Golde & Dore, 2001). Graduate students often do not observe experienced teachers or graduate student teaching assistants (as is customary in apprenticeships) as a part of their instructional training and may not have access to formal instructional training at all (Golde & Dore, 2001). In turn, the lack of emphasis on teaching as an important aspect of graduate student identity speaks to the imbalance in graduate student professionalization that is prevalent in the preparedness or lack thereof of new faculty to teach (Austin & McDaniels, 2006; Brownell & Tanner, 2012; Finkelstein & Price, 2005). The development of a teaching identity is difficult even for new teachers (Danielsson & Warwick, 2016). Therefore, if we do not acknowledge and support the existence and development of a teaching identity in graduate school then this may prevent its formation once in a faculty position. As stated previously, not all graduate students will become faculty members; however, half will teach at the college level within five years of graduation (Connolly et al., 2016). As well, skills in teaching can be useful in fields outside of academia (American Chemical Society, 2020; Gilmore at al., 2014). Thus, it is important to understand teaching sub-identity development in the context of the variety of sub-identities graduate students develop as these identities develop simultaneously.

In this study, sociocultural theory, CoP, and identity frameworks will inform the conceptualization of graduate student sub-identity development and intersection through the integration of theories of identity development, community multi-membership, and intersectionality. To make sense of graduate student identity and sub-identity development one must first understand sociocultural perspectives on learning, the constructs of communities of practice and identity within that perspective, related identity theories, and the present

applications of communities of practice and identity in the analysis of the graduate student experience.

Sociocultural Perspectives

Sociocultural theories originate with the work of Lev Vygotsky, whose contributions to psychology, and later education, research persist to this day. Vygotsky posited that the very essence of who we are is formed through interactions with others in a cultural setting influenced by history (Walshaw, 2016; Vygotsky, 1978). From this perspective, knowing and learning originate in the social plane (Confrey, 1995; Culligan, 2013; John-Steiner & Mahn, 1996, Walshaw, 2016; Vygotsky, 1978). This means that all learning is initially social, but does not imply that the subsequent individual construction of knowledge is not important. The individual and social aspects of a learner's life work synergistically in the construction of knowledge (John-Steiner & Mahn, 1996), leading to a fluidity between the boundary of self and others (Polly et al., 2017). Learners interact with others and as a result, those relationships and interactions can become internalized to configure one's ways of thinking. While the active individual construction of knowledge also follows a Piagetian perspective on learning (Piaget, 1947/2002; Pugh, 2017), Vygotsky emphasizes the social, historical, and cultural origins of knowing and learning that are distinct from Piaget (Cole & Wertsch, 1996; Vygotsky, 1978). This transformation and synthesis is actively done by the student through mutual appropriation or negotiation between the individual and the social world (Ash & Levitt, 2003; John-Steiner & Mahn, 1996; Vygotsky, 1978). This means that the student actively works to make sense of the content and the teacher or expert, in turn, reflects on the student's understanding in relation to their own previous knowledge and experiences to develop pedagogical content knowledge (Ash & Levitt, 2003).

Vygotsky (1978) also introduced the idea of the zone of proximal development (ZPD) to describe the range between a learner's current developmental level and the potential level of development a learner could reach when working with a knowledgeable other. Learners require the expertise and knowledge of those with more experience and over time acquire their own knowledge and thus more agency over their learning (Lave & Wenger, 1991). This process of guided participation allows a learner to immerse themselves in a culture or social group in order to acquire new knowledge, while the learner also shapes the environment in the process (Polly et al., 2017). For example, this immersion into a culture can occur when people enter into a graduate program that follows an apprenticeship model in which new students engage in guided participation with more experienced others. Apprenticeship and entrance into a culture is expanded upon by Brown, Collins & Duguid's (1989) description of situated cognition or situated learning.

Situated Cognition

The importance of culture and context in Vygotsky's theories were built upon in situated cognition (Brown et al., 1989). From this perspective, interacting with others in real-life contexts can lead to deeper levels of learning (Polly et al., 2017). There is a connection between what is learned and how the material is presented such that learning is situated in a context (Brown et al., 1989). Essentially, the context of an activity in which information is presented can influence what is learned as contextual associations may strengthen the understanding of a concept. The concept of situated learning or cognition is best described through authentic activity and enculturation into a practice within which authentic activity is embedded.

In authentic activity, the activity is the action that the learner takes to acquire knowledge and authenticity refers to the work that actual practitioners in a field perform with said

knowledge or tools (Brown et al., 1989). Thus, authentic activities are the "ordinary practices of the culture" (Brown et al., 1989, p. 34). This emphasis on authenticity of an activity for a learner is meant to highlight how knowledge is used in practice. Many times in schools, knowledge is completely removed from the context of the activities in which practitioners use knowledge. Students will associate the concepts with school activities rather than practical ones and may not recognize the use of knowledge in the context of authentic activities. This is problematic because the disconnect may lead to the view that a particular subject matter is intimidating, inaccessible, or not applicable to the real word. For example, efforts have been made to engage undergraduates in scientific research early on in their academic careers in order to connect science concepts they learn in class to authentic experiences in research (Auchincloss et al., 2014; Corwin et al., 2015). This is similar to the way graduate students enter into an apprenticeship situated in the authentic activity of research and scholarship. Graduate students enter as newcomers to a field and engage in authentic activities such as reading the literature, writing scholarly articles and grants, and designing and conducting experiments with the goal of learning by doing. Participation in authentic activities can lead to learning when used as a means to enculturate a newcomer into a practice.

From this theoretical perspective, learning is referred to as enculturation into a practice, which is how a newcomer or legitimate peripheral participant can become a full member of a group or community by participating in the customs, practices, culture, and activities (Brown et al., 1989; Wenger, 1998). Peripheral participants entering into a practice can become enculturated by watching and engaging in authentic activities, and adopting the norms of a community, a process known as apprenticeship. This is a major goal of research apprenticeships in graduate education (Golde & Dore, 2001, Hancock & Walsh, 2016) as students are paired with

experienced others (senior graduate students, postdoctoral fellows, and faculty) to hone their skills as researchers and scholars. Despite the link between research and apprenticeship in graduate education, the same cannot necessarily be said for instructional training. It is unclear whether the graduate experience provides opportunities for engagement in authentic activities in teaching in which students observe experienced others such as faculty or more experienced GTAs in the teaching community. Thus the degree to which graduate students learn how to teach and become enculturated into the community of teaching is unclear. Wenger's (1998) Social Theory of Learning further elaborates on the community aspect and how enculturation into a practice can support identity development.

A Social Theory of Learning

Within the sociocultural umbrella lies Wenger's Social Theory of Learning. Here learning is fundamentally social, situated within the context of one's lived experiences, and constantly occurring (Wenger, 1998). The key assumptions of this theory are that knowledge implies competence in some undertaking that matters, knowing involves participation in those undertakings, and meaning is what learning through social interaction is meant to produce. A key feature of this theory is participation, which entails active engagement in the practices of social communities and formation of identity or identities within a community(ies). Participation essentially shapes who we are, what we do, and how we make meaning of what we do.

Figure 2.1: A modified version of Wenger's (1998) depiction of the components of his social theory of learning. Community rather than learning is centered in this diagram to emphasize the importance of the structure within which learning and meaning-making occurs.

Wenger (1998) describes four main components of the social learning theory that describe how people learn through social participation (Figure 2.1): meaning, practice, community, and identity. Meaning is what we take as significant or meaningful in experience. This implies that we learn through our experiences. Practice is how we learn by doing. Practices are the shared cultural and historical ideas, resources, structures, and practical knowledge that frame collective engagement within a community (Polin, 2010). In simple terms, practices are the established ways of doing something or norms. Community is the structure within which we define why what we are doing matters and how we establish parameters for competence in what we do. Finally, identity is how participation in a community influences how we see ourselves and how others see us in that context. Each of the components are interchangeable and describe

each other. As a result, this framework is also referred to as communities of practice (CoP), which generally describes the theory and is a constituent within the theory.

Communities of Practice. A common misconception of communities of practice (CoP) is that it refers to a specific group of people (Farnsworth et al., 2016). A CoP more broadly is the process of mutual negotiation of competencies in a field of practice or domain, which often emerges from the interactions between a group of people. For example, a CoP and team are not necessarily the same. Teams generally have a particular goal to accomplish and are task-driven while a CoP is learning-driven and members may work on different teams on different tasks, but still learn in the same field together. The process of negotiation can lead to the structuring and restructuring of meaning within a CoP through participation and reification. This is the process of engaging in activities in the CoP (participation) and giving a concreteness and significance to those experiences (reification). In later work Wenger (2000) refers to CoPs as social containers of competencies. This means that the social structure that the negotiation of competencies creates in turn holds those competencies such that a CoP is self-regulated and self-contained. This is not to say that CoPs operate entirely individually and do not intersect, which will be addressed later.

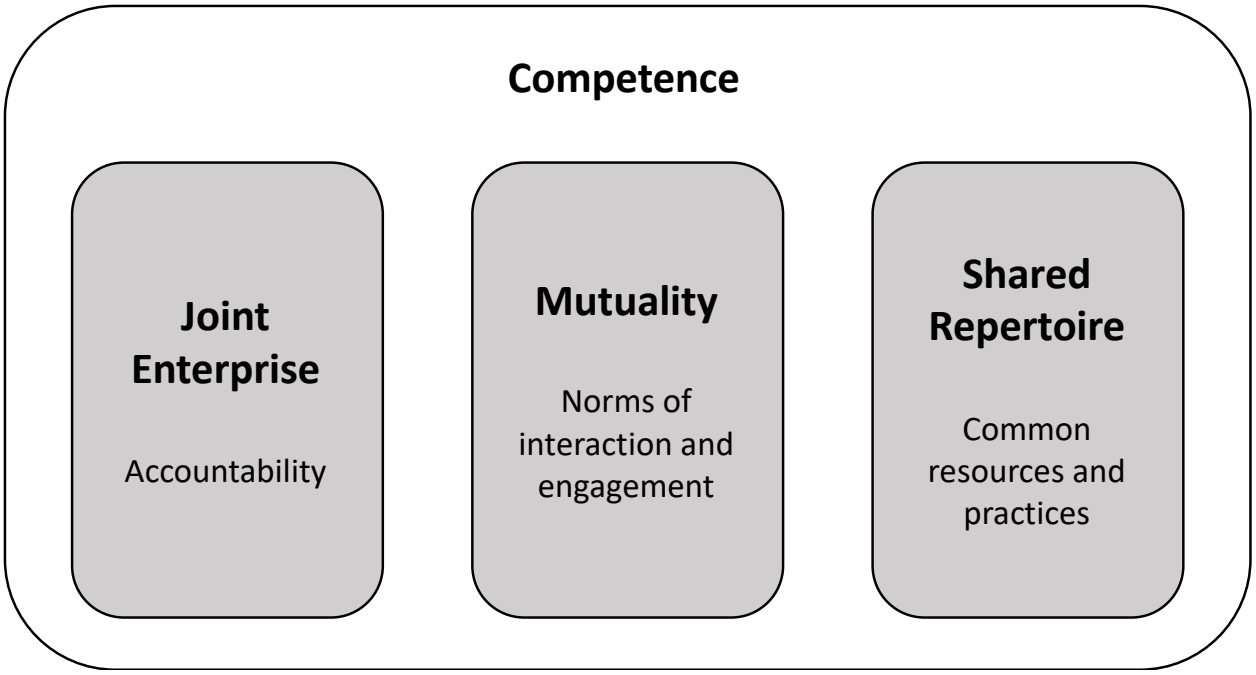

Figure 2.2: The three components of competence. Competence is valued knowledge demonstrated through participation.

Competence within CoPs is negotiated through the agreement and negotiation of three main elements: enterprise, mutuality, and repertoire (Figure 2.2). Enterprise, also called joint enterprise, is the component to which members of a CoP are accountable. Joint enterprise frames what the community is about. Mutuality is where norms are established. This is how members should interact and engage. Members of a CoP hold a shared repertoire of resources or practices. All members must have access to the repertoire and knowledge of how to use resources within that repertoire. For example, graduate students in an academic program are often accountable to the work of the program such as contributing to the wealth of knowledge through research. They are also held to certain standards and norms of engagement such as social norms between student and faculty or between peers. Graduate students may have varying access to shared resources and practices though there is an implied shared repertoire for students. These resources include research group-specific skills sets, for example in chemistry research groups often specialize in specific analytic techniques. As well, this can include access to university resources such as

social services, as research groups may value and highlight these services more than others. In addition to the negotiation of competencies, members or prospective members of a CoP must navigate degrees of membership or belonging.

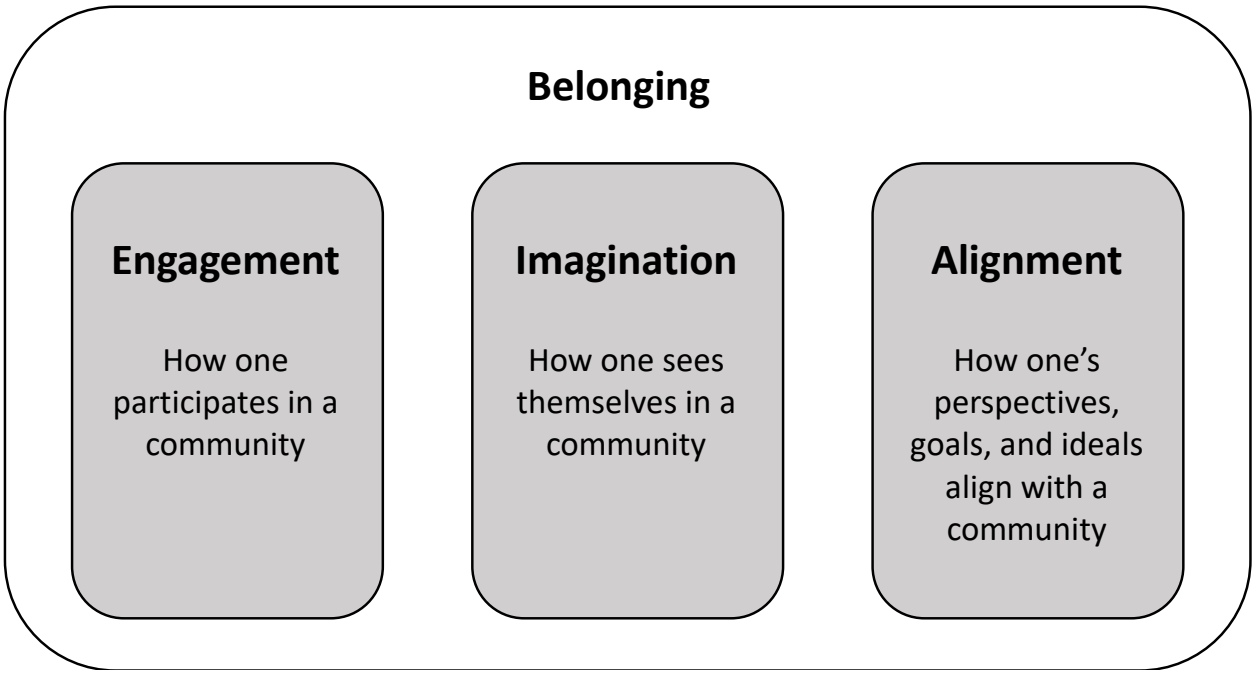

Figure 2.3: The three modes of belonging.

CoPs are imaginary structures within which people can makes bids for membership. Wenger (1998, 2000) describes the degree of membership to a CoP as modes of belonging. Belonging involves engagement, imagination, and alignment (Figure 2.3). Members of a CoP participate in practices and in turn learn what they are allowed to do and how others will react to what they do. Engagement involves a mutual negotiation of meaning through participation, which establishes competencies within a CoP. This is the cornerstone of how a CoP is formed. A graduate program or department is not inherently a CoP. Work must be done through engagement to establish a practice and community norms through social interactions. Imagination is how members of a CoP see themselves within the CoP as a whole. Imagination allows for the continual redefinition of roles within a community. This is not an individual act and is inherently situated in the social interactions and experiences within a CoP. Graduate students can imagine

their future roles in a program however imagination is rooted in the norms and experiences of a program thus limiting what can be imagined. Lastly, alignment is the acknowledgement of being a part of something larger than the individual. This includes the coordination of actions and practices by members of a CoP. Alignment may not be explicitly present in a graduate program depending on the presence of norms of collaboration between and within research groups. Each of these three constructs constitute the means by a which a CoP function and can have varying degrees of influence or importance depending on the context of the CoP.

Thus far the inner workings of how individual CoPs are negotiated have been described, however CoPs often intersect and people are generally members of many communities to differing degrees (Wenger, 2000, 1998). Wenger describes fluid boundaries or borders between CoPs, which allow for the crossing between CoPs through learning (Figure 2.4). Essentially, learning at a boundary enables the merging of competencies and experiences between CoPs. This overlap encourages acknowledgment of the differences between practices while also considering similarities that allow experiences and competencies to interact. This expansiveness strengthens identification through multi-membership. For example, a graduate student or faculty member who acknowledges the common skills required for both teaching and research can actively work on those skills, thus strengthening competence in both CoPs. As a result, one may come to have a stronger sense of belonging to both communities of researchers and communities of teachers such that belonging in each CoP strengthens belonging in the other. This identification with a CoP is connected to identity development.

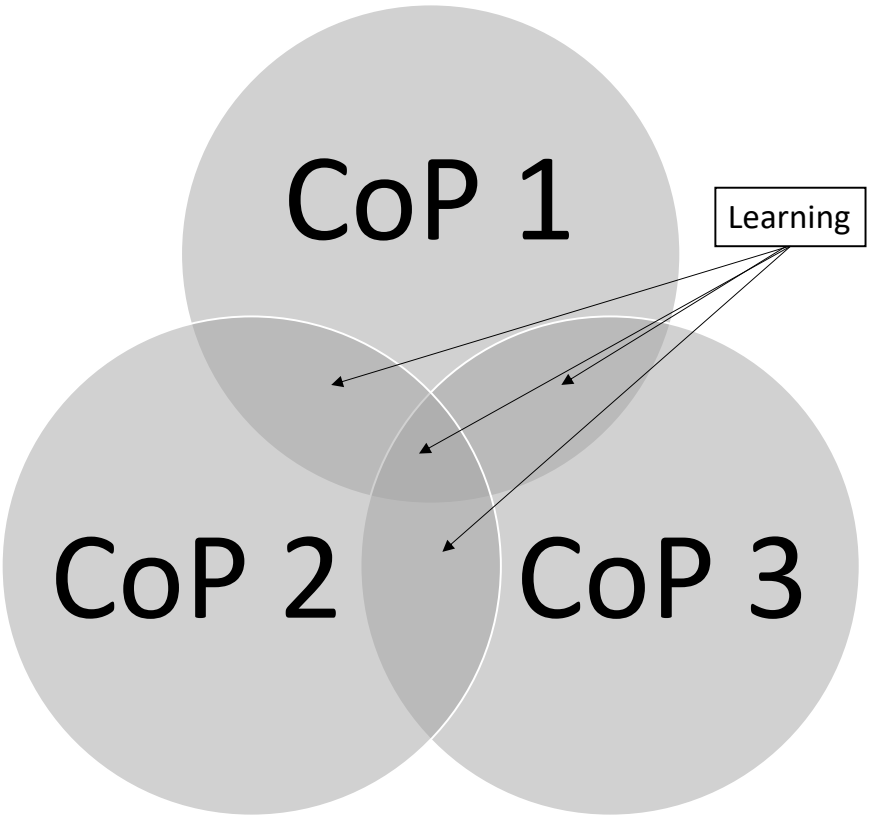

Figure 2.4: Intersecting CoPs and learning at a boundary. The dark gray intersections represent where CoPs shared competencies and experiences.

Identity. We also hold an image of ourselves that is reflective of the structure and function of a CoP and how we see ourselves in it. Wenger (1998) refers to this as identity, however there are other definitions, to be described later. In this way, the practice in communities of practice is explicitly linked to identity development. When forming a CoP, identities are negotiated through participation in social and cultural practices of the community. Nasir and Hand (2008) introduced the construct of practice-linked identities to describe the relationship between participation in a practice and identity development. This situates how one negotiates ways of being a person in a CoP. This includes the types of roles one takes up, the access to those roles, and the pliability or negotiability of those roles. Through this connection to practice, identities can be viewed as negotiated experiences, community memberships, learning trajectories, and community multi-membership (Wenger, 1998). Negotiation and membership

have been addressed previously. Next, identity as learning trajectories and identity as multi-membership will be elaborated.

Trajectories and Participation. Identity development is considered to be continuous and ever changing (Carlone & Johnson, 2007; Gee, 2000; Sfard & Prusak, 2005). Wenger (1998) conceptualizes this "continuous motion" and "constant becoming" as a learning trajectory within a CoP. From this perspective trajectory means a path that connects past, present, and future experiences. A learning trajectory is how one navigates through a CoP. Four major types of trajectories have been established, however possible trajectories are not limited to these four: inbound, insider, outbound, and boundary.

Inbound trajectories arise when the goal is to become a full member of a CoP. An insider trajectory goes beyond becoming a full member to negotiate new roles within full member status and, as a result, change what it can mean to be a full member. Outbound trajectories are ones that move out of a CoP, often to another. Boundary trajectories bridge CoPs. Trajectories are influenced by participation and non-participation, thus identity development is influenced by how one does or does not participate. Non-participation logically leads to a more outbound trajectory while participation leads to more inbound ones. Participation itself is not necessarily always a choice. A member of a CoP can choose to participate or not, but there are many instances in which the ability to participate or not is influenced by other structures within a CoP. For example, if a principal investigator is not supportive of a graduate student's teaching practice, then the ability to participate in teaching is controlled by the one in a position of power and not the graduate student. As well, paradigmatic trajectories can heavily influence the trajectories of others. These trajectories are highly ingrained models of how one can negotiate membership. They can enable membership through modeling or constrain through a lack of

opportunity for negotiation of trajectories. This can be seen in graduate programs in which there is a highly encouraged path of becoming a faculty member at a research institution and other avenues may not be as highly valued or encouraged. In this way, members may be less inclined to incorporate other trajectories or to take liberties in constructing their own. This incorporation of multiple trajectories is highlighted at the nexus of multi-membership.

Nexus of Multi-membership. Inherently, we participate in more than one community and have multiple identities such as that of teachers, researchers, students, etc. (Sfard & Prusak, 2005; Wenger 1998). Wenger (1998) describes this as the nexus of multi-membership in which one's identity is comprised of multiple identities. This also means that one does not have a single trajectory but multiple intersecting trajectories that are a part of each other and can conflict with or reinforce one another. The nexus of multi-membership is where identities are "at the same time, one and multiple" (Wenger, 1998, p. 159).This is similar to Crenshaw's (2017) concept of intersectionality, but provides an added layer of the power structure and privilege associated with an identity such as race or gender. Due to intersection one constantly does work to reconcile one's identity across boundaries. Reconciliation of competencies between communities is important for the maintenance of one overall identity made up of multiple identities, but is often difficult. For example, students often struggle to move between communities and resolve their identities within each (Hand, 2006; Nasir, 2002; Nasir & Hand, 2008).

In Nasir and Hand's (2008) study, school students on a basketball team and in a mathematics classroom exhibited differing levels of engagement and learning that coincided with differing levels of identity development. Due to a lack of opportunities for engagement in the mathematics classroom, students identified more strongly with the basketball community, which provided more opportunities for bids for membership. The current study regards multiple

identities as *sub-identities* which fall under the umbrella of graduate student identity. This terminology does not lessen the importance of the individual sub-identities, but recognizes that individual sub-identities also intersect and make one.

To better describe the navigation and reconciliation across communities, Wenger (2000) introduced three constructs for operating across boundaries: connectedness, expansiveness, and effectiveness. Connectedness refers to the degree to which one feels connected to a community. Expansiveness refers to multi-membership and spanning multiple communities. Effectiveness is the degree to which identification with a community lends itself to participation. A functioning community considers what opportunities have been taken to learn, socialize, and innovate. Communities reflect on their own image more broadly and how practices and shared purposes have been negotiated and upheld. The breadth of membership and connectedness to multiple communities can be drawn in comparison to the multiple communities with which graduate students align themselves. Graduate students may align themselves more strongly with one sub-identity or community (connectedness), while also identifying with multiple sub-identities (expansiveness), as well as being more inclined to participate in one over another (effectiveness).

Similar Perspectives on Identity

Identity as a larger construct has been defined more generally as being seen as a "certain kind of person" (Gee, 2000, p. 99). Gee states that people have multiple identities, but also have a "core identity" that exists across contexts. One's identity is fluid and forms over time, constantly being negotiated similarly to the mutual negotiations within a CoP (Wenger, 1998). Gee considers CoPs to be a type of Discourse or "way of being certain kinds of people" (Gee, 2000, p. 110) that is linked to identity development. This is not to be confused with lowercase

"d" discourses which refer to stretches of text or dialogue. Within Wenger's (1998) Social Theory of Learning identity is defined as:

> …the social formation of the person, the cultural interpretation of the body, and the creation and use of markers of membership such as rites of passage and social categories. They [identities] address issues of gender, class, ethnicity, age, and other forms of categorization, association, and differentiation in an attempt to understand the person formed through complex relations of mutual constitution between individuals and groups (p. 13).

This definition explicitly acknowledges multi-membership or the expansiveness of membership which constitute the identities one develops. Wenger also acknowledges the complex relationships between different community affiliations. His definition of CoP is strikingly similar to Holland et al.'s (1998) conceptualization of a Figured World (FW):

> …socially and culturally constructed realm of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others. Each is an amplified world populated by a set of agents who engage in a limited range of meaningful acts or changes of state as moved by a specific set of forces (p. 52).

Both acknowledge overarching social and cultural influences on identity where salient features of a practice or world are socially negotiated by its members. Hand and Gresalfi (2015) best synthesize these definitions of identity as "joint accomplishment between individuals and their interactions with norms, practices, cultural tools, relationships, and institutional and cultural contexts," (p. 190). Each of these perspectives relies upon similar assumptions about the social nature of learning and the importance of social interaction in identity development. The current study values the contributions of each definition of identity and will regard identity development as an ongoing social process of negotiation of how one is seen as a certain kind of person in the cultural and historical context within which one operates.

In practice, identity has been operationalized to describe more specific aspects of identity including science identity, physics identity, chemistry identity, professional identity, teaching

identity and graduate student identity (Abu-Alruz & Khasawneh, 2013; Baker & Lattuca, 2010; Carlone & Johnson, 2007; Hazari et al., 2010; Hosbein & Barbera, 2020; Zotos et al., 2019). Through qualitative studies, science identity has been broken down into three components: recognition, competence, and performance (Carlone & Johnson, 2007). Hazari et al. (2010) operationalized and amended this framework for physics identity to include interest. Hosbien and Barbera (2020) sought to theoretically ground the existing constructs of identity in a chemistry context as well. In this more recent conceptualization of this collection of identity constructs, competence and performance constitute one construct which describes one's belief in their ability to understand content specific information and perform required tasks in a domain. This is similar, though not identical, to competence in a CoP as this type of competence is more individualized. Recognition describes whether and how one is seen as a type of person by oneself and by others. Lastly, interest is one's inclination to think about and understand content in a specific domain.

The concept of identity resources have also been operationalized to make sense of identity development (Nasir & Cooks, 2009, Hyater-Adams, et al., 2018; Reinholz, 2019). These resources become available in a social setting and can be tangible or intangible. The resources include: material resources, relational resources, and ideational resources. Material resources are the tangible aspects of a social interaction such as physical classroom artifacts, relational resources are the relationships with others, and ideational resources are the ideas of one's place in the world in relation to others. The resources are similar to engagement, alignment, and imagination constructs but can more easily be operationalized to identify what is useful or not for identity development. While current work on graduate student identity does not utilize these identity resource constructs explicitly, graduate student identity research does focus on the social

and cultural resources that graduate students access in making sense of their identity. Hyater-Adams and colleagues have also coordinated Carlone and Johnson's identity constructs to the identity resource constructs such that recognition is often associated with relational and ideation resources, competence and performance are associated with material and ideational resources, and interest is associated with material and relational resources. The current conceptual framework will also take into account the coordination of these constructs.

Applications of Sociocultural Theories in Graduate Education

Graduate education lends itself well to analysis via sociocultural frameworks due to the implied apprenticeship model and connections to identity development (Baker & Lattuca, 2010; Golde & Dore, 2001; Hancock & Walsh, 2016; Thiry et al., 2015). As graduate students participate in an academic community learning *should* occur. Within such a community students should, "learn the concepts and principles associated with a field, its methods of inquiry and its criteria for assessing and validating knowledge" (Baker & Lattuca, 2010, p. 812). However, the case can be made that such supports may not be made available and as a result graduate students may find it more difficult to become a members of and identify with certain communities.

Winstone & Moore (2017) emphasize the importance of acknowledging the "malleability" of graduate student identities and that regarding a graduate student's teaching role as a legitimate part of "academic apprenticeship" may work to strengthen teaching identity development. Baker and colleagues' work on graduate student identity is positioned within a sociocultural perspective and focuses on student and researcher aspects of identity as well as on the actual social connections and resources upon which graduate students rely. Baker and Pifer (2014) acknowledge some conflicts between student and scholar (researcher) identities and briefly mention the importance of teaching in later work (Pifer & Baker, 2016), however do not

explicitly address the connections, constraints, or affordances or all three. Baker and colleagues do also acknowledge the extensive influence of personal identity such as race, gender, and familial status among others. Overall, the framework is limited and disconnected from the work of other identity scholars. This study will better position graduate student identity within the wealth of identity research.

In the context of graduate student identity, this study intends to make sense of the multiple intersecting sub-identities that graduate students develop and how those sub-identities contribute to overall graduate student identity development (Figure 2.5). The proposed sub-identities that constitute graduate student identity develop, often simultaneously, throughout graduate school as students take up multiple roles. It is important to understand the interactions between sub-identities, most notably between teaching and research, to ascertain how to better support graduate students in their enculturation into academic practice. As previously described, the lack of attention to teaching identity and the relationships between identities is detrimental to graduate student professional development as graduate students make sense of their professional duties. Without specific support of teaching identity development through instructional training graduate students may not develop teaching identities and as a result be unprepared for future careers and professional opportunities.

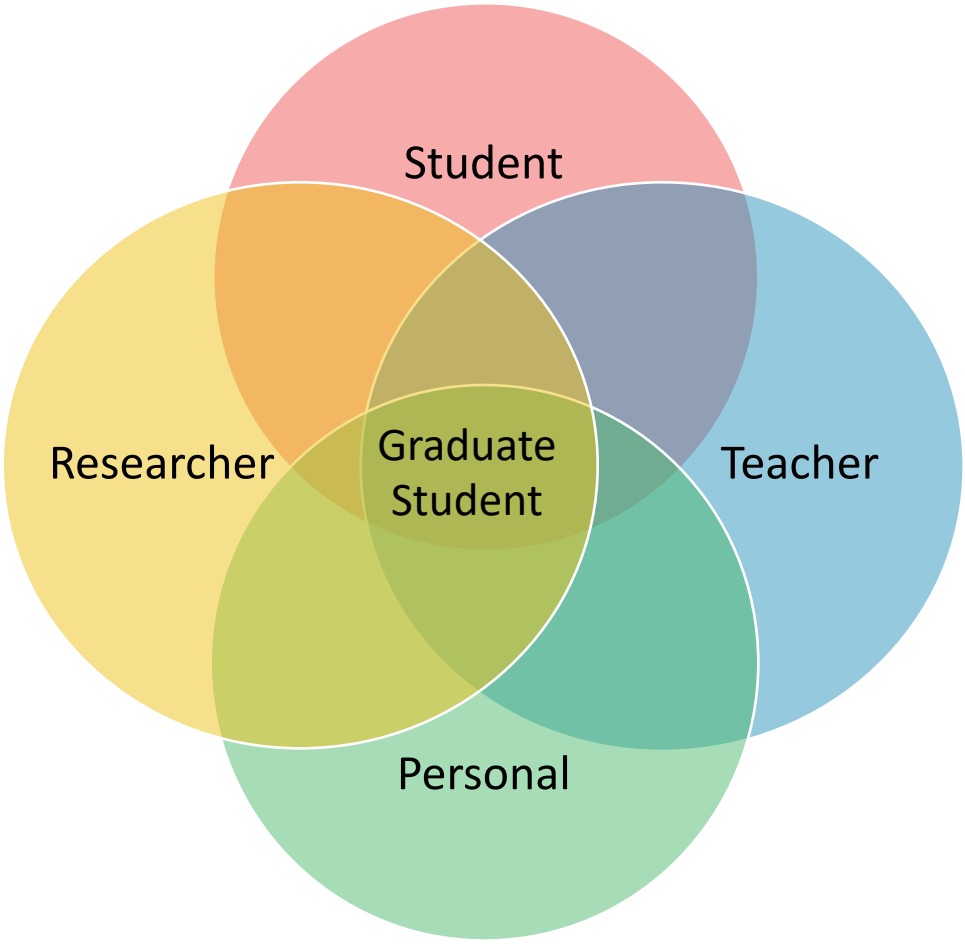

Figure 2.5: The potential intersecting sub-identities of a graduate student, which constitute graduate student identity.

An Integrated Conceptual Framework

To make sense of graduate student identity and associated sub-identity development, a cohesive and detailed framework is needed. This study will integrate the wealth of identity literature and Wenger's (1998) Social theory of Learning into one rich conceptual framework. The integrated conceptual framework is provided in Figure 2.6. Within this framework, identity will be regarded as the continuous social process of negotiation of how one is seen by others and how one see themself as a certain kind of person in context. Because identity is multi-dimensional and intersectional, graduate student identity will be regarded as both multiple and

one, meaning that graduate students negotiate both a graduate student identity, while simultaneously negotiating sub-identities such as teaching and research. It is important to note that sub-identities are not meant to be subordinate identities, but fit within the larger umbrella of graduate student identity. Thus, graduate student identity as one and as multiple are equally valued from a research perspective.

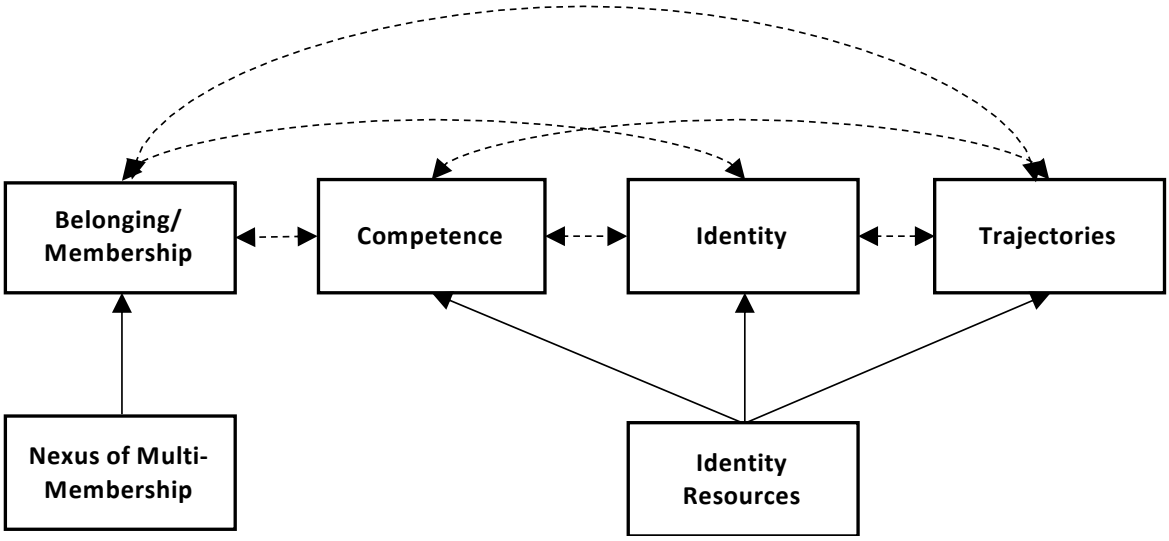

Figure 2.6: The integrated identity development framework and proposed connections. Solid lines represent construct linkages that will be directly explored. Dashed lines represent potential connections between constructs.

Wenger's ideas of multi-membership will be used to understand the intersections of different sub-identities. For example, a graduate student may exhibit connectedness to a specific sub-identity such as teaching, but may be more likely to engage with research due to established norms that prioritize research over teaching. Modes of belonging will address membership within individual CoPs in order to understand which sub-identities graduate students develop. In addition, linkages between Carlone and Johnson's (2007) identity constructs and identity resources may reveal mechanisms of identity development in individual participants. For example, relationships with others, called relational resources, are often linked to instances of recognition (Hyater-Adams et al., 2018). Lastly, trajectory codes will be used to explore the path

of one's identity to the extent that it can be modeled. This will, in combination with the identity resources accessed, provide a glimpse into the resources that enable or constrain participation. For example, a relational resource such as encouragement from a peer or faculty may lead to increased participation such that one may exhibit an inbound trajectory into a community. This would mean that one is actively working to be a part of a community and as a result identifies with that community in some way. Overall, the combination of constructs will allow for a holistic description of graduate student identity development.

This framework will also be used to evaluate a redesigned graduate student instructional training course. The training course will be redesigned with current best practices for GTA training in mind. Best practices include: a) providing ongoing support, feedback, and reflection, b) facilitating community (peer and faculty) support, c) providing guidance on GTA roles, d) incorporating modeling and apprenticeship, and e) fostering respect and accountability (Bond-Robinson & Rodriques, 2006; Marbach-Ad et al., 2012; Park, 2004; Rosales et al., 2013). These five best practices align well with constructs within the proposed conceptual framework.

Ongoing or continuous support honors identity development as a continuous process. In addition, continuous support from others allows for the negotiation and pliability of GTA roles. Peer and faculty support allow for alignment of actions and practices between members of a community. As well, this type of support can foster relationships that translate to the relational resources graduate students may access in identity development. Explicitly addressing GTA roles can aid in the imagination of oneself in relation to a community. Guidance on these roles that allows room for the negotiation and redefinition of roles can provide ideational resources from which graduate students can access as well. This will allow for one to negotiate their place within the community. Modeling and apprenticeship are the mechanism through which a shared

repertoire is often conveyed. This repertoire has the potential to contain all three types of identity resources. As well, modeling and apprenticeship may reveal paradigmatic trajectories that can both help or hinder graduate student identity development. Lastly, fostering respect and accountability within community can strengthen shared enterprise and encourage engagement in the practices of a community. Through this framework the alignment of best practices and identity development will be assessed.

Research Questions and Goals Revisited

This study will integrate constructs from the identity literature including Carlone & Johnson's identity constructs, Nasir and Cook's identity resources, and Wenger's CoP constructs in the analysis of graduate student identity and sub-identity development as students, researchers, teachers, and more situated in a chemistry context in multiple institutional environments with both master's and doctoral students. This study will examine graduate student identity development with the inclusion of teaching as a legitimate identity. The overarching goals and specific research questions I intend to address are as follows:

1. Understand graduate student identity development as researchers, teachers, and students throughout their graduate career.
    a. Which sub-identities do graduate students develop as a result of experiences with teaching and research?
    b. What are the trajectories of sub-identity development?
    c. What experiences and other resources contribute to the development of these sub-identities?
2. Understand the relationships between graduate students' multiple sub-identities in the context of particular institutional environments.

a. How do graduate students make sense of and sustain various sub-identities simultaneously?
b. Do graduate students' multiple sub-identities conflict with or reinforce one another?
c. To what extent do graduate students perceive an intersection between teaching and research sub-identities?

3. Redesign an existing GTA training course using best practices from the literature such as feedback and reflection, and evaluate the impact of the course on graduate student identity development.
    a. How does teaching experience and a formal GTA training course contribute to the teaching and research sub-identity development for graduate students?
    b. Which components from the course do graduate students value? Specifically, to what extent do students value the feedback and reflection components of the course?

Chapter 3: Methods

Currently, there is very little research regarding identity development of graduate students, particularly in chemistry, as it relates to the multitudes of sub-identities that graduate students develop and sustain over time. It is therefore unclear how sub-identities develop in relation to each other in context (Tran, 2011). As a result, the trajectory of identity development of graduate students as teachers, researchers, and other sub-identities is not well understood. This Institutional Review Board approved study will expand current knowledge of graduate student identity development in other content domains, explore the types of sub-identities that can develop when given the opportunity, and identify and explore the process through which specific resources support identity development.

It is important to understand graduate student identity development because these identities influence the professional identities of graduate students post-graduation, which includes as future faculty (Abu-Alruz & Khasawneh, 2013). This study aims to makes sense of graduate student identity development and the relationships between sub-identities in context using a concurrent transformative mixed-methods (Creswell et al., 2003) and embedded case study research design (Stake, 2006; Yin, 2017). The first section will provide a general overview of the study design followed by detailed descriptions of each component of the study.

Overview

Mixed-methods designs entail the collection of qualitative and quantitative data for the purposes of addressing the limitations of each method alone. This approach allows for the integration of information about the relationships between variables of interest from quantitative analysis with the detailed descriptions of a phenomenon of interest in qualitative analysis (Maxwell, 2005). The concurrent design refers to the concurrent collection of qualitative and

quantitative data in the study. In this study, though qualitative analysis will take priority, both types of data will serve to triangulate or cross-validate the overall findings. Transformative research designs require methods that lead to a better understanding of the phenomenon of interest while transforming the phenomenon being studied. In this case, change will occur though the graduate student training course and the resources provided therein to support graduate student sub-identity development. Transformative methods also require dedicated theoretical frameworks (introduced in Chapter 2) to guide the formulation of research questions and subsequent methodologies that will best suit that perspective. This work relies on multiple theoretical perspectives including sociocultural theories of learning (Vygotsky & Cole, 1978), identity (Gee, 2000), and communities of practice (Wenger, 1998) in order to guide the mixed-methods and case study designs.

A case study research design can be employed as a component of a mixed-methods study (Stake, 2006; Yin, 2017) to describe contemporary experiences in context using a breadth of data. Mixed-methods and case study methods are often complementary due to the need for at least two or more sources of data that can be both quantitative and qualitative. The case study component covers both graduate student identity development at the single student level and across cases to provide multiple levels of narrative description of identity development.

Data collection occurred in two phases: a pilot phase and the main study phase (Figure 3.1). The pilot study occurred in the Spring and Summer of 2020 followed by the main study phase during the Fall of 2020. Preliminary qualitative data in the form of semi-structured interviews was collected in the pilot stage and analyzed using a combination of a priori codes and inductive coding methods (Miles et al., 2014). The resulting codes were organized into a preliminary codebook and were employed to analyze subsequent interviews in the main study,

though inductive codes and changes to the pilot coding scheme did emerge from the data throughout all data collection, as will be discussed in Chapter 4.

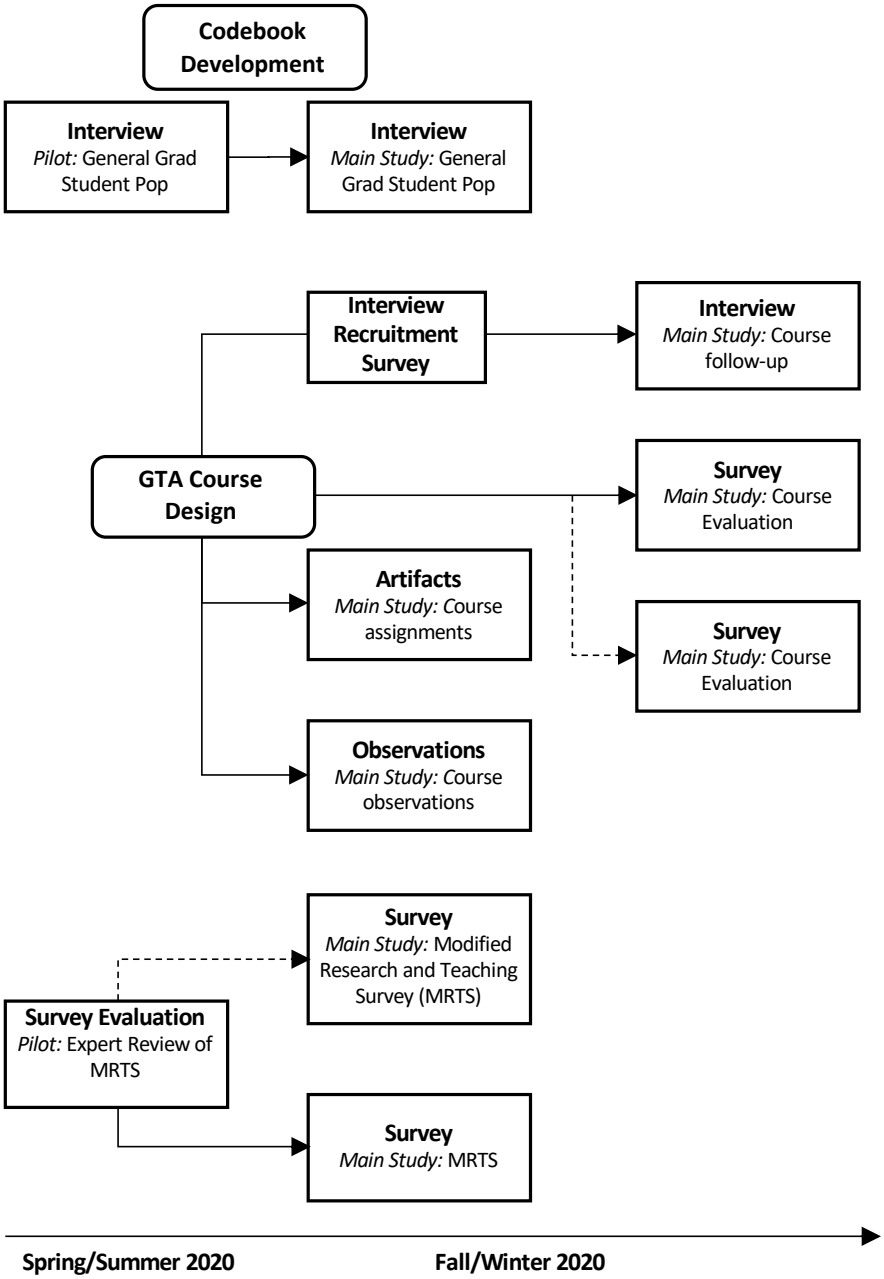

Figure 3.1: Data collection timeline for Spring and Fall 2020. Pilot data collection occurred in Spring 2020 and was analyzed using the preliminary codebook in Summer 2020. Tasks are in rounded boxes. Dashed lines indicate quantitative and solid lines indicate qualitative data.

In the main data collection phase of the study, qualitative and quantitative data were collected simultaneously, hence the concurrent mixed-methods designation. A mixed methods-

design with an emphasis on qualitative analysis via *a priori* (Miles et al., 2014) and inductive coding via Thematic Analysis (Clarke et al., 2019) was used to describe identity development of the broader graduate student population. An updated version of the pilot interview protocol was used for the graduate student interviews.

The qualitative data from the interviews was analyzed simultaneously with data collection and coding and theme generation continued after the completion of all interviews. First, *a priori* codes were used for data reduction. After the first round of analysis, inductive codes were added based on the data, while some a *priori* codes did not align with data and were removed. After data reduction, overall themes in the data were identified.

In addition, a modified survey (Gilmore et al., 2014) aimed at understanding graduate students' perceptions of the relationships between teaching and research was administered to the broader chemistry graduate student populations. The survey addressed the perceived teaching and research identity dichotomy and the development of those identities using both Likert-type quantitative questions and open-ended questions (OEQs). Qualitative data was coded using inductive coding methods and the quantitative portion of the course evaluation survey was analyzed using descriptive statistics. Qualitative and quantitative data (from both surveys) were integrated through both the linkage of single survey response questions and the overall distributions of survey subsection scores to qualitative pattern codes and themes.

A case study approach embedded within the overall study was employed to address the specific experiences of a cohort of new graduate students within the redesigned training course. The overall unit of analysis in the case study was the redesigned graduate student training course and the embedded units were the individual graduate student participants. A follow-up interview protocol was employed to collect further qualitative data after the course ended. Other sources of

data included observations of the redesigned training course sessions, training course artifacts, online course management system posts, and course evaluation surveys (researcher-generated and official university versions).

Positionality

Qualitative research is highly interpretative, thus is inherently influenced by the attitudes, beliefs, experiences of the researcher (Creswell & Poth, 2016; Foote & Bartell, 2011). While it is true that a researcher's positionality can negatively influence research claims (Maxwell, 2013), I take the stance that the researcher's positionality can also benefit a research study. Leveraging one's positionality to explore phenomena that a researcher of a different background may not have attended to is important to the exploration of the breadth of contextual influences that may exist (Santamaria et al., 2020).

I am an assigned female at birth (AFAB) Chicane person with a Bachelor's degree in Biochemistry and a Master's degree in Chemistry. I have experienced and witnessed a variety of *othering* experiences in my time as a student and researcher. Othering experiences are events in which one has been made to feel like an outsider in a community to which they made efforts to belong (Foote & Bartell, 2011). As a graduate student in chemistry, I have felt othered when expressing an interest in teaching and education research. In my personal experience, I had been led to believe that teaching is not an important skill for chemists and that research always takes precedent. More broadly, I have been othered due to my perceived gender and ethnic background. The culmination of these othering experiences throughout my academic career have influenced my research interests, such that I have an intimate knowledge of the inequities graduate students face. As a result, I have designed a study to investigate some of these issues including the lack of support for teaching. Having an insider's perspective on these issues has

allowed me to attend to these issues from a research perspective, thus my positionality can present as a strength. In order to combat my bias from my personal background, I recruited second coders and trusted critical friends to review my interpretations. This study is borne out of personal experience but will serve to aid a broader population of graduate students.

Study Design

Participants and Context

This study focuses on the first-hand experiences of chemistry graduate students at two institutions. This includes graduate students of all levels in each program including master's and doctoral track students. One institution is a research-focused university (RFU) on the West Coast of the United States. This university is highly competitive in admissions and has a larger student population and larger overall class enrollment per class the other institution of interest. This institution runs on the quarter system. The second institution is a four-year Hispanic Serving Institution (HSI) in a geographically similar region on the West Coast. This university is classified as a teaching-focused university (TFU) and has a high number of undergraduate transfer students from community colleges and other two-year institutions. This institution runs on the semester system.

This study will focus on the graduate student populations from the Chemistry and Biochemistry Departments at each institution. The demographic information for each population is described below (Table 3.1). The TFU reported nonbinary students while this was not reported for the RFU. Race and ethnicity information was reported as the percentage of underrepresented minorities (URMs) which include African American/Black, Hispanic/Latinx/Chicanx, Native American, Native Hawaiian/Pacific Islander, and Filipinx.

Table 3.1: Demographic information from Fall 2020 for both university sites of interest.[1,2]

University		Total (N)	Women	Men	Nonbinary	URM	International
RFU	**Degree**						
	MS	67	44.8%	55.2%	N/A	17.9%	35.7%
	PhD	271	41.3%	58.7%	N/A	19.9%	22.8%
TFU	**Degree**						
	MS	43	58.1%	41.8%	0.0%	30.2%	27.9%
	PhD	39	35.9%	64.1%	0.0%	17.9%	20.5%

The RFU has a traditional admission process in which cohorts of master's and doctoral students are admitted each year. In contrast, the usual path for graduate students at the TFU is to enter the program as a master's student and have the option to transition to the doctoral program in a later year. The TFU has only recently added the option to enter directly into the doctoral program. The TFU doctoral program is a joint doctoral program (JDP) with the RFU and as a result TFU doctoral students also take classes with RFU graduate students.

Graduate students at RFU are typically placed in graduate teaching assistant (GTA) positions based on availability and need for staffing and as a result course placements vary widely even within the first semester teaching unlike the TFU. The GTAs at RFU generally teach one section per term. Graduate students at TFU usually serve as GTAs for the introductory chemistry laboratory course in their first semester, however there are some exceptions. After the first semester, TFU GTAs can be "promoted" to teach other more advanced courses. The TFU GTAs generally teach at least two sections per term. At both universities the GTAs begin teaching in their first term on campus.

Both universities offer a first-term course coinciding with graduate students' arrival on campus that includes GTA training. All new graduate students are required to take the course in

[1]RFU demographic information can be accessed at: https://ir.ucsd.edu/grad/stats/enrollment.html
[2]TFU demographic information can be accessed at: https://asir.sdsu.edu/enrollment-data/enrollment-major-summary-data-table/

their first semester or quarter. The RFU course is focused on preparing graduate students to teach in both lecture and laboratory settings. The GTAs meet once per week for 10 weeks for 1.5 hours per week. The main goals of this course are to introduce and support proficiency in evidence-based teaching practices and cultivate a peer network of GTAs. The course includes opportunities for small group discussion, peer collaboration, and reflection on one's teaching practice. A 2.5-day orientation workshop is also held prior to the beginning of the term, which includes mainly logistics and safety information.

The TFU offers a general graduate student training course that includes some teaching training in a three-day bootcamp-style course prior to the start of the semester (Appendix A). The remainder of the course, which was traditionally held for four hours every week for eight weeks of total class time, has historically included more general graduate student information including selecting a research group, accessing library information, and grant writing training (Appendix B). As stated previously, one goal of this study will be to use graduate student interviews and best practices from the literature to redesign the TFU graduate student training course to include more sustained teaching training and support beyond the bootcamp-style training course. The RFU course will not be redesigned as it already includes extensive researched-based strategies for GTA training and is therefore not a focus of the current study. The current content and proposed changes to the TFU course will be described in more detail in the following section.

TFU Course Description and Redesign

The TFU course is designed for new graduate students to introduce useful teaching techniques, laboratory safety protocols, introduction to faculty research areas, helpful software, effective communication skills, tips for academic writing, and science and teaching ethics. The TFU course includes a pre-semester 3-day bootcamp facilitated by one of the department course

coordinators. Course coordinators closely oversee GTAs and laboratory activities and are often a point of contact between faculty and GTAs. Each day of the bootcamp includes 4-6 hours of lectures, activities, and/or panels. Day 1 of the bootcamp includes general university policy information, ethics discussion, technology training and usage, and general presentation skills. Day 2 focuses on laboratory safety training and familiarization with general chemistry laboratory experiments. Day 3 includes practice teaching presentations, experienced GTA presentations, and open discussions for new and experienced GTAs. This portion of the course remained unchanged as it is run by an experienced course coordinator.

The remainder of the course includes eight four-hour meetings that span about half of the semester. The original course included faculty presentations to introduce incoming students to the breadth of chemistry research at the university, an introduction to useful software and library resources, and a mock grant writing assignment. The new version of the course spanned the full semester such that each class is two hours for 15 weeks to provide continuous support for research and teaching. While the course spanned a longer amount of time, the total class time remained the same with the intention that shorter classes each week will better support students in the long term and better suit graduate students' busy schedules. The bulk of the faculty research presentations were moved to a separate seminar to allow more time for instructional training during class time. All other course activities were retained as detailed in the syllabus (Appendix C).

Teaching-related topics in the course included: a) equity and diversity in the classroom, b) implicit bias and microaggressions, c) how to give a short talk and other presentation skills, d) giving and receiving feedback, and e) how to deal with challenging scenarios in the classroom. This being an introductory course in which most GTAs will not have teaching assignments that

provide opportunities for implementing their own teaching approaches, active learning strategies are not a specific focus of this course. This course is intended to introduce students to balancing their own coursework, teaching, and research duties and supporting undergraduate student learning as well as possible as a new GTA. Teaching techniques were modeled through lessons on presentation skills, dealing with difficult scenarios, and through teaching feedback and reflection activities. Such activities included observing peers' mini-presentations on a research or topic or sample class lecture and critiquing and reflecting on their peer's presentations. Equity in the classroom and bias training are emphasized in the course because new GTAs may not have any experience in this topic depending on their background and may not have the tools to address these issues. Similarly, discussing challenging situations before they occur can help GTAs better handle them when needed (Dragisich et al., 2016). The full syllabus and schedule can be found in Appendix C.

Research and general topics included: a) how to access campus student services and other social resources, b) how to read scientific articles, c) finding external funding, d) using software and online resources, and e) networking and career planning. Often students do not engage with the resources available because they are unaware of the existence of these resources (Shortlidge & Eddy, 2018); therefore, information on student services included the discussion of mental health services as well as departmental and community social services available to both the graduate students and the undergraduates they teach (Dragisich, Keller, & Zhao, 2016). This course is designed to help students begin to hone their craft as researchers and students as they navigate resources for academic research, writing, and career planning. It is the goal that an integrated approach to graduate student training will support the development of multiple graduate student sub-identities including research and teaching identities. Overall, this course

will aid students in building camaraderie and community such that they will feel more connected to the program, faculty, and their peers in order to support overall graduate student identity development and the development of sub-identities as researchers and teachers.

The new version of the course, described in the syllabus (Appendix C), places a higher priority on community building and support, which are associated with best practices in STEM GTA training (Bond-Robinson & Rodriques, 2006; Dragisich et al., 2016; Marbach-Ad et al., 2012; Park, 2004; Rosales et al., 2013) and aligned with Wenger's (1998) theory of Communities of Practice (CoP) and identity. Within this framework, CoPs transcend groups of people to represent the social containers within which members continuously negotiate their goals, roles, practices, and modes of belonging. In supporting community membership, one's identity development and the learning of skills associated with that identity are supported. The course is intended to support identity development through membership and belonging by introducing concrete shared goals, encouraging participation in the graduate student community, allowing negotiation of roles within the community, and scaffolding the "bigger picture" of how the information introduced in the course relates to their roles as graduate students and beyond.

The course includes a community online portal using an online course management system to encourage community discussion and support. Students were prompted to start online discussions of struggles in teaching or research through approximately biweekly reflections on their research, teaching practice, and coursework. The reflections in the graduate student course expand upon the previous course design to provide longer-term support for teaching that reinforces what was learned in the bootcamp. Reflection prompts were adapted to the context of the course modules. Example prompts are provided in Table 3.2.

Table 3.2: Reflection topics and example questions. The full list of prompts can be found in Appendix D.

Week #	Topic	Example Reflection Question
4	Implicit Bias and Microaggressions	What comes to mind when you see the term microaggression? Were you familiar with this term before?
5	Equitable Teaching Practices	Do you see any opportunities to apply what we discussed to situations in a research or teaching context?
7	Mid Semester Check-in	How is your teaching going? How is your research/group selection going?
11	Week 11 Check-in	How are you doing with your research responsibilities? Any positives you'd like to share? Any issues you'd like to ask for help with?
14	Final Reflections	How were you able to manage your workload this semester? Looking back, what are you most proud of and what would you change about the way you managed your responsibilities?

After the completion of the course, graduate students were given access to a chemistry graduate student homeroom in order for them post teaching resources including rubrics, quizzes, readings, and lecture outlines on a private online file sharing service for other GTAs to access. This is meant to prevent GTAs from having to individually create their own resources and allow them to work collaboratively to design course materials. GTAs are not required to create all resources themselves, as most are provided, though they are sometimes tasked with creating or modifying some assignments or rubrics.

Pilot

Data Collection

In the pilot phase of data collection individual semi-structured interviews (Bernard, 1988) were conducted with one in person and one recorded via video conferencing software. Two Chemistry graduate students from the RFU were recruited via email for pilot interviews. The two pilot interviews were approximately 1-hour long and were used to craft a preliminary codebook of *a priori* codes (Appendix E). The interview protocol was designed using a combination of

science/physics identity frameworks (Carlone & Johnson, 2007; Hazari et al., 2010; Hyater-Adams, 2018; Reinholz et al., 2019), professional identity frameworks (Abu-Alruz & Khasawneh, 2013; Sturtevant & Wheeler, 2019), and community of practices constructs (Wenger, 1998) to yield a protocol that incorporates aspects of science/researcher identity, teaching identity, student/learner identity and various personal identities to yield a cross section of the multifaceted nature of graduate student identity (Appendix F). The protocol includes questions about personal experiences related to each sub-identity separately as well as questions regarding intersections and coordination between sub-identities. Analytic memos were generated after every interview to be used during analysis (Miles et al., 2014). Analytic memos are narrative notes documents generated by the researcher to record any initial thoughts and reflections about the interview. One interview was recorded in-person prior to the COVID-19 restrictions and one was recorded via Zoom after COVID-19 restrictions were put in place.

Analysis

Qualitative analysis via *a priori* coding was used to analyze pilot interviews (Miles et al., 2014). The first cycle of coding included coding via the proposed constructs from Wenger's (1998) theories of CoP and identity, Nasir and Hand's (2008) work on practice-linked identities, and Carlone and Johnson's (2007) identity constructs. Wenger's competency constructs provide information on the functioning of the community but did not prove useful for this study due to the lack of applicability to the dataset. The modes of belonging revealed the extent of belonging to a community and were minimally useful as the overall sense of belonging implied by the codes was more meaningful than the individual codes. The multi-membership constructs were used to understand the sub-identity intersections and the trajectory codes were used to describe the path of identity development, both of which were useful for data reduction. The practice

linked-identity resources revealed the types of resources students access during identity development, which are coordinated with Carlone and Johnson's (2007) identity constructs and were the primary codes needed for analyses in the full study. As a result of the pilot data analysis, a preliminary codebook was proposed (Appendix E). The codebook included identity constructs from Carlone & Johnson (2007), identity resources (Nasir & Hand, 2008), and CoP constructs of belonging, multi-membership, trajectories, and competence (Wenger, 1998).

Main Study

Data Collection

As described previously, the study is organized via three main goals: 1) understand graduate student identity development, 2) understand relationships between graduate students' multiple sub-identities, and 3) redesign and evaluate the impact of a GTA training class on graduate student identity development. In order to address the preceding goals, a mixed-methods approach with an emphasis on qualitative methods was used to address graduate student identity development of the broader graduate student population at both TFU and RFU (Goals 1 and 2). A single-case embedded case study approach was utilized to understand identity development of specific embedded student cases enrolled in the TFU course and assess the impacts of the TFU course (Goal 3).

The pilot data was used to inform the final versions of data collection protocols for the full study. Data in this study included individual semi-structured interviews, a modified version of Gilmore and colleagues' (2014) Teaching and Research survey, a researcher-generated course evaluation survey, the official university course evaluation survey, biweekly reflections, and classroom artifacts. The alignment of data collection with the research questions is shown in

Table 3.3. The qualitative data is the primary focus of the data collection with support from quantitative survey data.

Table 3.3: Research question and data source matrix. Gray- Graduate students taking the TFU course. Black- General graduate student population at either institution in any year and graduate students at SDSU taking the TFU course. [1]Gilmore et al., 2014

		Interviews	Surveys		Other
	Research Questions	Individual Semi-structured	Modified Teaching and Research[1]	Course Evaluations	Classroom artifacts
1a	Which sub-identities do graduate students develop as a result of experiences with teaching and research?	X	X		
1b	What are the trajectories of sub-identity development?	X	X		
1c	What experiences and other resources contribute the development of these sub-identities?	X	X		
2a	How do graduate students make sense of and sustain various sub-identities simultaneously?	X	X		
2b	Do graduate students' multiple sub-identities conflict with or reinforce one another?	X	X		
2c	To what extent do graduate students perceive an intersection between teaching and research sub-identities?	X	X		
3a	How does teaching experience and a formal GTA training course contribute to the teaching and research sub-identity development for graduate students?	X	X	X	X
3b	Which components or resources from the course do graduate students value? Specifically, to what extent do students value the feedback and reflection components of the course?			X	X

Individual Interviews. Graduate students were recruited through a survey sent out via the department email listservs and convenience sampling (Patton, 1990) was used due to the availability and interest from potential participants. It is ideal to have six to 12 graduate students per university to illustrate a range of perspectives and ensure data saturation (Guest et al., 2006). Data saturation means that no new themes or information are observed with additional qualitative data. Consequently, ten students were recruited from the TFU and eight students were recruited from the RFU in accordance with these standards for qualitative data collection. Demographic information for each participant will be described in Chapters 4 and 5. The interview protocol from the pilot was further refined through expert review, which included the recruitment of graduate students, faculty, and a postdoc who were familiar with identity or chemistry graduate programs more broadly. This protocol was used for student interviews of the general graduate student population at both universities throughout the Fall 2020 term (Appendix G). Analytic memos were written directly after each interview (Miles et al., 2014).

Graduate student participants were interviewed in the later part of the term (beyond week 7 of Fall 2020) to ensure that they had some graduate school experiences to report. Follow-up interviews with students taking the TFU course occurred after the conclusion of the TFU course in Winter 2021. Thus, first-year TFU participants were interviewed twice, while student participants in the general graduate student population were interviewed once. The interviews lasted between 45 and 90 minutes via videoconferencing software (Zoom) and consisted of background questions about their educational journey and professional goals, researcher/science identity questions, teaching identity questions, and intersection identity and closing questions (Appendix G). The follow-up protocol was similar to the original interview protocol, but included a question related to the TFU course in order to gather information about their

experiences in the course (Appendix H). The minimum sample size for a case study analysis is two participants (Yin, 2017) and 5 cases were included to ensure robust cross-case analysis (Stake, 2006).

Surveys. The Modified Teaching and Research Survey (MTRS) from Gilmore and colleagues' (2014) original Teaching and Research Survey (TRS) was administered to the Chemistry and Biochemistry graduate student general populations at both institutions and students taking the TFU course. The original TRS was designed to ascertain whether graduate students see a relationship between teaching and research, the nature of that relationship (if it exists), and the perceptions of that relationship as a function of teaching and research experiences and across disciplines. As well, the original survey was designed to understand how teaching and/or research facilitated the development of certain academic skills. Participant recruitment occurred via email through various graduate student department listservs. In accordance with common response rates for online data collection it was expected that 50% of the total graduate student population would respond yielding a hypothetical N=200. However, due to the COVID-19 pandemic the response rate was uncharacteristically low despite repeated efforts to reach students via email and classroom announcements. Only 45 responses were received and more details are provided in Chapter 4.

The MTRS builds upon the TRS to include similar questions regarding identity development from the interview protocol and pilot interviews (Table 3.4). The identity survey questions were designed using science/domain specific identity frameworks (Carlone & Johnson, 2007; Hazari et al., 2010; Nasir & Hand, 2008) and Wenger's (1998) theory of identity. Specifically, the survey included new questions regarding practice-linked identities, which are

the identities that people tend to develop through participation in the practices of a community (Nasir & Hand, 2008).

The original nature of teaching and research (T & R) relationship and T & R contributions to academic skills questions were retained from the original survey. The singular open-ended T &R relationship question was replaced with three "graduate student roles" questions that better fit the current framework. These questions include: a) What roles do you hold as graduate student?, b) How do you balance all of these roles?, and c) Do you perceive any overlap between these roles? The MTRS is presented in Appendix I. Before the new survey was deployed it was evaluated via expert review (Miller, 2003) with graduate students within the study population of interest and with faculty experts.

Table 3.4: Overview of the MTRS survey structure.

Section	**Number of questions**	**Format**	**New, Original, or Modified**
Identity	16	Likert-scale	New
Nature of T & R relationship	10	Likert-scale	Original
T & R contributions to Academic skills	5	T & R scale	Original
Graduate student roles	3	Open-ended	Modified

In addition to understanding identity development more broadly, this study aims to understand the experiences of graduate students in the new graduate student training course at TFU, the extent to which a teaching identity is developed when taking the course, and the most valued components of the course. In order to do this, a course evaluation survey was developed and administered based on graduate student training course design at the TFU. The course evaluation survey included multiple choice questions regarding each component of the course as

well as open-ended questions in which graduate students could elaborate on their most valued components of the course (see Appendix J). It is of particular interest to ascertain whether the reflection exercises and teaching feedback activities are valuable to the students as these are commonly cited as useful aspects of GTA training (Rosales et al., 2013).

Classroom Artifacts. Reflections via the online course management system and mini-presentation activities were additional data sources for understanding graduate student experiences in the course and the impact of these activities on identity development and course satisfaction. Graduate students submitted reflections biweekly as a part of the graduate student training course. Reflection with critical others is an important and necessary component of the process in order to consider different ideas and to be critical of one's personal experiences, feelings, and biases (Corrales et al., 2020; Rodgers, 2002). Students also had the opportunity to post on the online portal discussion board outside of class to continue discussion with peers outside of the course.

The primary investigator (AC) also acted as course co-instructor for the TFU course as a participant-observer. Participant-observation is common in case studies (Yin, 2017) in order for the researcher to build a rapport with the student participants throughout data collection. AC attended all classes and facilitated select modules but was not involved in any grading components.

Analysis

Analysis included both quantitative and qualitative analysis with an emphasis on the qualitative. The coordination of research questions and data collection are outlined below (Table 3.5). Data collection occurred primarily in Fall 2020 and analysis occurred simultaneously with data collection and continued post data collection in Spring 2021. Qualitative and quantitative

analysis will be described individually followed by data integration procedures via mixed-methods and case study designs.

Table 3.5: Table of data collection and preliminary analysis methods.

Data	Data Type	Primary Data Analysis	Collection Timeline	Research Question
Pilot Interviews	Individual interview	Qualitative analysis (coding)	Spring 2020	N/A
MTRS	Survey	Descriptive statistics, response distributions, Qualitative analysis (coding)	Fall 2020	1, 2 & 3
Main Study Interviews	Individual interviews	Qualitative analysis (coding)	Fall 2020	1, 2 & 3
TFU Course Evaluation Survey	Survey	Descriptive statistics, response distributions, Qualitative analysis (coding)	Fall 2020	3
TFU Course Reflections and Other Assignments	Classroom Artifacts	Qualitative analysis (coding)	Fall 2020	3
TFU Course Observations	Classroom Observations	Qualitative analysis (coding)	Fall 2020	3

Interviews. Interview data was analyzed in accordance with a qualitative coding approach which utilized both *a priori* and inductive coding methods (Miles et al., 2014). First cycle coding included both *a priori* coding using the pilot codebook and inductive coding using Reflexive Thematic Analysis (Clarke et al., 2019). Reflexive Thematic Analysis involves the development of themes or patterns as outputs of extensive data familiarization and coding for preliminary themes. A constant-comparative method was also used during this process to compare qualitative data sets as they were collected (Merriam & Tisdell, 2016). The final codebook can be found in Appendix K. After the first cycle of coding with the main study data

set, pattern coding was used to group first cycle codes into categories, themes or concepts. These pattern codes are "bigger picture" codes similar to codes generated in axial coding of grounded theory (Miles et al., 2014). In this phase of coding, codes may also be changed and refined. Connections between codes within and between big picture pattern codes were made in this phase. The patterns were used to generate output themes, as in Thematic Analysis, which together made up the narrative descriptions of the data. All themes, codes and raw data in the form of interview quotes were stored in a qualitative database spreadsheet. This data was coordinated with additional forms of data during the final data analysis and integration phase.

The open-ended questions (OEQs) from all surveys (MTRS and course evaluations) were analyzed using inductive coding and themes and codes were fully derived from the data. In addition to finding data to support emerging codes, incongruous data that did not fit within the coding scheme were identified in order to revise and refine emergent themes (Cobb & Whitenack, 1996). Incongruous data is as important as fitting data when refining codes. A second coder was also recruited during data analysis to guard against further bias. The second coder and the researcher met to discuss the codebook, the second coder was able to code two full interviews, and then the two negotiated the coding to consensus. Notes from these discussions were used to refine the coding and themes.

Quantitative Analysis. Descriptive statistics were run on the MTRS survey responses using R-Studio software version 1.2.5033 to display demographic information, MS or PhD designation, institution and international student status. The Likert-type responses were also analyzed using the Likert package to examine trends in the data. Specifically, graphical representations of the response distributions for each question or set of questions were used to illustrate trends in responses. The low response rate resulted in not using inferential statistics on

the dataset. Overall, the MTRS provided information to support qualitative claims about the types of identities developed, the perceived relationships between research and teaching, and the potential influences of those perceived relationships on identity development. The quantitative portions of the course evaluation survey were also analyzed via descriptive statics and graphical representations of survey responses.

Integration and Final Analysis

Following the analysis of quantitative and qualitative data separately, all data sources were integrated to address the overarching research goals: 1) understand graduate student identity development, 2) understand relationships between graduate students' multiple sub-identities, and 3) redesign and evaluate the impact of a GTA training class on graduate student identity development. Goals 1 and 2 will be addressed via a mixed-methods design and goal 3 will be addressed in a case study design.

Mixed-Methods Integration

Goal 1. The first goal is to understand which identities graduate students in this study develop and what experiences contribute to the development of those identities. In order to do so, qualitative information from the individual interviews and open-ended survey questions and the codes and output themes proposed therein were integrated with the quantitative data from the identity portion of the survey (Figure 3.2). Through the comparison of descriptive trends in survey responses to interview data, the survey identifies which identities are developed and interviews revealed information on the potential resources, experiences, and mechanisms involved in development. The quantitative results also revealed the prevalence of specific sub-identities within the sampled population. The quantitative comparisons among groups provides information about the types of identities specific populations of graduate students develop. While

this data is not meant to generalize the prevalence of specific identities in any graduate student population, this information, along with interview data, can be used to understand how such identities may have developed in this particular context.

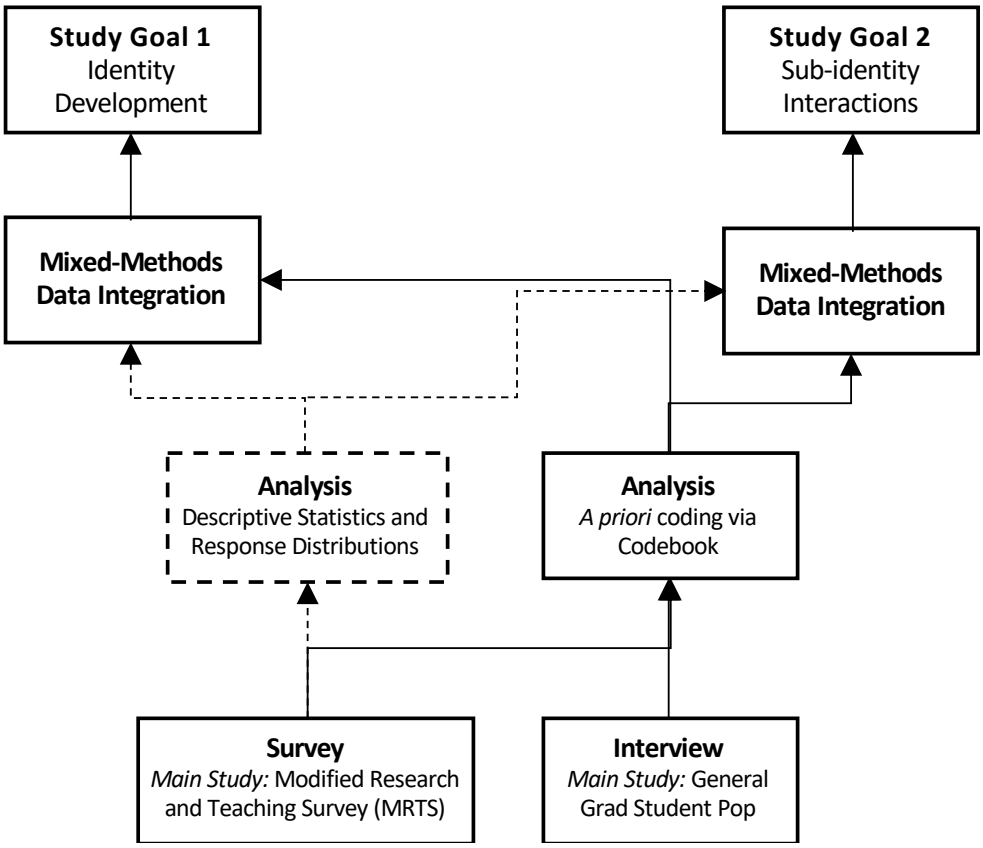

Figure 3.2: Data integration and research goal alignment for research goals 1 and 2. Dashed lines indicate quantitative and solid lines indicate qualitative data.

Goal 2. In addition to understanding the specific sub-identities graduate students develop, the remaining quantitative data provides information about the relationships between sub-identities with a focus on research and teaching identities. Themes among the qualitative data from the individual interviews and open-ended survey questions were compared to the graphical trends from the MTRS survey (Figure 3.2). The survey results show whether GTAs perceive a relationship between teaching and research, which provides potential contributions to the development of both research and teaching identities or the lack thereof. As well, the perceived connection, or not, between teaching and/or research to academic skills may reveal potential

reasoning for why GTAs may not develop certain identities based on perceived utility and importance of those roles. The quantitative results are used to support the cases from qualitative data to yield a rich description of sub-identity intersections and overall development. The triangulation of data is reported in Chapter 4 in the form of Joint Display Diagrams as shown in Table 3.6 (Kaiser & Presmeg, 2019). From the data collection for goals 1 and 2, a holistic description of graduate student identity development will be generated.

Table 3.6: Sample Joint Display Diagram, which will be used for research goals 1 and 2.

RQ	**Theme(s) [Qual]**	**Survey Data [Quant and Qual]**	**Compare**
1	Themes from qualitative data.	Data from MTRS- quantitative (Likert-style questions) and qualitative (OEQs)	Similar or Dissimilar, Explanation

Case Study Integration

Goal 3. A case study approach (Yin, 2017) was used to evaluate the TFU course and describe individual descriptive cases of identity development within the TFU course student population (Figure 3.3). The overarching unit of analysis in this case study is the TFU course and the embedded units are the individual graduate student participant cases. This embedded unit will serve as the units for cross-case analysis and the overall unit of analysis, the course, will be described as a whole using narrative explanation building (Yin, 2017) in Chapter 5. The MTRS survey data, interview data, the course evaluation survey, classroom artifacts and classroom observation field notes were integrated in this case study. Each student participant is reported as a separate embedded case with descriptions of their experiences, the identity resources they had access to and used, the extent to which they had access to those resources, and the identities they did or did not develop.

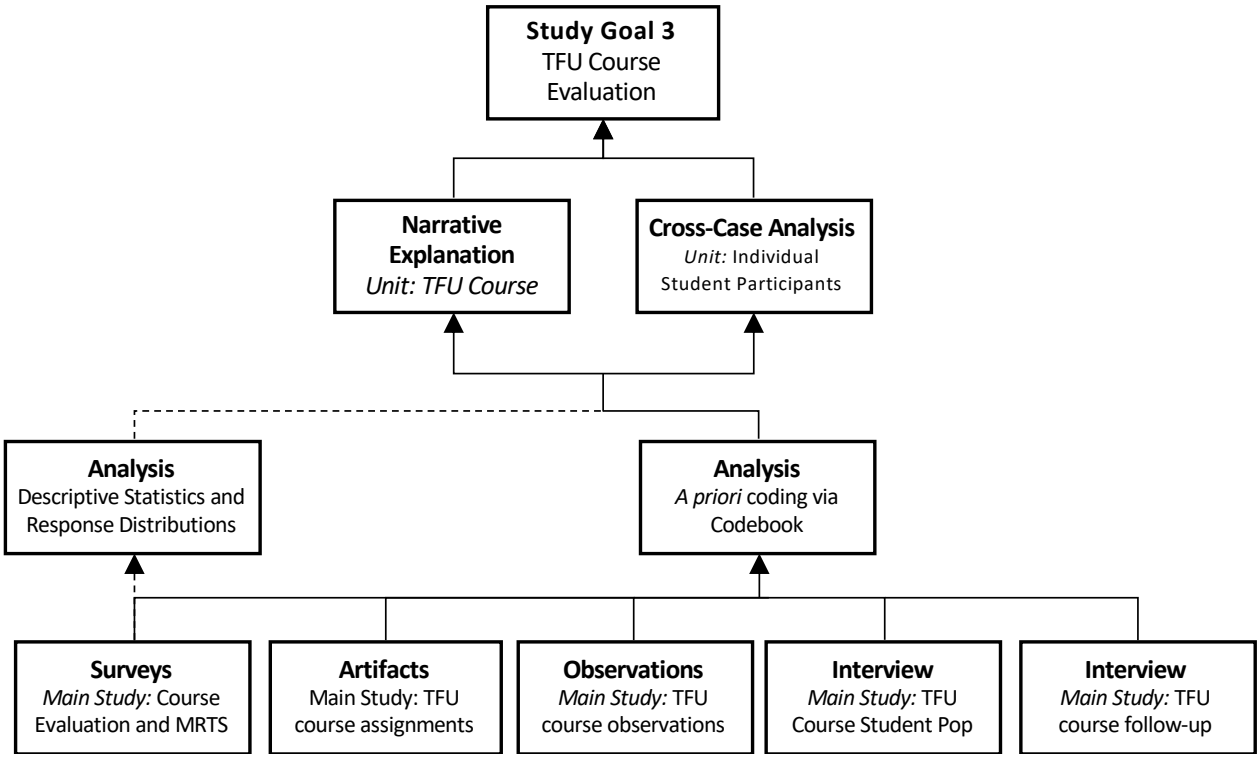

Figure 3.3: Data integration and research goal alignment for research goal 3. Dashed lines indicate quantitative and solid lines indicate qualitative data.

The impact of the existing course was assessed via integration of the course evaluation survey, classroom artifacts, and interview data (Figure 3.3). Consistencies between the sets of data revealed connections between engagement in the course and the satisfaction with the course, as well as the activities that were cited as most useful. This will also be reported as a chain of evidence (Yin, 2017). Figure 3.4 graphically depicts how the evidence will be connected with each claim. The specific evidence from the evidence database will be reported in text with the corresponding theme, while the database in the form of case profiles will act as a repository of case study qualitative data in the supplementary material. In addition to reporting on specific individual student cases, a narrative of the overall course is described to show what identity and course resources were commonly accessed and which were not, as well as themes in identity development within the course. This will inform future versions of the course and provide

preliminary information about which components of the course are important for graduate student identity development.

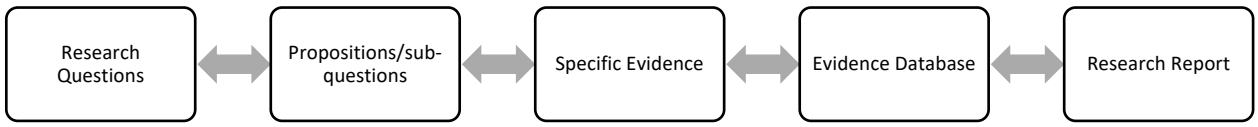

Figure 3.4: A general schematic for the depictions of chains of evidence.

Validity and Reliability

Two major concerns with studies that employ primarily qualitative methods are validity and reliability (Yin, 2017; Miles et al., 2014). Both mixed-methods and case study designs address construct validity through the incorporation of multiple sources of evidence. To check internal validity, rival data and explanations will be directly addressed during analysis and reporting. As well, a second coder aided in analysis to circumvent some issues of bias from the primary researcher. Extensive use of existing theories, namely Wenger's theory of identity, can ensure a degree external validity. Lastly, reliability issues will be addressed through reporting of chains of evidence and providing a case study database for reference. The validity of the survey data was assessed using expert review during survey design and refinement (Arjoon et al., 2013). Traditional reliability measures could not be carried out due to the low response rate; however, quantitative data was compared to qualitative themes to assess consistency.

Limitations and Disclaimers

TFU classes were online in Fall 2020 and all data collection and classroom activities were moved online as well. The content of the training changed to support GTAs as they learned to facilitate laboratories and discussion sections online rather than in person. There was a greater emphasis on online tools and methods of establishing meaningful connections in a remote

environment. All interviews were conducted via Zoom as well. This also impacted quantitative data collection and interview recruitment from the survey, despite multiple attempts at soliciting via email and virtual classroom announcements.

Chapter 4: Graduate Student Identity Development

This chapter focuses on research goals 1 and 2, describing graduate student identity development (GSID) and the relationships and intersections between graduate students' multiple sub-identities. The majority of the narrative descriptions of graduate student identity development come from the qualitative data collected from the individual semi-structured interviews with support from the quantitative and qualitative Modified Teaching and Research survey (MTRS) data. The narrative descriptions address the following sub-questions presented in Chapters 2 and 3 (Table 4.1) From these sub-questions, an overall story of GSID emerged through the description of the development of multiple sub-identities, the intersections between them, and the resources that contributed to development. With this account, stakeholders such as faculty, program directors or coordinators, department chairs, mentors, graduate students themselves, and others involved in shaping the educational environment for graduate students may better understand how to build supportive structures for graduate students.

Table 4.1: Research questions addressed in Chapter 4.

Research Questions
1A) Which sub-identities do graduate students develop as a result of experiences with teaching and research?
1B) What are the trajectories of sub-identity development?
1C) What experiences and other resources contribute to the development of these sub-identities?
2A) To what extent do graduate students perceive an intersection between teaching and research sub-identities?
2B) What are the relationships between graduate students' multiple sub-identities more broadly?
2C) What resources do graduate students access in order to make sense of and sustain various sub-identities simultaneously?

The chapter begins with demographic descriptions of the interview participants, survey respondents, and overall institutional contexts to situate the study. This is followed by a

discussion of quantitative analysis and qualitative data reduction and analysis. Qualitative data is then presented as a narrative description of GSID. Lastly, interview and survey data are integrated to further illustrate the themes of GSID and a summary of resources for GSID are presented.

Methods Revisited

Survey

The Modified Teaching and Research Survey (MTRS) data was collected simultaneously with qualitative interview data. The MTRS adapted from Gilmore and colleagues (2014) consisted of 16 identity-related questions, 10 teaching and research questions, 5 teaching and research skills questions, and three open-ended questions (OEQs) developed by the researcher (Appendix I). The teaching and research relationship questions and teaching and research associated skills questions were retained from the original survey with some modifications after expert review. The 16 identity questions and three open-ended questions were generated by the researcher using existing theories of identity development and refined via the same expert review process. The OEQs are listed below (Table 4.2). This data was used for the triangulation of themes generated by qualitative data.

Table 4.2: The open-ended questions from the MTRS in order of appearance on the survey.

OE1	**OE2**	**OE3**
What roles or responsibilities do you have as a graduate student?	How do you manage all of these responsibilities?	Do you perceive any overlap between responsibilities mentioned above? Why or why not?

The survey was administered to the graduate student populations in the Chemistry & Biochemistry Departments at two public universities on the West Coast. One is a research-focused university called RFU and the other is a teaching-focused university called the TFU,

which is also classified as a Hispanic-Serving Institution (HIS). The demographic information for graduate students in the Chemistry & Biochemistry department at each university is presented in Table 4.3.

Table 4.3: Demographic distributions of the RFU and TFU Chemistry and Biochemistry graduate programs in 2020 as seen in Chapter 3.

University		Total (N)	Women	Men	Nonbinary	URM	International
RFU	**Degree**						
	MS	67	44.8%	55.2%	N/A	17.9%	35.7%
	PhD	271	41.3%	58.7%	N/A	19.9%	22.8%
TFU	**Degree**						
	MS	43	58.1%	41.8%	0.0%	30.2%	27.9%
	PhD	39	35.9%	64.1%	0.0%	17.9%	20.5%

Interviews

Interviews collected in Fall 2020 were analyzed simultaneously with data collection and analysis continued after the completion of all interviews. According to the literature, 12 to 24 interviews is ideal for theme saturation, meaning that it is likely that no new themes will emerge beyond this number of interview (Guest et al., 2006). Thus, 18 interviews across the two institutions were conducted, providing an ideal sample size for qualitative analysis through *a priori* and inductive coding. The interviews were structured to allow additional follow up questions and many of the interviews followed a more relaxed and conversational flow that allowed participants to be fairly candid (Appendix G). The positionality of the researcher as a near-peer may have allowed for a more comfortable and authentic conversation.

To provide further context, a subset of 5 of the interviews come from students who participated in the TFU course for first-year graduate students, co-taught by AC (primary researcher) and RK (dissertation chair). There was no extra credit coercion in the course that required students to participate. The remaining interview participants were contacted via email, after interested participants either provided their email at the end of the MTRS survey or

contacted the author directly to participate as a result of recruitment via virtual classroom announcements. The individual participants' information and demographic breakdown is provided in Table 4.4. The interview participant pool somewhat mirrors the populations at the two institutions; however, only two international students from the TFU were a part of the study and no African American/Black students were a part of the study.

Table 4.4: Demographic breakdown of interview participants across both universities sorted by institution and year.

Participant	Gender	Race/Ethnicity	Year	MS or PhD	Institution
Owen*	Man	White	1	PhD	TFU
Alexia*	Woman	White	1	MS	TFU
Nathan*	Man	Hispanic/Latinx	1	MS	TFU
Mila*	Woman	White	1	MS	TFU
Enrique*	Man	Hispanic/Latinx	1	MS	TFU
Carly	Woman	White	1	MS	TFU
Alana	Woman	White	2	MS	TFU
Angelica	Woman	Hispanic/Latinx	3	MS	TFU
Jackson	Man	White	2	PhD	TFU
Matthew	Man	White	5	PhD	TFU
Henry	Man	White	1	PhD	RFU
Luis	Man	Hispanic/Latinx	1	PhD	RFU
Steven	Man	White	1	PhD	RFU
Emily	Woman	White	2	PhD	RFU
Parker	Man	White	6	PhD	RFU
Nidiya	Woman	South Asian	6	PhD	RFU
Jacob	Man	White	6	PhD	RFU
Adam	Man	White	7	PhD	RFU

*Students participated in two interviews as part of a separate case study analyzed in Chapter 5.

Data Reduction and Analysis

Quantitative

Forty-five graduate students responded to the MTRS, which resulted in 26 respondents after cleaning using the consent and check items. The consent item was used to filter out students who did not wish to participate. The check items were placed in two places within the MTRS and resembled the following: Choose “Strongly Agree”. These items were included to ensure that respondents were reading the survey questions carefully. Six students initially eliminated in the check item cleaning process were re-added because these respondents submitted meaningful open-ended question (OEQ) responses. In addition, the number of responses for each of the three sections of the MTRS fluctuated due to listwise deletion per section. The first section included the full 26 respondents while the following sections had n=24 and the final set of Likert-type question had n=20.

Descriptive statistics and response distribution graphs were generated using R-Studio software version 1.2.5033 (R Core Team, 2021). Response distributions from the survey were used to support or qualify qualitative themes through direct comparison. Demographic distributions for the MTRS are displayed in Table 4.5. The gender distributions between the general graduate student population across the two departments and the distributions of the survey respondents are somewhat similar with men being overrepresented. The race, ethnicity, and international student status distributions of the surveyed participants are somewhat consistent with the general population with an exception being that the distribution of white students in the study is markedly lower than the general population of the RFU. In addition, none the TFU survey respondents identified as Hispanic/Latinx though this institution is designated as an HSI. No further statistical analysis was carried out due to low response rate, despite attempts by the author to elicit more responses. Two email announcements were made over the course of three weeks at both institutions in addition to in-class announcements to solicit participation.

Nonetheless, the additional quantitative information does provide support for the qualitative themes. Unfortunately, the impact of the quantitative data is minimal and more responses would be needed for further analysis, comparison, or generalization of the data.

Table 4.5: Demographic information from MTRS data.

University	Total	Degree		Women	Men	Hispanic/ Latinx	Asian/Asian American	White	Multi-racial	Intl.
RFU	13	MS	23%	46%	54%	23%	15%	38%	8%	15%
		PhD	77%							
TFU**	7	MS	14%	33%	67%	0%	9%	71%	0%	28%
		PhD	86%							

*6 Participants declined to answer the demographic questions.
**One participant did not respond for gender.

Qualitative

Qualitative data, including interviews and open-ended survey questions, were analyzed using *a priori* coding (Miles et al., 2014) and inductive coding methods via Thematic Analysis (Clarke et al., 2019). *A priori* coding was carried out through the categorization of interview data into themes and concepts from identity and community of practice constructs organized in a preliminary codebook, also called codebook Thematic Analysis. In addition to *a priori* coding, reflexive Thematic Analysis was also used to develop new codes or patterns directly from interpretation of data. The inductive aspect allowed for refining of the overall codebook (Table 4.6) and tailoring of themes to the data collected. A constant-comparative method was also used during this process to continually compare qualitative data sets as they were collected (Merriam & Tisdell, 2016). Therefore, codes were fluid and constantly refined over time. Next, the process of data reduction and theme development are described in more detail.

Table 4.6: *A priori* and inductive codes used for this study.

Code	Description
Persistence*	Continuing on despite challenges, larger theme that encompasses multiple codes such as ideational and relational resources, interest, competence/performance.
Intersectionality*	The interconnectedness of social categorizations such as race, class, and gender, generally in reference to systems of power and oppression.
Confidence*	To what extent does one believe in themselves.
Agency*	To what extent does one feel in control of their trajectory, work, etc.
Belonging	The extent to which one feels like a part of a community.
Engagement	How one participates in a community.
Imagination	How one sees themselves (now or in the future) in a community.
Alignment	How one's perspectives, ideals, and goals align with a community.
Nexus of Multi membership	
Expansiveness	The degree of multi-membership. Leveraging experiences of one identity in another.
Identity	
Competence/ Performance	One's belief in their ability to understand content specific information and perform required tasks.
Recognition (Self/ Others)	Whether and how one is seen as a type of person by oneself and by others.
Interest	One's inclination to think about and understand content in a domain.
Resources	
Material	Tangible resources for identity development. Ex: grades, organizations, classes, jobs, thesis/papers, scholarship/awards etc...
Relational	Relationships with others that influence identity development. Usually denotes the relationship with the principal investigator (PI) or advisor.
Ideational (Science/Teaching/ Other)	Ideas (values, beliefs, narratives, etc.) that (dis)connect someone (from) to an identity.
Trajectories	*Used to describe overall identity development of the student
Inbound	The goal is to become a full member.
Insider	A full member who negotiates novel roles, practices, and norms in a community.
Outbound	The movement out of a community and often into another.
Boundary	A member who operates at the boundary of multiple communities. Usually research and teaching, but can include others.

*Indicates an inductive code which emerged from the data and was not initially considered in the original codebook.

Analysis began with 18 initial codes, which were reduced to 10 plus an additional 4 inductive codes (Table 4.6). After multiple rounds of the coding process, the *a priori* resources codes were identified as the most informative codes for analysis: ideational, material, and relational. The persistence code emerged from the data and was often associated with resources that students noted as helpful. The identity construct codes of competence/performance, interest, and recognition mapped onto the resource codes as expected based on previous work (Hyater-Adams et al., 2018; Reinholz et al., 2019). The inductive confidence code coincided with the competence/performance code nearly 100% of the time and the agency code was generally associated with the resources.

The multi-membership code of expansiveness was most useful to show intersections of student, researcher, and teacher identities, while connectedness and effectiveness were minimally useful for data reduction and theme generation due to limited applicability to the data. The intersectionality code emerged from the multi-membership coding due to the nature of expansiveness as relating to a hobby or other interest versus identification with a group that implied an additional layer of power and privilege such as gender or ethnicity. The trajectory codes were used more globally to categorize students and provided insight into moments in which students acted as insiders or operated on the boundary of multiple communities. The belonging codes, alignment and imagination, were useful for distinguishing the extent of identity development, while engagement was too general to provide useful information. The competence codes: joint-enterprise, mutuality, and shared-repertoire were minimally useful and disregarded during theme generation due to the fine-grained nature that was not suitable for this study.

The relevant codes and their connections are described in Figures 4.1 and 4.2. In the first figure, relational and identity constructs are coordinated as established by Hyater-Adams and

colleagues. This shows that relational and material resources bring about interest, relational and ideational resources bring about recognition, and material and ideational resources bring about feelings of competence. There are instances of crossover beyond these coordinations but the general trend holds. Inductive codes confidence and agency are often associated with competence/performance upon coding and illustrate how identity resources can contribute to feelings of confidence and agency. These constructs are situated within belonging and contribute to a sense of belonging. The second figure illustrates an additional layer within belonging in which multi-membership and trajectories are defined and show how these constructs contribute to persistence in a graduate program. The two-layered depiction indicates that these processes are happening simultaneously. The updated codebook with definitions and examples can be found in Appendix K. Narrative descriptions (Miles et al., 2014) of GSID were generated from the coded segments and subsequent emerging themes and will be presented later.

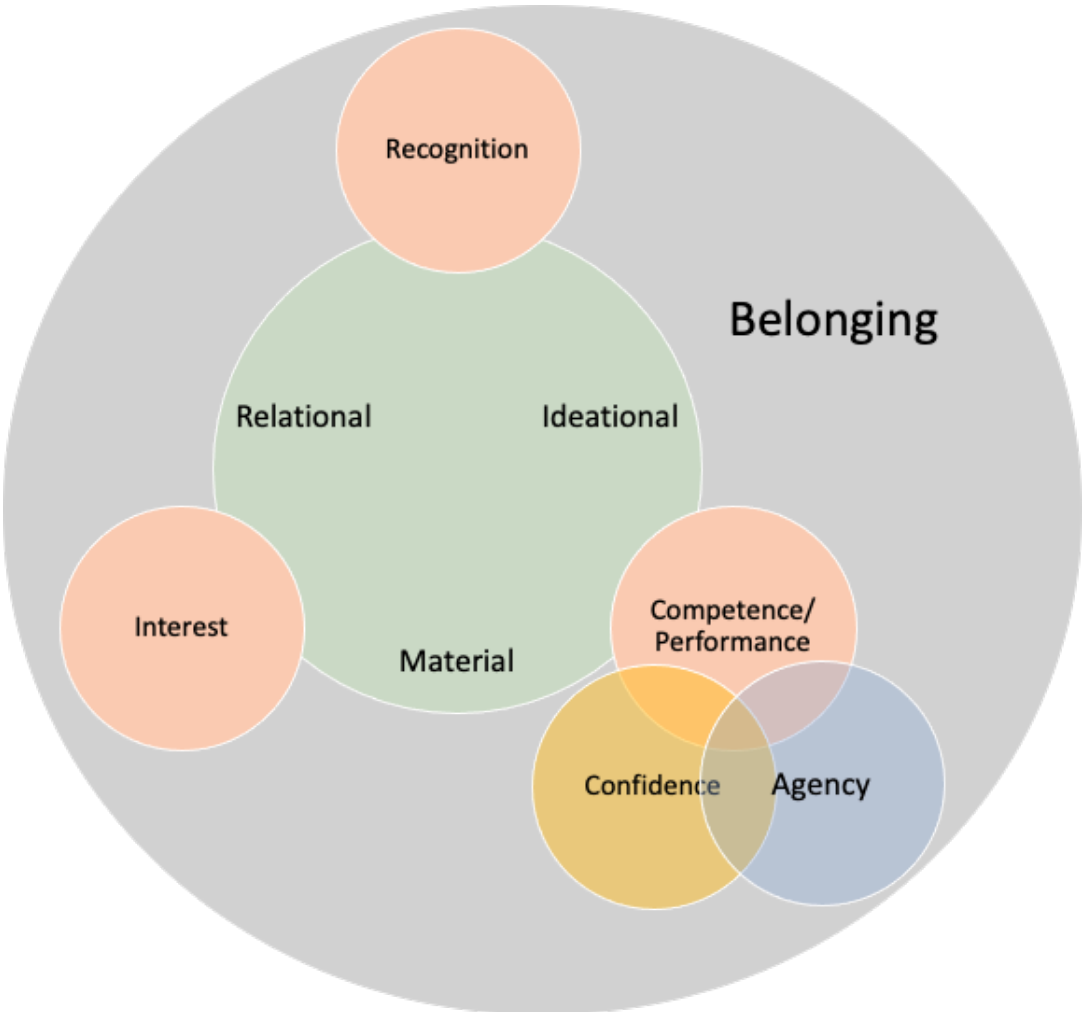

Figure 4.1:This figure illustrates the first layer of codes and their relationships. Identity constructs are coordinated with resources and confidence and agency often overlapped with the competence code. The combination of codes promote belonging.

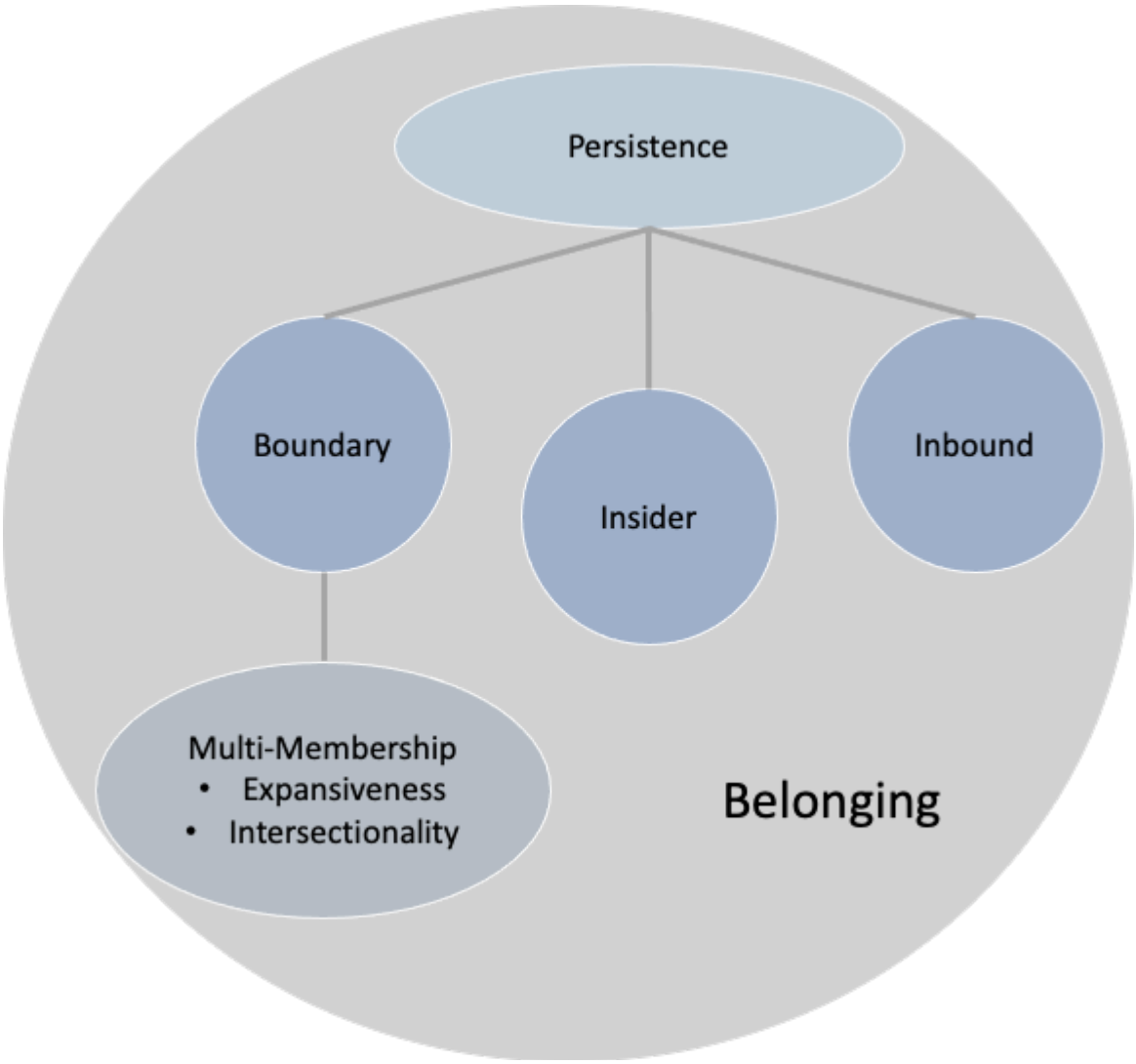

Figure 4.2: This figure describes the second layer identity development in which belonging contributes to inbound, insider, and/or boundary trajectories. Operation on the boundary involves either expansiveness or intersectionality. Overall, the matrix of codes describes persistence.

Integration

Qualitative and quantitative data was integrated through the comparison of qualitative themes with the results of descriptive statistics. Data were coordinated using Joint Display Diagrams to illustrate the similarities and differences between the results (Kaiser & Presmeg, 2019). Joint Displays provide a visualization of the links between qualitative and quantitative data, how the two are similar or dissimilar, and how the qualitative themes are supported or not

by additional data. This provides additional support for qualitative claims in order to resolve issues of validity and reliability in qualitative analyses. An example can be found in Chapter 3.

Results

Survey Results

Due to the low response rate, no comparative statistics were run on the quantitative data; however, the response distributions can still provide insights into the trends of the respondent population across the two institutions. This data can provide further backing or be used to qualify thematic claims from the interviews in order to yield more robust results.

The first set of 16 Likert-type questions are related to identity development, specifically research, teaching, and student identities (Figure 4.3). All respondents (n=26) either somewhat or strongly saw themselves as researchers and had interest in improving their scientific skills (Q1 and Q3). A majority of participants had a form of external recognition as a scientist, more likely within than outside the academic community (Q2 and Q5). A small but present percentage of respondents did not feel like a part of their lab group or did not find that question to be applicable to their situation, though a majority did feel like a part of the scientific community in some way (Q6 and Q7). All respondents saw themselves as learners to some degree but not all saw themselves as successful students nor did all respondents want to improve their skills as students (Q8-11). When it came to teaching, a majority, but not all graduate student participants saw themselves as teachers or instructors (Q13 and 14). Not all respondents felt that they needed to improve their teaching skills and were not always externally recognized or supported as teachers (Q15 and Q16).

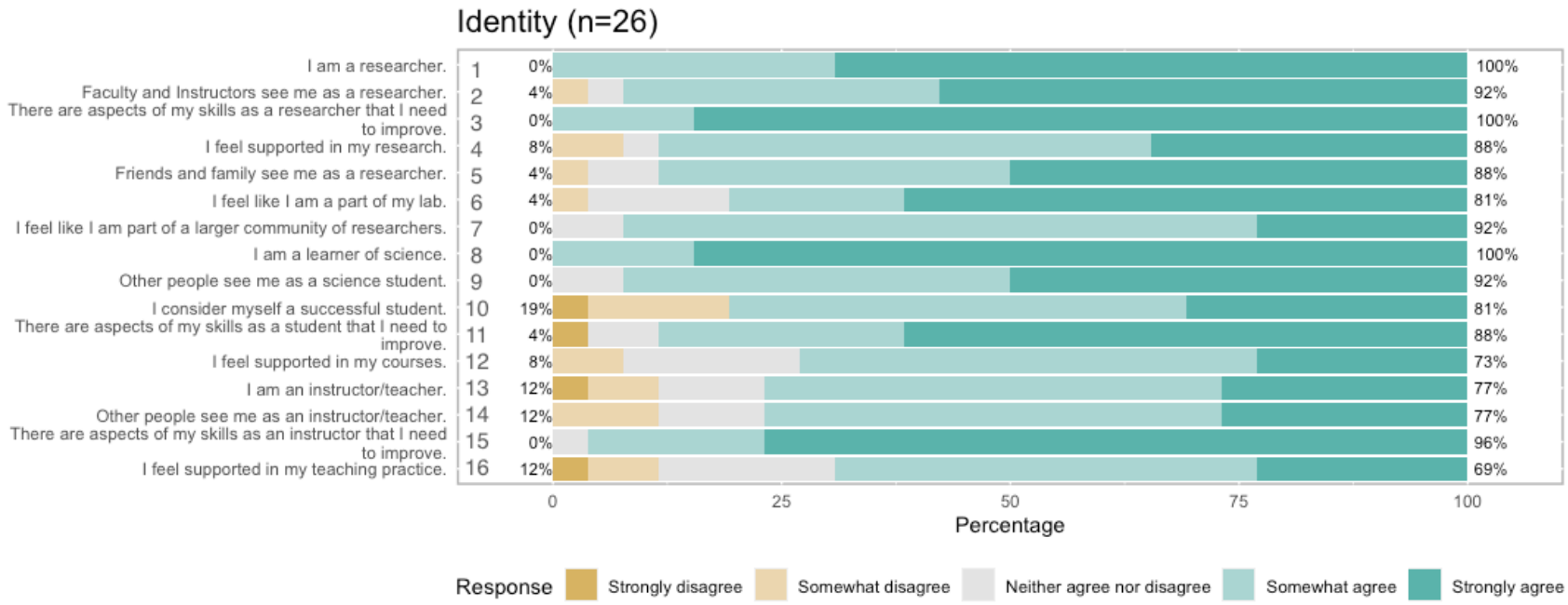

Figure 4.3: The distribution of responses for the Identity survey questions in the MTRS. Questions are grouped based on sub-identity type.

The second set of 10 Likert-type questions are related to the teaching and research relationship (Figure 4.4). Based on the patterns, a majority (95%) of the responding graduate students (n=24) acknowledge that one can be a good teacher and researcher, but the connection between the two roles is unclear. Half (50%) agree that there is a connection between research and teaching skills (Q9). Respondents acknowledge that teaching can help their research through the generation of new research ideas and that teaching will help them find other students who are interested in research (Q4 and Q6). In contrast, respondents were less likely to incorporate their students' ideas into their research or found that question to not be applicable at all (Q8). Most students agreed that conducting research is directly related to teaching students how to do research (Q1), but they were not necessarily inclined to share their research with their students (Q3). From this the directionality of the connections between research and teaching are not clear, but there is an opportunity to make those connections through the explicit discussion of overlapping skills.

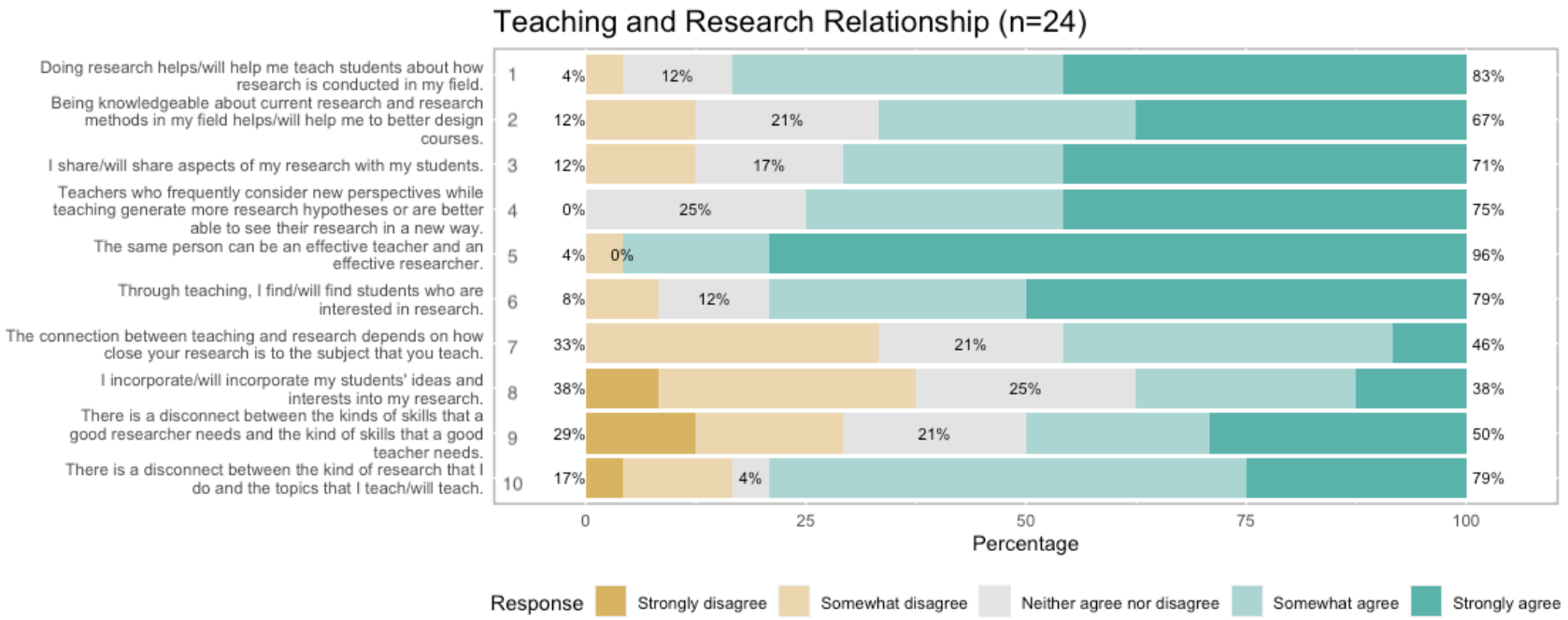

Figure 4.4: The distribution of responses for the teaching and research relationship (TRR) survey questions in MTRS.

The final set of 5 multiple choice questions illustrate the skills associated with either research, teaching, both, or neither (Table 4.7). These questions deviate from the canonical Likert-style and are consistent with the original survey design. The skills listed (knowledge development, communication, writing, creativity, and conducting systematic observations) have the potential to be applicable to both research and teaching (Figure 4.5). Based on the survey results (n=20), knowledge development was more closely related to research than teaching. Communication skills are developed from both research and teaching with some saying mostly teaching. Writing skills and conducting systematic observations are more research related. Lastly, creativity and thinking from multiple perspectives was related to both with some saying mostly teaching. Overall, the responses show the potential for understanding intersections of research and teaching based on transferable skills, but the extent of that understanding is unclear from the quantitative survey alone.

Table 4.7: Teaching and Research Skill Association Questions.

Question #	Question
Q1	Provides/will provide me with an opportunity to develop knowledge about my field.
Q2	Improves/will improve my ability to communicate about my field.
Q3	Improves/will improve my writing skills.
Q4	Encourages/will encourage me to view problems from multiple or new perspectives.
Q4	Improves/will improve my ability to conduct systematic observations.

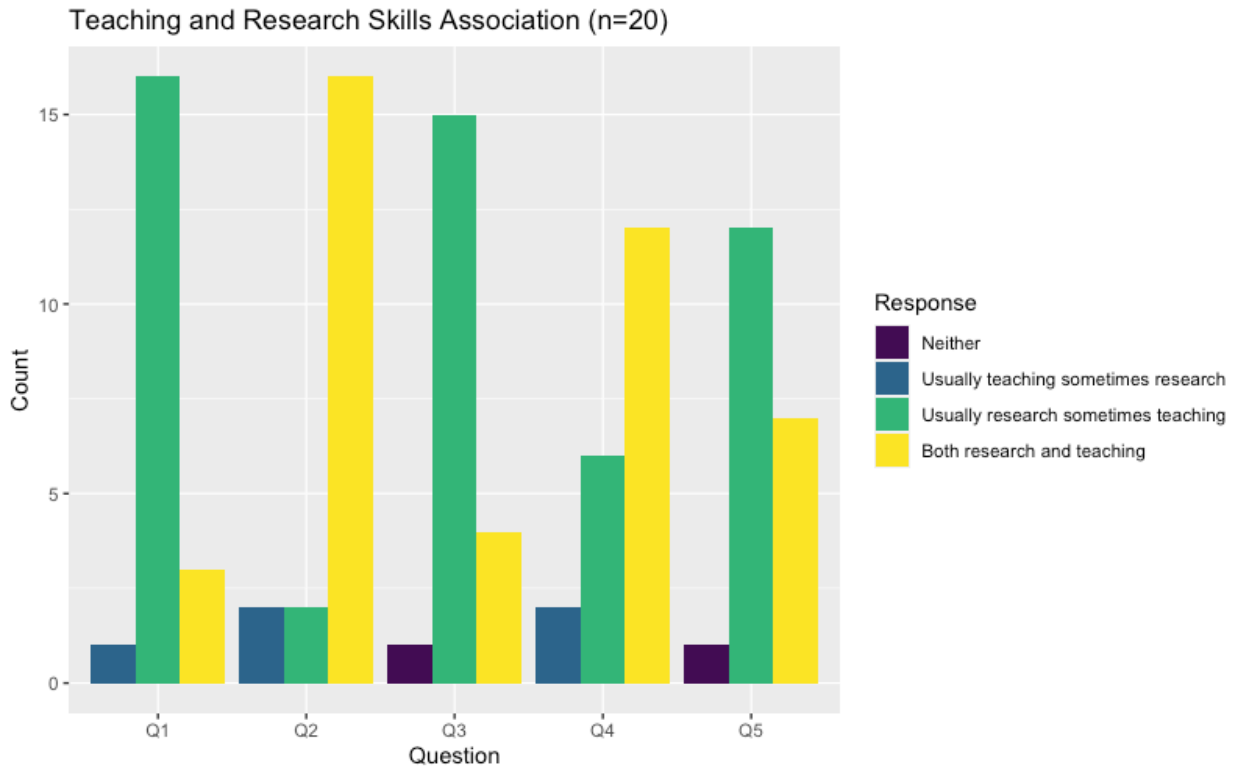

Figure 4.5: The distribution of responses for the teaching and research skill association (TRA) survey questions in the MTRS.

For the qualitative portion, the first two OEQs provided information about the perception of graduate student roles and how they manage them. All respondents reported that one responsibility was research, with five students only mentioning research as their primary role. Of the 19 respondents, 84.2% reported teaching as a responsibility. Students rarely mentioned

taking classes, learning, and mentoring as major responsibilities. In response to how students manage their roles, a majority (63%) mentioned highly planning their days through calendar apps and planners, while some (21%) also needed external motivation or were not managing well (26%) at all. The OEQs provided useful information about the overlap between teaching and research and were coded inductively to show the distribution of the perception of overlap (Table 4.8). The distribution is split between some perception of overlap and unsure of overlap. This is compounded with the fact that some students did not recognize or have teaching as a main responsibility at all.

Table 4.8: Overlap between teaching, research, and student responsibilities according to MTRS open ended questions.

Overlap	**Count**	**Percentage**
Yes	8	42%
No	3	16%
Unsure	8	42%
Total	19*	100%

*Only 19 of 26 responded answered the open-ended questions (OEQ)

Interview Results

As has been stated previously, the multifaceted nature of graduate education and the many hats graduate students wear has been studied extensively (Brown, 2016; Brownell & Tanner, 2012; Park, 2004; Tran, 2011; Weidman & DeAngelo, 2020). However, how students can be supported in this process is still a subject of interest. Students have been considered "neither fish nor fowl" (Park, 2002) and "sometimes fish, sometimes fowl" (Winstone & Moore, 2017) going from having an ambiguous niche to holding many roles, but what does this mean and what are the implications? The overall findings from this work is that students generally recognize their various sub-identities (research, teaching, student), but do not value them equally

nor are they always given opportunities to recognize and leverage the intersections of their multiple identities. The remaining qualitative results section of this chapter provides a description of GSID and the importance of support in development.

Based on the previously reported coding procedures, the coordinated identity constructs and resources codes provided insight into the types of identities graduate students developed, which aligned with the hypothesized identities of interest: research, teaching, and student sub-identities. The inductive codes, agency and confidence, in addition to the interest and competence/performance codes provided information about the identity subtypes from which themes emerged. Expansiveness and intersectionality codes provided insight into the intersection of teaching and personal identities with the research identity. Lastly, the overlap of persistence, identity constructs, and resources gave rise to the themes of graduate student support. The resulting themes are presented below (Table 4.9).

Table 4.9: Coordination of qualitative codes and emerging themes. One if not all resources codes were included in each theme.

RQ	Codes	Themes
1	Agency, Imagination, Recognition, Interest, Competence	Graduate students are teachers • Teaching identity requires agency • Teaching is knowing and explaining content • Teaching is mentoring
	Recognition, Competence, Interest	• Graduate students are students. • Graduate Students are life-long learners.
	Agency, Recognition, Interest, Competence, Alignment	Researcher/Scientist is primary identity • Researcher is proficiency in certain skills • Researcher is agency and greater impacts
2A	Expansiveness	• Research always above teaching • Teaching is part of the researcher identity
2B	Expansiveness, Intersectionality, Persistence	Personal sub-identities can conflict or intersect with the researcher/scientist identity
2C	Identity Constructs, Persistence	Relational, ideational, and material resources for reconciliation of sub-identities

The first section provides a description of individual graduate student sub-identity development; specifically, the first section describes the types of sub-identities that graduate students may develop and the resources and experiences that contribute to sub-identity development. The next section addresses to what extent graduate students perceive an intersection between teaching and research sub-identities. The third section describes the relationships between graduate students' multiple sub-identities more broadly. Lastly, the experiences and resources that support the development and maintenance of various sub-identities in context are outlined. Throughout the results sections, I will *italicize* qualitative constructs to illustrate direct connections between interview data, codes, and themes.

Graduate Students Wear Many Hats

Graduate student participants recounted their experiences as teachers, students, and researchers and the extent to which they feel a part of each sub-community or identity. Specifically, this section addresses the following research questions:

1A) Which sub-identities do graduate students develop as a result of experiences with teaching and research?

1B) What are the trajectories of sub-identity development?

1C) What experiences and other resources contribute the development of these sub-identities?

The three questions have been collapsed into one overarching question: Which sub-identities do graduate students develop and what experiences and other resources contribute to the development of these sub-identities? Results are reported in the following section holistically. Overall, research is the primary identity that other sub-identities generally develop around; however, the extent to which each participant identifies with each identity varies widely. First, I will discuss the research sub-identity development, also called the scientist sub-identity, and the affordances and constraints to developing this identity. Next, I will characterize the teaching sub-identity and the barriers and affordances to development. Lastly, I will describe student and learner sub-identities, which are least discussed and developed.

Graduate Students Are Scientists. Graduate students in this study primarily discussed the development of their scientist and/or researcher identities with other identities often developing in relation to this identity. Interview participants used the terms scientist and researcher interchangeably and in response will do the same here. Scientist identity development, according to graduate students in this study, can be categorized via two major themes, scientist identity as proficiency in certain skills and scientist identity as contributing new knowledge and

broader impacts. Each theme builds upon the next showing a progression of graduate student conceptions of a researcher identity as being *competent* to contributing to the science community more broadly.

***Scientists are Proficient in Certain Skills*.** Graduate students often struggle to call themselves full scientists or researchers and feel that there are some skills or *competencies* that are absolutely necessary to master before being able to call themselves scientists (Mantai, 2015). As far as specific skills, many of the graduate students were *interested* in improving their scientific writing because they had not been explicitly taught to do so. Being able to write and publish papers or write grants is one key component to *belonging* for many graduate students. Matthew talked about his struggle with writing at length:

> So it's the writing and the organization, especially for, I'm starting to put together my dissertation, at least the intro and sometimes it's hard to find all the papers because I know I had a system. And so, and I can't remember the names. Yeah, so, and everybody else seems to be able to, and I don't know why I can't.

Other students like Angelica and Enrique also mentioned that they want to improve their scientific reading and writing skills. Angelica specifically mentioned that graduate students are supposed to know how to write in a concise way, but that just reading other articles is not helpful for her. She said, "it's mostly just me, learning how to write better and being able to explain myself a little bit more in scientific terms." It is a struggle to learn to write papers with little direction on how to do so and that keeps students from feeling like they are scientists. Owen said, "I think after maybe a couple years of graduate school I'll have a better idea because, I mean, I've never written a grant. I've never written a paper." He doesn't feel like an academic researcher because he has not done those things yet, but he feels like he will once he does accomplish those goals. Writing research articles and grants is this black box in graduate

education and also seems to be a major scientist identity gatekeeper for science graduate students, according to previous literature (Nolan & Rocco, 2009; Zimmer et al., 2021).

In addition to writing skills, students noted their lack of proficiency in many laboratory skills which coincided with not identifying as full scientists. First-year graduate students especially mentioned difficulties in learning new laboratory skills because they had never been exposed to those techniques before. They felt like they did not *belong* because of the idea that they should know these techniques already. Mila said, "what I have to do in my research is like more pure cell biology things, pure biochemistry things and like I'm more aware of biochemistry things, but wasn't aware of that cell biology stuff so I had to do it, I failed several times." She had to change specialties when joining her new lab and she often made mistakes, which could lead to a sense of not *belonging* and as a result not feeling like a scientist. Overall, it is difficult to develop a scientist identity when one is struggling to learn the *valued knowledge* of the science community.

Relational resources such as support from faculty were integral to research identity development through the development of research competencies. For example, Mila said:

> When I started, I told my PI that I'm not a professional in this stuff so she understands and now if I'm going to do something I'm going to mess up something. Well, even if it's my fault, even if I shouldn't have made that mistake, she gives me some space to learn. Even if I fail, I know that the second time… I have my space to learn and develop myself.

She discussed how she was given space by her PI to fail and learn from that failure in order to improve over time. Alexia mentioned similar instances in which her PI was willing "to go over everything in detail" regarding her research project to ensure that she understood. She felt well *supported* by her PI as well as her labmates who were also invested in her success and often gave her advice.

Scientists Have Agency and Contribute New Knowledge. When students are given the chance to learn and improve in their scientific skills they then have the opportunity to reflect on their niche as scientists and how they fit in the science community as a whole, thus developing a stronger scientist identity. This is because as one learns the *skills of a community* they in turn can become *full members* and negotiate their place in the community as an *insider* in that community (Wenger, 2000; Wenger, 1998). From the student perspective, they describe being a scientist as having agency in their work, being able to make something new, and having a broader impact on the community.

Emily expressed her interest in, "pursuing a research scientist kind of role, like in a national lab and kind of go out and do my own thing, be able to kind of structure more of what I'm doing instead of just kind of following rules and having someone tell me what to do." Emily seems to value her independence and individual *agency* as a scientist. She wants to pursue her own interests rather than someone else's. As well, students like Alexia emphasized the importance of *agency* and self-motivation. She said, "you don't need to be told by someone to go to your work. You just go and do your work and then you present it." She went on to say the scientists should be self-motivated because it is one's own work that *interests* them and that she will feel like a scientist when she comes up with something novel. Essentially, to Alexia, being a scientist means pursuing your interests and contributing something new. Even more senior graduate students like Parker struggled with this aspect of their science identity. He said:

> This last year where all of this has been going on has actually been huge in my growth because it's the first time I've really asked myself: What is it that I want to study? And I forced myself to sit down to come up with a proposal that's waterproof for how to actually study that thing.

He was at the point of defending his dissertation and looking for postdoctoral positions and had just reached the point of finding what it was that he wanted to study in the future. Owen on the

other hand mentioned that his PI "respects [his] independence" and would give him advice without "micromanaging," in turn providing him with a sense of *agency* in his work. From this we see that some students are afforded agency at varying time points depending on their lab placement, but based on the general need for agency it may be beneficial to provide this opportunity sooner rather than later.

In addition to valuing agency as a scientist, students grappled with *defining a niche* in their field. Nathan, for example, said, "I mean like I don't feel like I'm a chemist, though, but I don't feel like I'm a physicist either. I feel like I'm in between." He struggled less with identifying as a scientist, but more with the type of scientist he would be. Angelica grappled with this issue as well. She said:

> I've always liked science ever since high school. I've always been intrigued about chemistry. And then once I got introduced to biomolecules. I just didn't want to stop. After that just structural analysis and being able to do stuff like from my computer just really intrigued me so I really liked the computational part and then kind of opened myself to other fields. So I started kind of merging towards that side. I thought as a scientist, I need to have more broad scope. Instead of doing dry lab work, I needed to experience wet lab also. So pretty much, there's the reason why I joined my lab because it's a little bit of both.

She wanted to merge her science interests to carve out a niche in chemistry. This personalization and *negotiation* of one's place in a community illustrates her scientist identity development and her trajectory as an *insider* in the community.

Along with finding a scientific niche and having agency, students emphasize the importance of creating new knowledge that contributes to the science community more broadly. There is a need to make noticeable impacts in science and society. Jacob, for example, described his progression of becoming a scientist once he was able to publish his research and contribute to the scientific community:

> I think that when I got to grad school, then I actually started doing research, and I felt more like a scientist. But, I think, for the first few years I felt like I was a terrible scientist. So then I was like, well, does that even count? And so that took a while. But I think the last couple of years I felt much better about calling myself a scientist and in my scientific abilities and I finally published a paper, which means that I've actually contributed to the scientific community now, so that feels good.

He did not feel confident in his researcher identity because he had not contributed to the community in a meaningful way and once he did he was able to *recognize* himself as a scientist. This could stem from the emphasis on publishing as a graduate student and the competitive nature of chemistry graduate programs as well (Seymour & Hewitt, 1997; Shortlidge & Eddy, 2018). Learning new techniques and carrying out experiments was not enough for Jacob to call himself a scientist even though he was performing the duties of a researcher. This hints at a need for support in researcher identity development such that students are able to recognize their *competence* sooner and value that competence in basic research tasks.

As far as having a tangible impact on science, Henry mentions that he has considered other careers, however what appealed most to him was science because he could have a significant impact on society. He said:

> You know, I have a very strong sense of my having a role in the world at large. As a scientist. It's not an isolated career. It does have an impact. It should have an impact. I took a number of classes in undergrad, to try to gain a better sense of how science fits within a larger system because I want my career to have an impact on people. I wanted to improve people's lives. I want to share my advantages with others. And so that's why I want to go into academia.

He identifies with being a scientist because he *values* being able to help others and sees that as a significant part of being a scientist. Adam also shared this view; however, as an older graduate student he found that over time his *ideals* of helping others did not *align* with the goals of his lab and his project. He said:

> I thought I would be working with these enlightened people working together to make the world a better place and kind of tackling the biggest problems in the world at this big institution and I realized that nobody wants to make the world a better place. Everyone wants to get famous and that research isn't done because it's important and needs to be done and is going to help. Research gets done because he's like, I can see a place where we can publish this good paper and get our name out here.

His idea of what a researcher is was shattered and he was highly discouraged by that. He didn't feel like his, " research [was] meaningful and valuable in any way." This shows that if one's *values do not align* with one's work, further identity development may not occur. There is evidence that graduate students value having an impact on the world and when that does not come to fruition that can discourage persistence in the field (Tran, 2011). Therefore, in order to prevent other students from encountering this same conflict they need support in aligning their work with their values and ideals.

Graduate Students Are Teachers. In the context of chemistry graduate programs, the teaching aspect of graduate education is a major factor in the graduate experience and identity development since most chemistry graduate students will teach at some point in their program (Golde & Dore, 2001; Kuniyoshi et al., 2021). This leads one to wonder: how do chemistry graduate students perceive teaching? Do they see it as a form of employment, a burden, a learning experience, training for a future career? What can be said is that graduate students form *ideas* about teaching, how they *align* to those ideas, how they *imagine* themselves as teachers, and their *competence* in it. Each of these aspects contributes to a teaching identity held at least in part within the context of graduate school. These include the following themes of teaching identity: teaching requires agency and creativity, teaching is knowing and explaining content, and teaching is linked to mentoring.

When describing graduate students' teaching identities, other research has demonstrated graduate students often do not refer to themselves as teachers. Often those that do identify as teachers have some past teaching experience either as an undergraduate in their content area or even teaching experience outside of higher education (Lane et al., 2018; Zotos et al., 2020). This was the case with Nathan, who described his past experiences as a martial arts instructor. Alexia described her background in teaching at her undergraduate institution and that she was also inspired by her mother who is a teacher. Most other students only had teaching experience in their graduate program.

Some students like Mila have noted that they enjoy teaching but are afraid of losing out on research time due their investment in teaching, which is a common fear for graduate students (Shortlidge & Eddy, 2018). These students may feel that they are good teachers, but do not necessarily want to pursue teaching as a career or work in a job that requires teaching. Simply *being recognized* or *recognizing oneself* as a good teacher does not mean that graduate students will want to teach in the future such as in an academic position. Some students in this study seemed to understand the extent of the work that is required to be a good teacher and as a result would prefer to spend that time and effort on research.

Teaching Agency and Creativity. While students in this study often self-identified themselves as teachers (50%), many did not due to the lack of agency they had in designing and carrying out their courses. Students often felt that "teacher status" was something they had yet to reach because they did not have their own class to teach and they did not make their own materials. In contrast, others strongly identified as teachers because they had the space to make their discussion or laboratory session their own. Previous work (Lane et al., 2018) shows that when students are given *agency* in teaching through more independent teaching experiences this

can lead to teaching identity development due to *recognition of self* as a teacher, as well as recognition from others. Of course this requires individual as well as collective agency (Bandura, 2000) such that students have a hand in course design while more experienced others provide resources for successful teaching. For example, Jackson shared:

> Oh yeah, I call myself a teacher. Actually, when talking to friends and stuff, I mean, I explain I'm a TA, but I definitely consider myself a teacher especially because, since it's a zoom class...I can spend more time lecturing than I normally would have because they don't have to do as much within that time. So what I do is I make PowerPoint presentations associated with the lab and I always try to add in the big picture.

He went on to describe how he incorporated real-world examples into his lab section lectures and his students responded well to his additions, providing a level of *recognition* that affirmed his self-identification as "teacher." His students saw him as a teacher due to his innovations and *agency* and he *recognized* himself because he was able to do those things. Alexia described a similar feeling:

> Right now, yes, I guess, I am a teacher, because I do everything that teachers do. I review material, I put my slides together, and I put material together and present to them and then I grade. So yes, I guess, technically I'm a teacher, I do everything that teachers do.

She still qualifies this by saying she is "technically" a teacher, however due to her sense of *agency* and *performing teacher tasks* she is able to call herself a teacher. This, however, is not often the case for many graduate student teaching assistants (GTAs) in this study.

In the case of providing training in order to do more innovative teaching, one student had some issues with the practicality of the information they were learning. They felt that despite having *teaching support* in a quarter-long course at the RFU, the pedagogical skills they were developing felt far *removed from practice*. Henry said:

> So we would be given the opportunity to talk about some things that were being discussed in class as a group. So there was some group work that we did, but

> again it just felt isolated. This was stuff to worry about [in class] and it stayed there. It didn't transfer as much.

He discussed the idea of learning by doing much like an *apprenticeship*, which was not happening for him and his classmates. While they may have been exposed to certain teaching techniques, there was not as much support or opportunity for carrying them out in practice.

In addition to these issues, graduate students tended to not see themselves as teachers because they mainly perform what they consider menial tasks including acting as "babysitters" in labs and serving as graders**.** They often did not have *agency* in designing courses, were not given the tools to make *connections* between the teaching practices introduced in their training and practical *applications of that knowledge*, as described above, and are only given explicitly prescribed tasks. Angelica points out this issue when she said:

> I, myself, wouldn't consider myself as a teacher. It's like I just, not to be put in a mean way, by calling TAing as more of a babysitting job because I'm literally just there to make sure that the students should do their lab work. They clean the glassware, they put everything away, and they don't get hurt in the process...It's like, oh, we're doing calculations, just set up your apparatus, do this, and then you're out. Just clean it and we're all good...I wouldn't consider that teaching because most of it's just them on their own. So you're just observing and that's about it.

She felt more like a safety manager who was far removed from teaching content. This is further supported by Alana who said, "Sometimes the people that manage like the lab coordinators and the professors, I think they just see the TAs as like babysitters and that they don't necessarily see that we have the capacity to actually educate and teach." She feels like she has the *capacity to teach*, however she is not given the *opportunity* to do so. Lack of access to *legitimate teaching experiences* leads to a stifling of teaching identity development even when GTAs are *interested* and *competent*. Despite these barriers to teaching identity development, graduate students do *value* certain aspects of their teaching experiences.

Teaching as Knowing Content. Equating teaching with knowing content is another major theme of teaching identity. Some graduate students in this study did not consider themselves to be good teachers or good GTAs because they were not *competent* at explaining topics or think they will be better teachers if they learn the material better. This notion could be tied into their perceptions of professors as holders of knowledge and that in higher education professors must know everything (Wheeler et al., 2017). It is interesting to note that this idea of teaching is more common with first-year graduate students across both institutions, meaning that this may be a notion that changes over time as graduate students gain more experience in teaching.

Students with this conception of teaching often mentioned needing to "think quicker" to answer all student questions and that improvements in teaching will come from a strong content background. This could be linked to student identity as graduate students are also taking classes that often have the lecture format in which the professor is the expert and holds and disseminates knowledge. Thus their own experiences with teachers and professors may play a large role in how they model their own teaching (Lane et al., 2018). For example, first-year student Owen, described a professor's teaching style as less personal or from a book and that a professor disseminates knowledge to the class. He views the teaching that professors do in in their own research labs as a completely different type of teaching. He goes on to describe his teaching style and how it is reflective of a professor with a lecture-style of teaching that involves knowing and conveying content, whereas teaching in a research lab is more related to mentoring.

Other students echoed this claim, such as Luis who said, "Knowing the subject deeper, that's always something I want to improve on." He regards teaching as knowing content and that if he can do that, he can be a good teacher. Others expanded on this idea by saying they want to review the content so they can ask better questions of their students and more easily answer

student questions. These *ideas align* with the idea of the teacher as the holder of knowledge and the student as the receiver.

Some students described teaching as going beyond knowing content and emphasized knowing how to explain content in many forms. This means that teachers, specifically GTAs, should know the content and be able to explain the content in ways in which different students will understand. Steven described this idea:

> A good TA needs to be able to explain a concept in multiple different ways because a while they might have learned it, and it might have clicked with them in a very specific way. It's not going to work for everyone. So you need to be able to come at it from a bunch of different angles.

Nidiya expressed a similar sentiment:

> But like taking a step back and realizing, hey, like, not every student learns the same way. Some students might learn this way. Other students don't learn that way, some will be visual learners. Some students are auditory learners. And so because of that, like you want to try to cater to that as much as you can. Because if you think about it, like if I was in their position and I was really struggling to learn the material and I had questions of course I'd want them to be answered. Right. And so I think that's something that's really important for a good TA to be able to know how to do.

Taken together these students show a need for teaching skills beyond delivering content. Nidiya extended this idea of multiple ways of learning and knowing and added that one must be empathetic to the needs of students. They both *reflect* on their own learning experiences and conclude that not everyone learns the same, thus as a teacher one must make the effort to personalize learning to the specific students they teach. These skills however are difficult to develop without support as will be described later and while graduate students may *value* these *competencies* they may not have a means to develop them.

Teaching as Mentoring. Some students described mentoring as a part of teaching and that being a good GTA meant being a good mentor to students. Students with this idea

mentioned explaining content in a variety of ways in order to make sense to students but went beyond that to describe the mentoring aspect of gaining the trust of students and forming a good relationship with them. Parker described this:

> The role of teacher and mentor are really intimately intertwined and the way I approach my teaching is like a person first mentality. Because if you can give the person space to come to the table, I think that they will absorb knowledge more effectively, listen more. They'll be willing to be challenged because you're asking them to be challenged more because they trust in you and in the interaction that you're having with them.

Parker continued on to say:

> I think it's good to be liked by your students, to a degree. So I think that that was always, it was always easier for me to feel like I could form that human connection with somebody that I related to the teacher, student relationship or the mentor, mentee relationship. I always felt like I could get that a lot easier and feel like I was in this position of having wisdom to share with someone who didn't have as much.

Parker values trust and a mutual relationship with his students. He describes a mutuality to teaching and mentorship that allows both parties to thrive. In this way, he gives his students confidence through the *mutual negotiation of knowledge* and receives *recognition* as a good teacher because his students are encouraged to provide feedback. The development of such a relationship is unique among student participants and is only brought by more experienced graduate students preparing to graduate.

Nidiya recounted a similar ideology. She thinks that "it's kind of an overlap right between being a TA and like being a mentor." She *relates* this back to her undergraduate *experience* as well and that she valued GTAs who did these same things as well as referring to her pedagogical content *knowledge* of knowing that there are different ways of learning, integrating both formal and experiential knowledge in her perspective of teaching (Horn et al., 2017). Nidiya in particular emphasizes the importance of empathy and patience especially because she at points

had been impatient and realized that was not serving her students. She describes key pedagogical knowledge, which she learned more through her own *teaching experiences* and talking with *peers and mentors*. Her knowledge was not developed in a training course, but through her own *interest* in improving as an educator. This is not always the case for graduate students, due to interest and time barriers (Lane et al., 2018), therefore this perspective may be rarer among chemistry graduate students. The next section describes student sub-identity development as scientists-in-training and as life-long learners.

Graduate Students Are Students. While from some perspectives the idea of being a student or learner can be considered a part of being a researcher (Castelló et al., 2015), these roles can also be fairly distinct in graduate school. In some cases, one may consider themselves as a science student and as they become more proficient and show their *competence* come to consider themselves scientists. Often students will refer to themselves as scientists-in-training implying that they are learning to be scientists. This learning is happening in classes and also in the laboratory. While in coursework the learning goals may be more explicit, the learning through research may not be as clear. Adam, a seventh-year graduate student, felt more disconnected from learning science:

> I don't really feel like I'm learning anything about science. I think I probably would enjoy it if I was. At this point, you know, what am I learning? Last year I learned a lot about academia. I don't know a lot about the science itself and running the same crap over and over and the same thing predicated on the same ideas and troubleshooting and trying a million different things that don't work.

Adam does not feel like a science student or that he is learning from his research experiences. Adam describes in more detail that he felt that his research experience was more about making a huge discovery and his PI seeking clout and fame. Understanding the science and learning were secondary.

Another example of this disconnect comes from Luis who did not consider himself a good student because he did not come into graduate school with good grades, a *material resource*. He said:

> I had a 3.0 GPA so that's kind of the minimum to get into grad school. So I've kind of had this mindset of like I have to be good in every other way because apparently I'm not that good of a student. So I need to be good at research, I need to be good at talking, I need to be good at everything else.

He noticed this pressure to prove himself in other aspects because he was not a good student. He needed to go above and beyond in research and presenting his research in order to counteract his low undergraduate GPA. He later mentioned his imposter syndrome, but that he would use his position he was "lucky" to enter into in order to "get all the benefits and help that all these geniuses are getting." He ultimately was *committed* to learning and improving in order to combat his poor student identity.

Other students described themselves as life-long learners because learning is an integral part of doing science. They said that there is always something new to learn and they appreciated this aspect of being graduate students. Steven said:

> I would definitely say I see myself as that [a science student] especially while I'm pursuing my PhD. There's still like so much more to learn. Even in just like the courses they offer for the first years or book or whatnot, you know, like eventually stop taking those courses and you can still learn because you read papers in your field and all that and you do your experiments to learn more about the field.

Steven acknowledged his role as a life-long learner and even after he has finished taking classes he will always learn something new. Carly recounted a similar *idea* and as a first-year student taking classes she is more attuned to the idea of being a student. She said she feels like she's "barely scratched the surface" and there is "definitely a lot more to learn."

Alana described the *idea* that "grad school is learning how to learn differently and is so different from undergrad." So not only are they learners, but they are learning how to learn in a new way. There is this element of creating new knowledge and discovery. This *idea* can also be *motivating* for students such as Parker who said in response to being asked if he considers himself a continual learner:

> I think that has been a necessary mindset for me to remain resilient enough to survive this long. Then if I didn't accept this idea that I can learn more and that if I do learn more, I will be better. If I didn't think those two things, then there's no way I would have made it this far.

He attributed being a continual learner as an essential part of his success. To *value* learning and to continue learning new things is integral to who he is. This is in contrast to Adam who felt like he was not learning anything new and as a result did not feel as successful. Graduate students who had fostered a learner identity acknowledged that they have the ability to grow and improve, which may in turn strengthen other sub-identities such as the scientist or research identity to be illustrated next. The following section will address intersections of teaching and personal identities with the research identity and provide a summary of resources and support needed for the reconciliation of multiple identities.

Graduate Students Are More Than the Sum of Their Parts

Despite the siloed perception of graduate student roles or sub-identities, identities do intersect and often students must quickly transition from one to another or figure more than one identity at any given time (Figure 4.6). Here, graduate student identities are both one and many and together mean more than the sum of their parts (Crenshaw, 2017; Wenger, 1998). Students note the intersections of teaching and research identities as well as the intersections of personal and research identities. From this, resources were identified in supporting the development and maintenance of multiple sub-identities. In addition, when given the opportunity to operate on the

boundary of two sub-identities more positive outcomes were reported and contrarily negative outcomes were seen when students were pushed to fully separate out their sub-identities.

Figure 4.6: This representation illustrates the coordination of graduate student identities with research being the most salient and central.

Intersections of Teaching and Research. Similar to the teaching and research intersections investigated in the MTRS, graduate students were asked about the intersections between research and teaching and the benefits and drawbacks to teaching and conducting research simultaneously. With this information, this section addresses the following research question:

2A) To what extent do graduate students perceive an intersection between teaching and research sub-identities?

Students take two distinct stances on the subject of research and teaching intersections: a) research takes priority and teaching is not always necessary for being a scientist and b) teaching is an integral part of being a scientist.

Research Takes Priority. In accordance with previous literature, graduate students in this study emphasize research responsibilities as their priority with all other duties becoming secondary, including teaching. Both students who see some links between research and teaching and those who do not see links hold this view; however, those that do not necessarily see the importance of teaching and its connection to research are more likely to deprioritize teaching. Steven, who *recognized* himself as a teacher, still asserted that research is his priority and teaching is something he has to do on the side. He stated:

> The [research] rotations were the most important part. I did enjoy teaching and I thought I did a decent job, but the rotations are kind of the thing that's going to decide my trajectory for the next five years versus teaching is just a quarter to quarter thing.

He held this view despite the fact that he enjoys teaching and he feels he is good at it. This is often the case according to previous studies (Lane et al., 2018). *Interest* and *competence* alone are not always enough to encourage students to *value* teaching. This is not to say that graduate students are doing something wrong but that other resources external to the student are needed to convey the importance of teaching. Mila shares a similar view:

> To be honest, because even though teaching is fun and even though it's helpful, I still feel like I am investing so much time in teaching that I might have less time for my research and that scares me. That’s the only thing that I have an issue with teaching, otherwise I am so glad that I'm teaching.

Graduate students in this study perceive a teaching-research tradeoff (Shortlidge & Eddy, 2018) and see it as a major obstacle even when they do have teaching interests. There is still an issue of time and limit on the amount of time students can devote certain roles.

Other students also mentioned that teaching experience is not necessary for all graduate students and is only beneficial if one has a goal of staying in academia, such as becoming a professor. In response to being asked whether teaching should be required for all graduate students, Alexia said:

> I don't think so. It depends what you want to do after you graduate. If you want to go and be a professor, then yeah of course it is. But if you just want to be a researcher, then I don't think it's very important to have a teaching experience because you just do your own work, like when you're a researcher, you just do your own work.

She *aligned* the importance of teaching with a future career and as she did not aspire to that career, focusing on teaching was not as important as her research duties. She also did not describe any tangential benefits to teaching that could translate to research.

Nathan had similar views and while he did acknowledge an overlap in skills between teaching and research he affirmed that teaching experience is not always needed:

> I will say that the presentation skills are helpful right, but that really isn't necessary. If their information is good it's presented in itself. They kind of like are just there to be the body that pushes the button to move the slide. So, at that point in time, your presentation skills really don't matter if you can convey your logic very well like what your slides are with your written words.

Here, he is saying that while teaching can be helpful it's not necessary for being a scientist as long as someone does quality research. Owen also said that "teaching is just a job" and is just "something to get done." From their views, teaching can be separated from research and as a result these students may not develop strong teaching identities and do not prioritize those duties and skills. In contrast, a majority of the student participants did see teaching as being an integral part of being a researcher, as will be described next.

Teaching is Part of Being a Scientist. A majority of graduate student participants (89%), regardless of the stage in their program, recognized connections between research and teaching

and *valued* both roles; thereby, developing *integrated* teaching and research sub-identities in which they operate on the *boundary*. Students recognized the importance of teaching roles in developing communication and presentation skills, reviewing science content, and generating new science ideas.

Steven described the importance of teaching in improving science communication. He said, “If you're a scientist, but you can't explain your science to somebody who is outside of your field, you're not very good in your field. You need to be able to do that.” He emphasized that teaching experience is useful for developing better communication skills and those skills are absolutely necessary for being a good scientist. Henry added that, “Science doesn't matter if no one knows what you did. You have to be able to communicate what you did with people.” He went on to say that a way to ensure that you can do that is to teach and use those *transferable skills*. Presentation skills are important to many of the students in the study and they note that through teaching they have been able to improve upon those skills. Emily said, “[Teaching] is something that I really need to keep on working on and just like getting more comfortable talking in front of large groups.”

In addition to improving communication skills, students cite reviewing content and coming up with new science ideas as important skills that are developed through teaching experiences. In response to being asked if teaching experiences are necessary for graduate students Mila said:

> I think yes, and there is a very specific reason why. So whenever I personally am teaching something I am thinking about that topic more, I get more ideas. So it doesn't matter how simple it is or how difficult the topic is I'm teaching. It still makes me think about some topics deeper and maybe it's going to be good for my own research. Maybe I will get more ideas about what I can do with my research. And that's why I think that it is very useful for the grad students.

Steven also said that teaching is:

> Just more chances to explain things in different ways, which I think will probably become useful when I'm trying to pitch ideas and proposals and whatnot and when I'm trying to think about new concepts and also when I'm going back to old concepts. If I've taught it that just deepens my understanding.

Both students acknowledge that teaching will strengthen their knowledge which in turn enables them to formulate new ideas and expand their research.

Parker, who also held a more sophisticated view of teaching, expanded on this *intersection* further. For background, Parker had recently taught as an instructor of record for a summer chemistry course and was provided the *agency* and *material resources* to teach his own course. As a result of this experience he explained that:

> I've been trying to work on, through largely actually my development as a teacher, is the importance of critical feedback. I want to be able to give students feedback that is critical that can help empower them in the long run.

He noticed the value of providing critical feedback to his students and that in doing so they were able to improve in the long run. He *connected* this experience with a discouraging experience he had regarding his research. He recounted:

> The very first grant application I put together for this postdoc proposal I sent it off for review and I got back that it was not even discussed. So it was the lower 50% of all of the grants that they had reviewed for that application. And I don't think I've ever felt imposter syndrome so strongly since that moment. So that was definitely a really big like "This sucks." I don't know if I can do this. I don't know if I'm capable of it moment for sure.

He felt a sense of *not belonging* because of the rejection and negative comments on his postdoctoral grant proposal. He had not encountered that level of rejection before and did not know how to handle it at first. However he added:

> I need to be able to look at the feedback that I received the same way. So I think like, once I let the emotions of the situation settle, I was able to think a little bit more logically about it. And the really cool thing is that I learned so much from the feedback I got from the reviewers as to why they didn't even want to look at it

> and I understand what they meant now. Yes, then the new [proposal] is so much better.

He made *direct connections* between his ideas about teaching and his own work such that it encouraged him to continue and improve upon his own work. He held himself to the same standard of his students and was able to move past the initial rejection to improve just like a student would need to keep working after receiving a poor grade.

Taken together students often see connections between teaching and research, but only unidirectionally as is seen in previous work (Gilmore et al., 2014). Student participants recognized that teaching can be beneficial for their research but did not discuss how research can be beneficial for their teaching. Thus, the connections between sub-identities generally center around the research identity and reflect the priorities of the academic community.

Resources and Experiences to Sustain Intersecting Personal Identities. Enculturation into a graduate program includes not only learning from more experienced others but leveraging the identities and experiences of graduate students as they negotiate their place within an academic community of practice. This means that in order for graduate students to enter and belong in a community, enculturation should not just equate to assimilation. Assimilation can refer to the blending in of newcomers into the rigid norms of a community. From the literature, enculturation includes the mutual negotiation of norms, meaning that norms and roles can and will change over time; thus, graduate students can learn from the existing structures but should be afforded the opportunity to change those existing structures allowing who they are as people to add to the culture (Brown et al., 1989). As a result, graduate students can have the opportunity to take ownership over their place in the community and feel like contributing members or even insiders in a community that had once appeared exclusive rather than inclusive. When operating at the boundary of multiple sub-identities, one can reconcile or understand how they intersect

and how to navigate that nexus of multi membership (Wenger, 2000). However, graduate students cannot always reconcile their multiple sub-identities on their own within institutional power structures and others within the community, namely oldtimers and those with power in the community, should provide opportunities for graduate students to reconcile their identities and operate on the boundary of multiple identities. With this in mind, this section addresses the following research questions:

> 2B) What are the relationships between graduate students' multiple sub-identities more broadly?
>
> 2C) What resources do graduate students access in order to make sense of and sustain various sub-identities simultaneously?

Personal sub-identities that student participants discussed included socioeconomic status, race, gender, age, mental health, international student status, as well as personal interests and hobbies outside of science. This section illustrates the conflicts between and reconciliation of sub-identities and the resources that can be useful for reconciliation and support in identity development.

Conflicts Between Multiple Sub-identities. When making sense of various sub-identities graduate students may enter into situations in which their personal identities and situations are in conflict with or put entirely to the side for their research identities. Being placed in this position can often lead to more difficulties for graduate students (Afonja et al., 2021; Sharpe et al., 2018) because they are not able to fully be themselves.

Multiple graduate students discussed that they needed to put their other identities aside and focus on research in graduate school. Alexia said:

> You need to put it [personal life] aside and be more focused on school. You have to be focused on researching in school. So I guess that's one of the sacrifices that

> you make as a grad student. I barely started but I'm sure after some time, it will get harder. So I'll have way less time on my personal interests.

Alexia is a first-year and from her limited experience she anticipates that she will only get busier and accepts that she will not have time for much else besides research. Matthew had a similar mindset. He said that he spends a majority of his time in the lab, including weekends. His boss "really wants about 60 hours a week at least" and he keeps to that, if not more. He says work is his primary focus and he does not spend much time doing anything else.

Angelica described a similar experience and reported that she was struggling with her sense of self due to the amount of time she spent on her research. She said she spent a majority of time in the lab because she was tasked with helping her PI build his new lab. She learned a great deal in that time including the logistics of ordering equipment and materials and preparing a laboratory for use; however she said:

> As a grad student at least ever since I started the grad program, I think my head's always revolved around school and just lab lab lab lab work. So I think it plays a really huge role, especially the person I am, because I now see myself analyzing a bit more like what I'm doing, how I'm managing my time…That's really affected me.

She became critical of how she was spending her time which affected how she saw herself, her identity. She noticed that who she was as a person was fully taken up by productivity in laboratory work.

When students in the study did bring up personal identities they often noted how they were in conflict with their research identity. Alana in particular mentioned conflicts with her age and her research identity. She graduated with her bachelor's degree in 2008 and pursued a different career prior to changing gears to chemistry. Her family members were *not encouraging* of her *interest* in chemistry and stated that, "Oh, no, it's too late for you." She also had, "internal messages that really gave [her] a lot of doubt." She asked herself, "why would people want some

old lady applying to grad school?" This ultimately pushed her not to pursue a chemistry degree for many years before she finally applied. Even after she joined the masters program she felt like the odd person out because of her age and noticed there was not much support for "non-traditional" students like herself.

Students also noted issues due to their socioeconomic status. Graduate students generally have stipends that are not adequate to live on (Kuniyoshi et al., 2021) which is also the case for students in this study. Nathan, Owen, and Luis all discussed their financial issues and how they had to handle it in the program. Nathan had to move back home after trying to live on his own, while being supported on just his stipend. He said he was "breaking even with bills" and essentially living paycheck to paycheck. Luckily, his parents lived in the area and were willing to have him live at home. This did not go without challenges as he had to live in a home with kids, which proved to be challenging while working from home during the COVID-19 pandemic. Luis also had issues with money, but without a parental safety net he had to work for a local food delivery service to make ends meet in his free time. He found it difficult because it did interfere with his lab time, but that it was necessary for him to live in the area. Owen also took up an additional job. He was "tutoring students to make a little more money" as well. He still struggled financially which contributed to other problems at home. He said, "I'm definitely not getting paid what I'm worth because I have to live in this whole terrible, not awful, but pretty not safe place." He had to live in a place where he dealt with theft and other issues due to his low pay, all contributing to stress outside of research.

The two international students also cited issues that interfered with their research. Alexia said she "mostly had a negative experience with administration" because there were delays with her stipend and tuition payments, which took up a large part of her time. Her PI did attempt to

help, but her status as an international student and poor institutional support caused some delays that interfered with her work. In addition she was worried about getting to school without having a US driver's license and as a result was preoccupied with acquiring that. Mila also struggled being an international student as she was in a new country and it was her "first experience living independently." Both students went through major life adjustments while getting started with their research that other students would not have necessarily had.

Reconciliation of Multiple Sub-identities. This section provides examples in which students were afforded the opportunities and resources to reconcile their personal identities such as race, ethnicity, and gender with their research identity. This means that graduate students were able to recognize the *intersections* between their identities and *value* their sub-identities individually and as part of a larger whole. Graduate students were given the opportunity to be people in academic spaces.

While some students asserted that their personal identities were not as important as their research identity, others emphasized the importance of having other interests and being their full selves. Steven described his cohort positively because they also had interests outside of science. He liked that they "talk[ed] about things other than science, which is always a good trait to have." He said, "there's nothing wrong with having a bit of science talk, but you know if that's your only thing about you it becomes stale a little bit quick." Luis, who was in the same cohort as Steven, said that he prioritized his health and fitness while in graduate school. Alexia, who initially did not find it important to take time for herself, said in the second semester of her program that "it's very important to have fun, even if it's just like after school to go with my friends and drink and talk." She realized that making time for herself was important and she

needed to do so for her own mental health. Parker, a sixth-year, expanded on this idea when he described his identity:

> I am somebody who definitely does not look at my identity as solely a scientist. I have a lot of other interests and it's important to me, for my own health and well-being, to try to engage those other interests as well.

He valued his *multiple identities* and acknowledged that cultivating those was integral to his success. He said, “I no longer look at my career as much as the thing that satisfies me. What I've learned is that the work that you put your soul into will inevitably have points where it's not feeding you anymore, so I need to have options to look into to feed myself instead.” Essentially, he is saying that work will not always go well and fulfill you, thus having other interests and finding other sources of enrichment was vital for him. Owen, as a first-year, shared a similar philosophy:

> I think people are working themselves way too hard in graduate school. And so at the beginning I'm like, you know, I'm going to try to make this work on my own, at my own wavelength and my own speed my own style. I'm going to go surfing on the weekends. I'm going to go out. Well, I can't go out, but I'm going to hang out with my friends and do whatever on the porch.

Owen was already aware of the over-working culture of graduate school and committed to tailoring the experience to his *personal* needs rather than fitting into the status quo. Enrique echoed this idea as well because he had noticed the same cultural norms of graduate programs. He said, ”some people think you need to be doing science all day, every day, or you need to be focusing only on science and not have other activities,” but he did not agree with this mentality. He made sure that he “start[ed] the day not doing chemistry and end[ed] the day not doing anything related to” chemistry. He made time to decompress and take care of his mental health. He also shared his aspirations of merging his *interests* in art and chemistry. He studied animation

as an undergraduate and hopes to find a career that marries those interests. Overall, these students placed their personal well-being in the forefront so that they will be successful.

Another student, Jackson, was fairly open about his Obsessive Compulsive Disorder and shared that he had a network of *relational resources* including a mental health professional and his PI that afforded him the opportunity to work through difficulties related to his disability. He had trouble with grading in a timely manner in part due to this, but because he had *access* to the mental health resources he needed and an understanding boss he was able to *persist* through this experience. He also said:

> I actually have Obsessive Compulsive Disorder and I keep it in check mostly by entertaining myself with thoughts and one of those things is science. And so that's like a healthy obsession I can have. So...sometimes I'll just be in the mood. I need to find out something and so I'll just keep reading and reading and reading about some science-related thing and I think it's really cool.

Therefore, he was able to view his disability as an asset as well and had the support system he needed to be successful. This is not to say that positive thinking is the only solution and that time and care still need to be taken in order to provide equitable *access* and *opportunity* for students with disabilities.

Nidiya reported that she felt supported as a woman of color in chemistry due to the amount of *representation* on her dissertation committee. Her committee was mostly women and she had multiple women of color *supporting* her. She said she used to worry about the departmental culture she was entering into; however, in her experience she never "felt attacked or anything." She said it was in large part due to "having women on [her] committee" and said that was especially important for women in the sciences. Her "committee [had] been really nice and very supportive." She added:

> But I know that that's not always the case and there are a number of instances I know of where it's been a woman who's the PhD student and she'll go to defend

> her thesis and it's and all male committee and [they] tear her apart, you know, and so it's like, yeah, it's not fair.

She acknowledged that her experience was not the norm and that it should be more common for students to have that *representation* and *support*. She also was able to *leverage* her identity as a social person in science. She used to feel like her personality was not desirable in her field but over time felt more empowered to be herself, a confident and social person. She said:

> I think I definitely felt more like a scientist when I had those identities merged together because I can actually use how extroverted I am to advance not only my own career, but to also hopefully help science. To kind of collaborate to set up these relationships with other scientists to investigate our world.

She worked in an environment where she could be herself and as a result was able to *merge* her personal identities and her researcher identity.

Contrastingly, Angelica had a more challenging *trajectory* when it came to being supported as a woman of color. She initially said, "I think I hit rock bottom for that at least at the beginning of my grad program and like how did I get in, even a year after I'm like did I really just join this program? Did I really make it here? So it took a toll on me." She did not have *mentors* who looked like her and generally did not know any other researchers that shared her identity. This made the first part of her graduate school experience difficult. However, she later had the opportunity to attend a conference that ultimately improved her graduate school experience. She recounted:

> I see people's projects where you know they're doing similar things as me. Students who also look like not, you know, your typical like white person and such. It really opened my eyes like okay that I feel like I *belong* here a bit more and I was actually presenting more of my work and I got some *praise* from other professors in my department. "Oh, you do really great work." Hearing from my PI [principal investigator], like, oh, this is really great. Like that's little stuff like that but it sucks that that had to happen for me to realize like, okay, like you do great work. You are a scientist. So instead of me, figuring it out.

She finally was able to see herself as a researcher because she received *recognition* from her PI and she saw other people like her in chemistry doing great research. She was disappointed that it took *external recognition* and *vicarious experiences* for her to see that, but it was vital to her identity development.

Luis had a similar experience as an undergraduate and he carried this mindset into his graduate program. He said:

> I didn't really see myself as...my own *representation* as a scientist until I started doing research at [University]. I joined a big research group and there were a few Latinx researchers there that were bold and proud about their culture and background.

With this *representation* in the laboratory, he developed the notion that he could be "loud and proud" about being a Latinx scientist. He joined a Latinx professional society soon after and continued to be active in the Latinx community in his current program. He had a *support system* that enabled him to be *confident* in his ethnicity and that he could *integrate* that with his scientist identity. Students in this group were able to acknowledge and value aspects of themselves outside of science and in some cases were able to merge those identities.

Summary of Results and Resources

As expected, graduate students have complex identities and hold a variety of ideas about each identity and how those identities are related. To answer research question 1, graduate students are researchers, teachers, students. Graduate students primarily identified as researchers and if they did not, they described specific criteria for identification. Students developed researcher identities through demonstration of competence in certain skills like writing academic articles and performing tasks in the lab. Researcher identities can be further developed when provided the opportunity to think creatively and take ownership over one's ideas. As well, graduate students in this study often have altruistic motivations and feel connected to the science

community when their work makes an impact on the scientific community or is used to help others, similar to results from previous research (Brown, 2016; Kuniyoshi et al., 2019; Tran, 2011).

Graduate students in this study were less likely to identify as teachers due to their lack of agency and competence in chemistry content. Contrastingly, people who did see themselves as teachers often had more autonomy in their classrooms and appreciated the opportunity to have a larger teaching role. More senior graduate students who saw themselves as teachers also recognized mentoring as a part of teaching. The student identity was not emphasized and was more closely linked to research identity because students saw themselves as scientists-in-training. They identified as life-long learners rather than students, which is interesting considering the presence of "student" in their title: Graduate Student.

To answer research questions 2A-C, the narratives presented above illustrate that graduate students are multi-faceted people with intersecting identities and supporting them as such is important to their success and well-being. For research and teaching intersections, graduate students are aware of an intersection, but may not have the resources to make sophisticated connections between the two. The connections that were made were unidirectional such that students thought about how teaching can benefit research including developing communication and presentation skills, reviewing science content, and generating new science ideas, but not the other way.

Participants also demonstrated ways in which their personal identities were in conflict or reconciled with their research identity. There is still this primacy of the research sub-identity and how their identities as people fit within that. Regardless, as these accounts are generally from graduate students who have persisted thus far, the stories exemplify the types of resources

needed to persevere in a graduate program (Pfund et al., 2016; Tran, 2011). These resources include: a) faculty, staff, and peer support, b) recognition, representation, and vicarious experiences, and c) legitimate peripheral participation. It is beneficial to have relational resources for each aspect of graduate student roles and these can come from different sources to form a network of relationships. It is also useful to provide recognition for successes and promote representation for different student identities, much like Nidiya had multiple women of color on her committee. This can also come from providing students the opportunity to find representation elsewhere such as at a conference if representation is sparse at their institution. Lastly, students can benefit from being afforded individual and collective agency, meaning that students are supported by more experienced others in learning by doing and being afforded more autonomy over time. In summary, the above narratives provide insight into how support for reconciliation of personal identities can be beneficial to graduate students and promote positive outcomes of persistence.

A summary of the themes is outlined in Table 4.10. The research questions, themes and corresponding survey data are coordinated to further support the claims. Overall, the survey data was similar to the qualitative themes presented, though the survey did not provide sufficient evidence for students' ideas about personal sub-identities. This is to be expected as this was not the original intent of the survey. In the OEQs, some respondents did mention their personal life and work-life balance but were still minimally present in OEQ responses. The results illustrate that graduate students are aware of their interacting identities, but may need more support in navigating them in a way that is constructive and useful for their professional development.

RQ	Theme(s) [Qual], n=18	Survey Data, [Quant] n=20-26, [Qual] n=19	Compare
1	Researcher/Scientist is primary identity • Researcher as proficiency in certain skills Researcher has agency and greater impacts	• 100% of respondents identified themselves as researchers • 100% of respondents want to improve their research skills	Somewhat similar, No mention of greater impacts in the survey
	Graduate students are teachers • Teaching identity requires agency • Teaching as knowing and explaining content • Teaching as mentoring	• 77% of respondents see themselves as teachers (50% somewhat agree) • 96% of respondents want to improve their teaching • Usually research and sometimes teaching will help develop their knowledge of the field • 8 respondents mentioned mentoring in OEQ	Somewhat Similar, No mention of agency in teaching (Quant)
	• Graduate students are students. • Graduate Students are life-long learners.	• 92% of respondents identified as successful science students • 100% of respondents identified as learners of science	Similar, identify as learner/student
2A	Research and Teaching • Research always prioritized above teaching • Teaching supports the researcher identity, not bidirectional	• 96% - same person can be an effective researcher and teacher • 50% - there is a disconnect between teaching and research skills • 42% of OEQ respondents noted an overlap between research and teaching	Somewhat similar, Recognize potential to do both, but unsure of connections between the two
2B	Personal sub-identities can conflict or intersect with the researcher/scientist identity	• 2 respondents (10%) mention work-life balance in OEQ	Dissimilar, work-life balance was not commonly mentioned in survey
2C	Relational, ideational, and material resources needed for reconciliation of sub-identities	• 88% feel supported in research • 90% recognized by others as researchers • 81% feel like a part of the lab • 92% feel like a part of the larger community of researchers • 69% feel supported in teaching • 77% recognized by others as teachers	Similar, More students feel supported in research than teaching

Figure 4.7: Joint Display of qualitative and quantitative data and comparisons. The qualitative and quantitative participant pools may not be fully distinct; however, the two cannot be fully dissected due to the different modes of data collection as the survey responses were anonymous.

Discussion

In the same way that research in K-12 and undergraduate education has recognized the importance of student centered learning and valuing student identities, the same must be done in graduate education (Brown, 2016; Griffin et al., 2020; Tran, Minh C., 2011). Graduate students are multifaceted people and should be regarded in a way that supports their whole selves. The omission of support for identities other than research can be detrimental to graduate students and can prevent different types of students from persisting in the field as evidenced by the demographic data from each university and the voices that are not included in this work. Graduate students primarily see themselves as researchers and their other identities are secondary. These other identities include who they are as people. That may mean they do not take care of their mental health and have hobbies outside of work or that could refer to having to disregard ethnic and racial or gender identities. What is evident is that students who do have support for their personal identities are the students that persist in their programs (Hurtado et al., 2010: Tran, 2011); while students who did not persist in their programs frequently point to the lack of support as whole people as a major contributor for leaving (Butz et al., 2019; Wilkins-Yel et al., 2021). Essentially, this work shows how graduate students can be supported and that more work needs to be done on the specific mechanisms for success (Tran, 2011). This provides further evidence that treating graduate students like people rather than just workers is paramount to resiliency and persistence. A more detailed discussion of research results and implications will take place in Chapter 6.

Chapter 5: TFU Case Study Results

Disclaimer

This chapter is a summary of the case study analysis (research goal 3) and is formatted for submission to an academic journal in accordance with chemistry dissertation standards. Therefore, this chapter is formatted with its own introduction, theoretical framework, and implication sections which would normally be written elsewhere. The overall formatting of this dissertation reflects the nature of the multiple communities within which chemistry education research is housed, much like the multiple intersecting communities described within this dissertation.

Introduction

Serving as a graduate teaching assistant (GTA) while in a graduate program is becoming increasingly common in STEM (Kuniyoshi et al., 2021). On average, in chemistry graduate programs 83% of graduate students are hired as GTAs (Golde & Dore, 2001). As well, at research intensive universities chemistry GTAs are responsible for 88% of chemistry laboratory instruction. These teaching positions often provide income for graduate students who may not be supported directly by research funding. Graduate teaching assistantship opportunities also provide a source of much needed teaching labor for undergraduate courses under the justification that serving as a GTA will provide the necessary teaching experience needed for academic jobs (Hancock & Walsh, 2016; Johnson, 2011; Park, 2004). However, the efficacy and impact of GTA training and subsequent teaching experiences on graduate students' teaching and professional development is unclear.

There are concerns that, while some posit that graduate programs operate under an apprenticeship model (Golde & Dore, 2001; Hancock & Walsh, 2016; Keyser et al., 2008; Thiry

et al., 2015) in which students learn through legitimate peripheral participation in the academic community, the actual support systems and resources needed for apprenticeship are not always met. Most notably, teaching is often neglected in the apprenticeship model (Austin & McDaniels, 2006; Brownell & Tanner, 2012; Kendall et al., 2013; Lane et al., 2018; NASEM, 2018) in part due to the emphasis of a graduate degree as a research degree (Golde & Dore, 2001). Furthermore, almost half of STEM doctoral students will teach at the college level within five years of completing their degree (Connolly et al., 2016) and when one becomes a STEM faculty member with teaching and research responsibilities, they may not receive formal pedagogical training. From this, there is a clear mismatch between the needs of students in graduate programs and the training that is provided. Thus, having structures in place for formal pedagogical training of STEM graduate students is necessary.

Teaching and Research Relationship

There are conflicts, within the STEM community, regarding how much space should be made for pedagogical training for GTAs and its impacts on graduate student success (Brownell & Tanner, 2012; Connolly et al., 2016; Shortlidge & Eddy 2018). This is referred to as the "teaching-research tradeoff"; however, there may not necessarily be a tradeoff when graduate students are more effectively supported in their many roles. There are also social and cultural factors that fuel the idea of a tradeoff such as established departmental or institutional norms of teaching being secondary to research, which is quite common in STEM departments (Beath et al., 2012; Brownell & Tanner, 2012; Zotos et al., 2020). However, evidence shows that devoting time to teaching does not have a negative effect on degree completion (Connolly et al, 2016) or the number of publications (Shortlidge & Eddy, 2018).

Teaching and research require a variety of complementary skills that can be leveraged in different contexts (Gilmore et al., 2014; Light & Calkins, 2015). The two roles require communication, organization, and critical thinking skills and often require creativity. In practice, graduate students have cited that they use their research as examples in the classroom and find that they are able to better understand scientific concepts as a result of teaching (Gilmore et al., 2014).

Graduate Student Training and Best Practices

Most often, graduate student training courses contain information about logistics, safety, and content, but may not provide information on how to teach the content, facilitate a course (Luft et al., 2004; Jensen et al., 2005), or how to balance competing responsibilities graduate students have as researchers, teachers, and students. As well, the formats of trainings vary widely and may be 1-day workshops, 3-to-5-day bootcamps, or semester or quarter-long courses (Estrada & Tafliovich, 2017; Marbach-Ad et al., 2012; Marshman et al., 2016; Reeves et al, 2018; Rosales et al., 2013; VanValkenburg & Arnett, 2000). From the STEM GTA literature (Bond-Robinson & Rodriques, 2006; Dragisich, et al., 2016; Marbach-Ad et al., 2012; Park, 2004; Rosales et al., 2013; Zotos et al., 2020), themes for best practices in GTA training have emerged and include: a) providing ongoing support, feedback, and reflection for teaching, b) encouraging community support from faculty, staff, and peers, c) explicitly addressing GTA roles, d) modeling teaching using evidence-based techniques, and e) respecting and accounting for time constraints between teaching, research, and other responsibilities. Given the demonstrated importance of providing ongoing support, shorter trainings like boot camps and workshops may not be ideal for GTA training. Incorporating more of these practices can provide

a space for the development of a supportive community for graduate students and allow GTAs to better understand their responsibilities and the utility of the skills they will learn.

Research Questions

The goal of this research was to examine how first year graduate students conceptualized their teaching and research identity development and identity intersections throughout their involvement in a semester-long graduate training course designed using best practices from the graduate student training literature. The two research questions are:

1) How does teaching experience and a first year graduate student training course contribute to the teaching and research identity development for graduate students?
2) Which components from the training course do graduate students value? Specifically, to what extent do students value the feedback and reflection components of the course?

Theoretical Framework

In order to better understand the graduate experience and how they can be supported, this work uses a sociocultural lens, particularly Communities of Practice and Identity. Through the use of these frameworks we can better understand the impacts of training on graduate students' development as researchers and teachers in context. The incorporation of context and social factors is important because graduate student training is but one aspect of a much larger picture of graduate student education and leaving out these pieces leaves an incomplete image.

Communities of Practice and Identity

Communities of Practice (CoP) is a sociocultural framework that involves the mutual negotiation of practices within a "social container" or community (Wenger, 1998). This includes ideas of apprenticeship and legitimate peripheral participation, in which a newcomer learns through observing and engaging in practices of the community with help from more experienced

others (Brown et al., 1989; Lave & Wenger, 1991). In the context of this study, graduate students enter the community of practice of academia as legitimate peripheral participants, due to their prior experience as students, and are enculturated into, or learn the practices and valued knowledge of, that community. However, the scale and breadth of a CoP can vary and as such one can belong to multiple communities. In this case a graduate program can be considered a CoP, but so could the sub-communities of GTAs and graduate research assistants. Thus graduate students work to become members of teaching and research communities which often overlap. According to Wenger (2000), this is the nexus of multi-membership in which one can be a member of multiple intersecting communities and operate on the boundary of those communities. Operating on the boundary means to leverage skills from one community in another. This is where identities are "at the same time, one and multiple" (Wenger, 1998, p. 159). In practice, students often struggle to move between communities in school and reconcile their identities within each (Hand, 2006; Nasir, 2002; Nasir & Hand, 2008).

Participation in a community or communities also informs what we value, and what we learn and relates to the ongoing development of how we are seen and how we see ourselves or our *identity* (Gee, 2000; Hand & Gresalfi, 2015). These identities are linked to participating in the practices of the community, also called practice-linked identities (Nasir & Hand, 2008), thus the negotiation of membership in a CoP and identity development are connected. Historically, identity development is also linked to retention in STEM, for example if one sees themself as a "science person" they are more likely to stay in a science field (Carlone & Johnson, 2007). The components of science identity include interest, recognition, and competence/performance (Hazari et al., 2010) and map onto the experiences that influence identity development as a science person. Interest relates to one's inclination to pursue and understand concepts in a field.

Recognition describe the acknowledgement of oneself or from others as a certain type of person. Lastly, competence/performance is the extent to which one feels that they have ability to do or understand something in the field. Hosbein and Barbera (2020) have theoretically grounded the existing constructs of science identity in a chemistry context as well.

The concept of identity resources has also been operationalized to make sense of identity development (Nasir & Cooks, 2009, Hyater-Adams, et al., 2018; Reinholz, 2019). These resources become available in a social setting and can be tangible or intangible. The resources include: material resources like grades, relational resources such as one's relationship with a teacher or mentor, and ideational resources such as ideas about science or teaching that one values. Hyater-Adams and colleagues have also coordinated Carlone and Johnson's identity constructs to the identity resource constructs such that recognition is often associated with relational and ideation resources, competence and performance are associated with material and ideational resources, and interest is associated with material and relational resources (Figure 5.1). This provides insight into how components of identity development are influenced by social components.

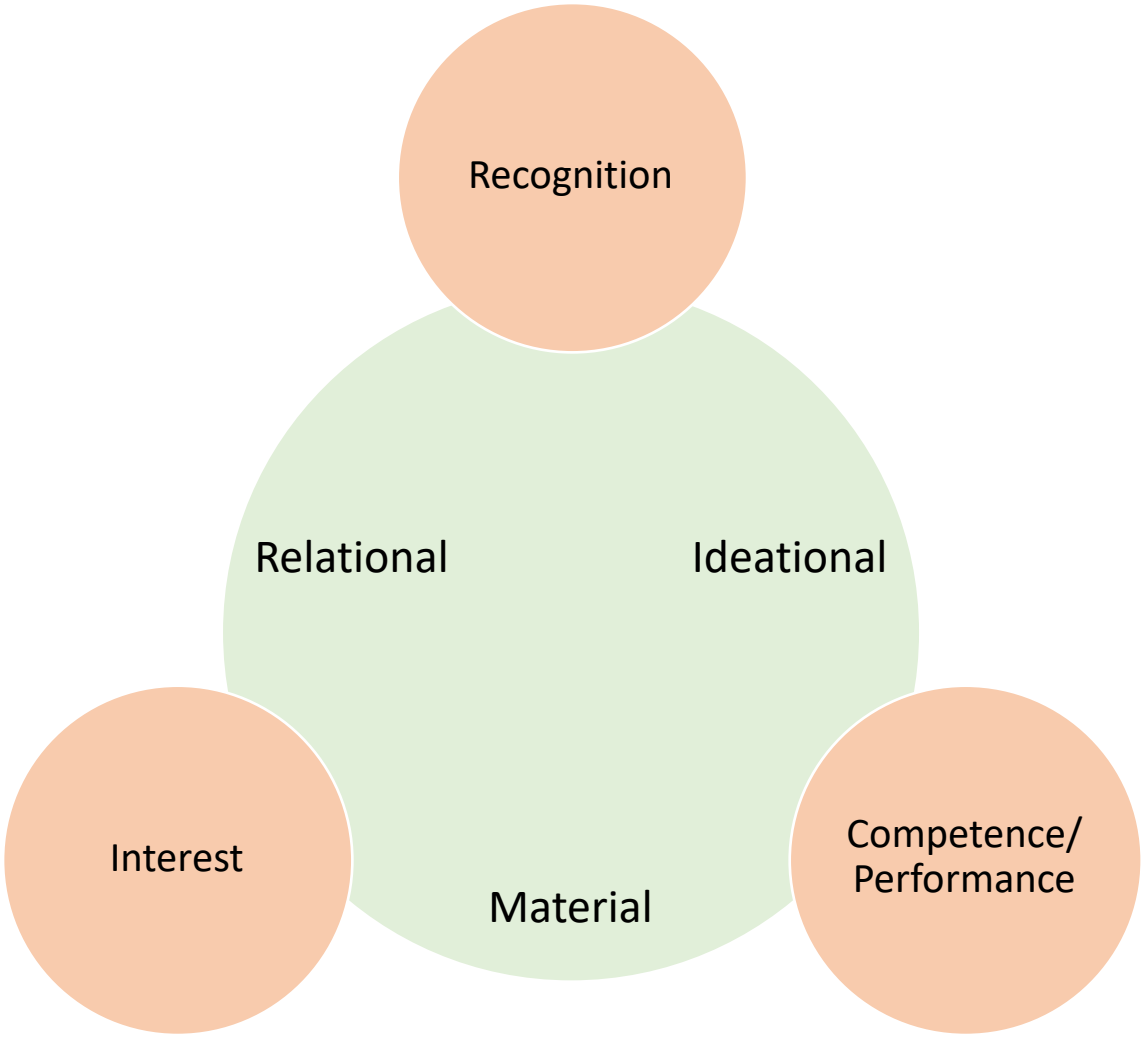

Figure 5.1: The coordination of resources (center) and identity constructs (edge) adapted from Hyater-Adams et al., 2018.

Methods

Course description

This study was carried out in the context of a redesigned first year graduate student training course. This course is required of all first year graduate students in the department and in prior years was used to aid students in choosing a research group, accessing library information, using chemistry software, and learning laboratory safety, with minimal content around teaching. Most of the teaching training was contained to the 4-day bootcamp offered prior to the start of

the semester. Topics of the bootcamp included completing required university paperwork for hiring and logistics, becoming familiar with the learning management system and grading technology, lab safety, and attending a questions and answer session with an experienced GTA panel.

The redesigned course centered around intentionally interweaving support for both research and teaching with regular reflections regarding the course content and graduate students' teaching and research experiences so far. The 4-day bootcamp was retained and the 14 week course was modified from its previous form to better suit the needs of the students. In alignment with best practices for GTA training the course was redesigned to cover the full semester rather than the first 8 weeks to provide ongoing feedback and support. Students were connected through the online course management system in order to communicate with each other asynchronously on the discussion board. This was meant to set a norm of sharing resources and working as a community.

Additional teaching-related topics were added to the course throughout the 14 weeks to provide more support as GTAs began their teaching assignments. Evidence-based teaching practices were modeled in the course as well as explicitly discussed. Specific teaching topics included: preparing and giving presentations, incorporating equitable teaching practices, handling difficult classroom situations, and providing feedback. In addition, students gave two 10-minute presentations on a topic of their choosing. This could be either a research talk or a lecture related to their GTA assignment. Students were given peer feedback and feedback from one of the co-teachers. For the follow-up presentation they were asked to incorporate the feedback and provide a reflection on how they improved their presentations based on previous feedback.

Research-related topics were also covered including research ethics, finding a research group, finding funding, using technology and library resources, creating individual development plans, and career planning. Students also discussed mentoring and how to build a mentoring network to support them in all aspects of their graduate career (Appendix C).

Reflection assignments were incorporated throughout the course to provide a space for students to think about the course content and how it can apply to their work in all aspects. Reflection on teaching is an integral aspect in improving teaching practice (Corrales et al., 2020) and could prove useful in other graduate student roles. Reflection questions included topics related to research, teaching, classes, the course content, and intersections between them so graduate students could be explicitly tasked with considering intersections between their roles (Table 5.1). Reflections and surveys were also used to modify the course in real time to create a course comprised of mutually negotiated set of topics that were both supported by previous research and relevant to the needs of the students. In practice, the reflection prompts and responses were used to facilitate whole class discussions and demonstrate that student feedback was acknowledged and incorporated. Additionally, due to the COVID-19 pandemic the course was modified for online instruction and as a result many of the modules were catered toward online teaching.

Table 5.1: Reflection topics and example questions. The full list of prompts can be found in Appendix D.

Week #	**Topic**	**Example Reflection Question**
4	Implicit Bias and Microaggressions	What comes to mind when you see the term microaggression? Were you familiar with this term before?
5	Equitable Teaching Practices	Do you see any opportunities to apply what we discussed to situations in a research or teaching context?
7	Mid Semester Check-in	How is your teaching going? How is your research/group selection going?
11	Week 11 Check-in	How are you doing with your research responsibilities? Any positives you'd like to share? Any issues you'd like to ask for help with?
14	Final Reflections	How were you able to manage your workload this semester? Looking back, what are you most proud of and what would you change about the way you managed your responsibilities?

This course was meant to help students begin to hone their craft as researchers and students as they navigate resources for academic research, teaching, and career planning. It was the goal that an integrated approach to graduate student training would serve to support the development of multiple identities including research and teaching identities through the incorporation of material, relational, and ideational resources. Coordination of GTA training best practices, course components, and identity resources are found in the table below (Table 5.2).

The first training practice emphasizes the importance of ongoing support, and in turn the course was extended from an 8-week to 14-week course in which teaching and research topics were incorporated throughout. The extended course can be considered a material resource as it is a tangible aspect of training that was not previously available. The second practice was incorporated through the implementation of multiple modes of communication for reflections and feedback. Students and the course instructors were able to communicate through google

forms, in class, via the learning management system and more in order to provide multiple access points for relational resources. Evidence-based practices in teaching were modeled by the course instructors and subsequently by students in the course providing material resources for teaching and giving presentations more generally. The last two practices were incorporated through the inclusion of modules and reflection assignments pertaining to graduate student perceptions of their roles. Students in the course were able to discuss their roles and responsibilities with their peers in class (relational) and reflect on their experiences via online assignments, thus providing a space to develop ideas about teaching and research (ideational) through tangible assignments (material).

Table 5.2: Table of design elements from the GTA literature, the course components, and the resource(s) that component represents.

Training Practices	**Course Components**	**Resources**
Providing ongoing support, feedback, and reflection for teaching	8-week to 14-week course	Material
Encouraging community support from faculty, staff, and peers	Synchronous and asynchronous communication and feedback, reflections on community support	Relational
Modeling teaching using evidence-based techniques	Instructor modeling of teaching and peer modeling via mini presentations	Material
Explicitly addressing GTA roles	Modules pertaining to and reflections on perception of roles	Material, Ideational, and Relational
Respecting and accounting for time constraints between teaching, research, and other responsibilities	Discussion and reflections on holding multiple roles	Material, Ideational, and Relational

Study Design

This study uses an embedded case study and transformative mixed-methods research design (Creswell & Poth, 2016; Stake, 2006; Yin, 2017). Transformative research designs

require methods that lead to a better understanding of the phenomenon of interest while transforming the phenomenon being studied. In this case, change occurred though the redesigned course and the resources provided therein to support graduate student sub-identity development. Transformative methods also require dedicated theoretical frameworks and this work relies heavily on multiple theoretical perspectives including sociocultural theories of learning, identity, and communities of practice in order to guide the mixed-methods and case study designs.

Qualitative data is the main source for analysis and includes semi-structured interviews, open ended survey questions from course evaluation, and course artifacts. Quantitative data in the form of a course evaluations surveys, one from the university and one that was researcher-generated, were administered as well to assess the course. Multiple sources of data are accessed to ensure well supported claims according to case study best practices (Creswell & Poth 2016; Yin, 2017). Via case study methods, each student participant is reported as a separate embedded case as one unit of analysis with descriptions of their experiences and identity development and cross-case analysis is used to describe themes in identity development across cases. The impact of the course and valued course components were assessed via the triangulation of qualitative and quantitative data as well.

Positionality

The first author is an assigned female at birth (AFAB) Chicane person with a Bachelor's degree in Biochemistry and a Master's degree in Chemistry. I have experienced and witnessed a variety of *othering* experiences in my time as a student and researcher. Othering experiences are events in which one has felt like an outsider in the community to which they make efforts to belong (Foote & Bartell, 2011). As a graduate student in chemistry, I have felt othered when expressing an interest in teaching and education research. In my personal experience, I worked in

an environment in which teaching was not considered an important skill for chemists and that research should always take precedent. The culmination of these experiences throughout my academic career have influenced my research interests and as a result, I have designed a study to investigate some of these issues including the lack of support for teaching. Having an insider's perspective on these issues has allowed me to attend to these issues from a research perspective. In order to combat bias from my personal experience (Maxwell, 2013), second coders and trusted critical friends were recruited to review the analysis.

The second author identifies as a white woman with bachelors, master's, and doctoral degrees in chemistry education. She has experienced similar othering experiences due to parallel interests in science and teaching. As a result, this has influenced the direction of her research program and her commitment to encouraging graduate students to develop as both researchers and teachers. The second author was the primary instructor for the redesigned course. Due to this closeness with the research setting, she did not participate directly in data collection or analysis until all data had been de-identified and initial coding was completed by the first author. This study was approved by the Institutional Research Board of the university where it was conducted.

Participants and Context

The study occurred in the Chemistry and Biochemistry Department at a public university on the west coast, which is classified as a Hispanic-Serving Institution (HSI) as reflected in the demographic breakdown of the graduate student in the chemistry department (Table 5.3). Race and ethnicity information was reported by the university as the percentage of underrepresented minorities (URMs) which include African American/Black, Hispanic/Latinx/Chicanx, Native American, Native Hawaiian/Pacific Islander, and Filipinx. This university is classified as a

teaching-focused university and has a high number of undergraduate transfer students from community colleges and other two-year institutions. All participants in this study are first-year master's students who intend to apply for the doctoral program (Table 5.4). Participants were recruited from the redesigned course on a voluntary basis and were provided a monetary incentive. The course enrollment for the first-year graduate student training course was 14 students total.

Table 5.3: Overall demographics of the chemistry graduate program.

Degree	Total (N)	Women	Men	Nonbinary	URM	International
MS	43	58.1%	41.8%	0.0%	30.2%	27.9%
PhD	39	35.9%	64.1%	0.0%	17.9%	20.5%

Table 5.4: Demographics of case study participants.

Participant	Gender	Race/Ethnicity	Year
Owen	Male	White	1
Alexia	Female	White	1
Nathan	Male	Hispanic/Latinx	1
Mila	Female	White	1
Enrique	Male	Hispanic/Latinx	1

Data collection

Semi-structured interviews with case study participants were collected at two time points: mid semester of Fall 2020 and in Spring 2021 after the completion of the course. The interviews lasted between 45 and 90 minutes via videoconferencing software and consisted of background questions about their educational journey and professional goals, researcher/science identity questions, teaching identity questions, and intersection identity and closing questions. The follow up interview was condensed from the initial interview and modified to uncover changes from semester 1 to semester 2 (Appendix H: Follow-up Protocol). A question about the graduate

student training course was also added. To further support qualitative claims, qualitative and quantitative data from an official university course evaluation survey and a researcher-generated course evaluation survey were collected (Appendix J). Lastly, classroom artifacts such as class reflections were accessed for analysis.

Analysis

Qualitative data was analyzed using *a priori* and inductive coding methods via Thematic Analysis (Clarke et al., 2019; Miles et al., 2014). *A priori* coding was carried out through the categorization of interview data into themes and concepts from the identity and community of practice literature from a preliminary codebook also called codebook Thematic Analysis. Unlike pure *a priori* analysis and codebook Thematic Analysis, reflexive Thematic Analysis was also used to develop new codes or patterns directly from interpretation of data. This is the inductive aspect, which allowed for tailoring of themes to the data collected. A constant-comparative method was used during this process to continually compare qualitative data sets as they were collected (Merriam & Tisdell, 2016); therefore, codes were fluid and constantly refined over time.

After the first cycle of coding, each student-level case consisting of the two interviews per student were revisited to generate case profiles with case-level themes. Once cases were defined, cross-case analysis was carried to understand similarities and differences between student-level cases to give overall themes across cases (Stake, 2006). Narrative descriptions (Miles et al., 2014) of the cases were generated from case-level and cross-case analysis. Quantitative data from the course evaluation surveys were analyzed using descriptive statistics. Open-ended questions from the surveys were analyzed using inductive coding methods as described above. Data from these sources were used to strengthen the claims from the qualitative

theme generation in accordance with case study methods (Yin, 2017). Next, the survey data, interview themes, and narrative descriptions from data integration will be presented.

Results and Discussion

Surveys

The official university course evaluation survey and the researcher-generated surveys had low response rates, thus only descriptive statistics were conducted; however, the open-ended responses provided some insight into the valued components of the course. Generally, students rated the course highly across all aspects. Interestingly, one student chose "not applicable" when asked about their interest in the subject matter, which could stem from a lack of interest in teaching, but cannot be confirmed from the survey alone. From the researcher-generated course evaluation survey students reported that the difficult classroom situations and finding a research group modules were the most useful, while the networking was not as relevant to them.

Case Study Participants

To provide additional context for the case study participants, narrative descriptions of each student's experience in the graduate student training course as well as with teaching and research will be presented. A detailed description of each participant's experience in addition to the reporting of themes across cases will provide a rich description of identity development over time in context. As previously stated, all of the participants are first year students in the master's program who intend to apply to the doctoral program within the same department meaning they are PhD bound and perform research and teaching duties in addition to completing coursework.

Alexia. The first student in this set of cases is an international student who self-identifies as a white woman. She has encountered some roadblocks due to her status as an international student, however the principal investigator (PI) in her lab has been exceedingly helpful in this

process, which has allowed Alexia to focus on her research and teaching responsibilities more easily. She makes a point to prioritize research over teaching most often, but also has some experience in teaching. From these experiences she acknowledges that she is a good teacher showing some signs of competence and self-recognition of her teaching identity; however, she does not want to pursue a teaching career in the future. She reports that she enjoys putting slides together and helping students and that she is technically a teacher because of the duties she carries out. In addition, she briefly mentions that her career plans could change, but it is too soon to know. She also has interest in improving her skills as a teacher, another aspect of identity development, which shows that she has the potential to grow as a teacher as well as see how improvements in her teaching skills may be applicable to other areas of her work.

That said, she is very clear about her interest in research and posits that the teaching aspect of graduate school is really only beneficial if one is intending to be a professor. Specifically, she recognizes that as a researcher one does not have to explain scientific concepts in the same way to other researchers as one would to a student, therefore teaching skills are not always necessary. This is a fairly common way of thinking for graduate students who primarily intend on conducting research (Gilmore et al., 2014; Shortlidge & Eddy, 2018; Zotos et al., 2020). Unlike other students in the class, Alexia does not see any benefits to having teaching experience when her primary interest is research. Despite her focus on research she does not yet recognize herself as a scientist, saying that she has improved in her scientific skills, however she still has many more skills to develop including writing academic articles and being able to independently plan and carry out experiments. She says she is not a scientist yet, but she will be in the future.

Enrique. The next student, Enrique, self-identifies as a Hispanic man. He describes

himself as an introvert and has a strong interest in animation and the arts, in addition to science. He describes himself as a successful GTA; however, he does not feel comfortable calling himself a teacher because there are many things that he does not do as a GTA, which he considers important to being designated as a teacher. He says he is, “just a lab TA so [he doesn’t] take everything into consideration.” He doesn’t design much of the course or have much teaching agency; therefore, he doesn't necessarily identify as a teacher. However, he does acknowledge that he is great at directing students to useful resources and has developed excellent communication skills.

Enrique feels that he belongs to the science community because of his quiet and humble personality, which he has noticed other scientists have. As well, he cites that his ability to problem-solve on his own has boosted his confidence and belonging to the science community. He has had some issues with belonging due to his interest in the arts. He says, “I've always had the problem of like in science I'm always a more art-person, but in the arts I'm always a more science-person so you can't really win.” Despite this conflict he hopes to improve his scientific skills and potentially integrate his interests in the future.

Overall, Enrique has great mentors in teaching and research including his PI, the course coordinator, and his labmates who TA the same course as him as well. Because he has stated that he more highly values recognition by others, it is likely that these relational resources have helped him greatly in both his research and teaching responsibilities. Thus, he reports feeling like he is improving in both aspects and he acknowledges the intersections of these roles, though he would not call himself a full scientist or a full teacher yet.

Mila. Mila is an international student as well who self-identifies as a white woman. In addition to starting a new graduate program, she has had to settle into a new country and live on

her own for the first time. She has had teaching experience in the past including tutoring and holding an undergraduate TA position. She confidently calls herself a teacher, reports plenty of support from the course coordinator, and has gotten positive feedback from her students. She has a combination of material (teaching experience) and relational (course coordinator) resources, in addition to recognition from others, which has facilitated her identity development as a teacher.

She also is comfortable calling herself a scientist. She says she has "more of a scientist vibe" because she has picked up a variety of new lab techniques since she joined a lab. She's also had great communication with her PI and a supportive relationship where she has been able to try new techniques and fail until she was able to successfully perform tasks. She does mention she will prioritize research over teaching because that is what she will be defending when she graduates, however she does enjoy both. She also thinks that teaching can be beneficial to her research, which reinforces her interest in both roles.

Nathan. Nathan self-identifies as a straight Hispanic/Latino man. He emphasizes early on that he is interested in industry and does not want to teach in the future. His PI has also mentioned supporting him on research funding so that he will not have to serve as a GTA in the future and will be able to focus on research. This type of financial support from a PI is not always guaranteed and varies widely among programs and even between labs. Despite Nathan's clear disinterest in teaching as a career he asserts that he is a good teacher and has a wealth of experience in teaching both as an undergraduate as well as outside of academia as a martial arts instructor. These experiences, in a way, did contribute to his teaching identity development as he was able to gain experience in teaching, consider this path, and ultimately decide that it is not his primary goal.

Nathan reports that he is quite confident as a scientist and only struggles with the type of scientist that he wants to be in the future. He has many interests in both physics and chemistry and has struggled to find a niche. However, he reports that his PI has been fully supportive of his work and his journey to find a research topic that will suit his interests. When asked about any connections between teaching and research he says that generally the two are not connected and that teaching experience is only necessary for those looking to be a professor, which aligns with his lack of interest in teaching.

Owen. The final student of interest, Owen, self-identifies as a white man. Interestingly, Owen emphasizes the importance of having time for himself in graduate school including being able to enjoy hobbies and generally engaging in self-care. This was unique among this subset of interviews. Owen has experience working in industry and recognizes himself as a scientist. He is unsure of his intention to stay in academia, but knows he will pursue protein biochemistry in some way.

Owen does not identify as a teacher due to the lack of agency he's given in facilitating his course, but does think he has improved in his facilitation skills since taking the graduate student training course and has an interest in continuing to improve his teaching skills. Most notably, Owen makes a clear connection between teaching and research as ways of disseminating knowledge. He later reported that this notion was supported by his PI and they both agreed that teaching serves a purpose not only for the experience and career exploration but because teaching *is* a part of science and research.

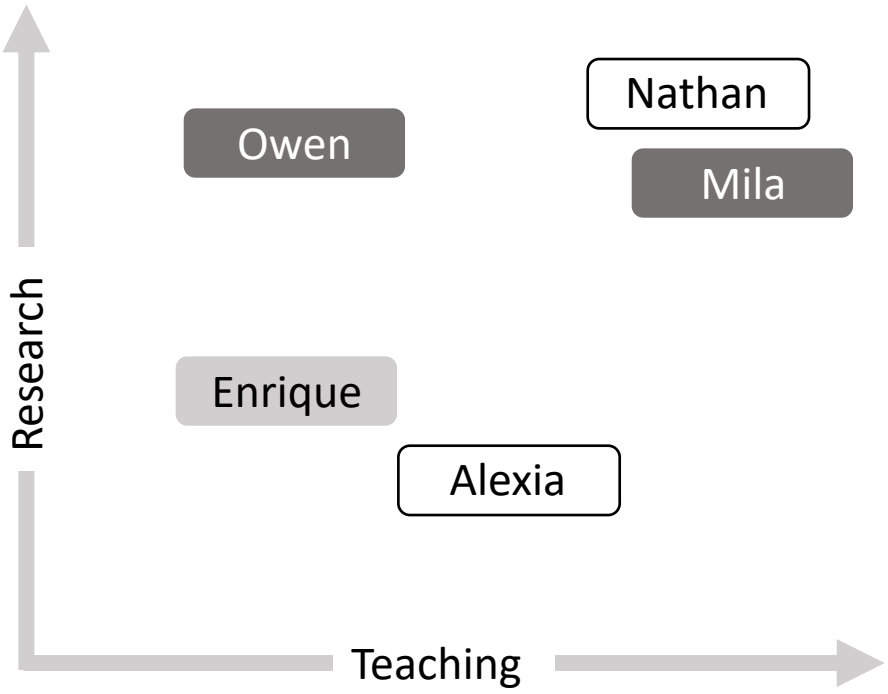

Figure 5.2: A summary of research and teaching identity development and the perception of an overlap. The placement on the graph represented the extent of research identity development (Y-axis) and teaching identity development (X-axis). The shading represents the perception of overlap between the two identities with white being the least and dark gray being the most.

Comparison Across Cases

To answer research question 1, students in this study are in the process of developing research and teaching identities and have demonstrated growth over the course of their first year in the graduate program (Figure 5.2). From previous work, Lane and colleagues (2018) designate teaching identity development in three categories: no noticeable teaching identity, nascent or emerging, and salient and stable. However to avoid regarding identity as a stable construct and acknowledging identity development as constantly changing and flexible, teaching and research identities are reported on a fluid continuum for this study. From the results, there are different ways in which students develop strong teaching and research identities. In addition, the extent of perceived intersections between those identities may not necessarily preclude students from developing both strong teaching and research identities. To expand on findings from each

student-level case, cross-case analysis provided insight into the degree to which students perceived connections between teaching and research and the resources that contributed that development.

Mila and Owen exhibited strong research identities and a strong perception of teaching and research intersections. Owen's teaching identity is still developing, however he shows an interest in further honing his teaching skills. On the other hand, Mila has a well-developed teaching identity in part due to the material, ideational, and relational resources to which she has access. The material resources include her teaching experience and positive feedback from students. In her second interview, Mila shared the contents of a thoughtful student email. In it her student expressed how grateful they were to her for being helpful and caring. The student expressed that Mila demonstrated a genuine investment in their learning and it was very beneficial to them. Owen had similar experiences, in which he would check on students in breakout rooms and he noticed that his students were communicating well and staying on task, yielding direct evidence that his teaching was effective. Relational resources for both students included supportive PIs and staff who cared about their success in teaching and research. Lastly, their ideas about research and teaching aligned, thus reinforcing the connections between the two. Owen asserted that teaching is "fundamentally helpful" in science and Mila explained that teaching can help her "think about some topics [more deeply]" and generate "more ideas about research." Their trajectories of identity development work synergistically and allow them to demonstrate integrated identities.

Enrique's research and teaching identities are still in the process of development. He does not consider himself a researcher or teacher, yet. He does however acknowledge a potential intersection between teaching and research. He said,

> The more you teach the more experience you get explaining things in your field, so I mean it might have to be like you're explaining something to a new lab mate. And I'm sure that that kind of training can come actually. It's probably necessary that you have that kind of experience.

He says there is probably a connection but he seems unsure. He adds that he has gotten better at presenting and communicating science concepts after taking the course and teaching for a semester, but does not explicitly make the connection between the two roles. There is an opportunity for further identity development and intersection, but he has not developed either identity to the extent that he is able to recognize and value those intersections. This may be due to the lack of relational resources for his development. He did not often mention how relationships with others were helpful in his teaching and research roles.

Alexia and Nathan minimally acknowledge the connections between teaching and research; however, the extent of identity development for each of them is different. Nathan sees himself as a teacher and a researcher and is confident in both identities. Conversely, Alexia reluctantly calls herself a teacher and is still developing a scientist identity. She says she is "technically" a teacher because she performs the duties of a teacher, while Nathan acknowledges that he is an excellent teacher. Alexia feels like she is not a scientist because she has not yet published a paper, while Nathan is more concerned with the type of scientist he wants to be rather than his designation as one. Despite their contrasting experiences, they both assert that teaching is only important for being a researcher if one plans on becoming a professor. Outside of those career goals, teaching experience is not important. This may be due to relational, material, and ideational resources to which they have access. For example, Nathan mentions that his PI still struggles with teaching and does not prioritize it (relational). His PI also demonstrates his prioritization of research over teaching (ideational) through his verbal commitment to provide research funding (material) so that Nathan does not have to teach. Alexia's development may be

tied to her own ideas (ideational) about research and her personal career goals and priorities. She said "you have to be focused on researching" and everything else is secondary. This may also be due to the fact that she is still developing her researcher identity and is more concerned with her development in that area. As a result, she cannot think about teaching and how that fits into her identity.

Lesson Learned from the Course

The next section addresses research question 2: the course components students valued. Of the new components of the course, students reported that the teaching-related modules and reflection assignments to be the most useful. In addition, students communicated a need for more practical training with grading and using rubrics. While grading was not a focus of the course, it was clear from the case study interviews and course surveys that training in grading could be beneficial at this stage.

Teaching Modules. It has been well established that graduate students need more training and support for their teaching (Brownell & Tanner, 2012; Kendall et al., 2013; Lane et al., 2018). This was made even more apparent as GTAs were tasked with teaching online courses. The students found that the teaching-related modules including the difficult classroom situations, equitable teaching practices, preparing and giving presentations, and mini-presentation lessons to be most useful for their teaching roles. These lessons were highly rated in the researcher-generated course evaluation survey, though the overall response rate on the survey was low. Student feedback in the interviews and qualitative sections of both course evaluation surveys supported this. Mila shared that, "the class that I took last semester, it was also helpful because I acquired some techniques of how to actually work efficiently during a pandemic

because teaching online and teaching face to face are two different things." Enrique mentioned the equitable teaching practices module explicitly. He said:

> The implicit bias stuff and thinking about things in those realizing like how you think about a scientist and, like all that stuff. I think it's super valuable, I think that stuff is super valuable even. As much as I like I think I have a good or most of us like in this department have a good moral compass. I think it's good that we keep it in the back of our heads or keep reminding people of it in classes and stuff because I mean the problem still exists.

He not only saw the value in teaching-related training, but in equitable teaching, which is has only recently been included in GTA training courses (Dragisich, Keller, Black, et al., 2016; Dragisich, Keller, & Zhao, 2016). He used this resource to reflect on his own practices and how he could better serve his students.

Owen described how he incorporated some of the techniques from the course in his teaching:

> I think I've kind of got like a rhythm going in for lecture as opposed to last time. I explain the concept of the lab and then I'll probably show them the video of the actual heading. You know the experiment and they write observations and then I break them out [into] four different discussion groups. And then, like letting them talk amongst themselves about the lab without my presence like I just sit in the main room and do whatever and I wait for them to like flag me for a question. Like if they're all sitting in the main room they'll say nothing but I've noticed that I'll jump in sometimes and they'll be like in the middle of conversation about the lab, so I think I've made some progress there.

He found success in incorporating breakout rooms into his online laboratory facilitation and had noticed that his students were talking more. He had previously reported that he did not feel he was doing well because his students were not talking to each other. He had found a way to improve that issue.

From the course evaluation surveys, students reported that the mini-presentation exercises were helpful. One anonymous student said, "Presenting is associated with stress for me and these mini-presentations helped me to get used to presenting and get less nervous." Another

added that they were especially useful for, “practicing or if you ever have a limited amount of time to give your presentation and/or wanted to try something new in your teaching.” It also was helpful because “everyone took it seriously and gave some good pointers so the second presentation could be better.” Overall, students in the study recognized the value of working on their presentation skills, which was reflected in some of their teaching practices. It should be noted that some students chose to give research-related presentations, which was an option for the assignment, thus students who chose that option may not have made similar connections. The flexibility of the assignment in relating to teaching or research could also convey that communication skills are relevant for teaching and research, thus planting the seeds for connections.

Reflection Assignments. From the course evaluation surveys, students expressed that the course reflections “served as a good mental check throughout the quarter for how things were going. I also felt like I could be honest about my experience when I would write them.” The reflections “made me think about either what I just learned or how I was feeling about the semester. I did enjoy the half-way reflection and the final reflection of the class.” Another student [found] it helpful when it [came] to finding out what went wrong during this semester.” Students from the course recognized that the reflections were meant to help them think about the course content, how they could apply that content, and how they could improve in the future. This was also demonstrated through the incorporation of teaching techniques from the course into their teaching as described above.

What’s missing: Grading. Due to the nature of GTA assignments and the presence of course coordinators, the graduate course did not include a lesson on grading or any grading practices. This was justified because it was understood that course coordinators would provide

rubrics and direction on grading assignment specifically for their course. However, based on the student interviews graduate students needed more experience with grading. They felt that grading was extremely time consuming and often the rubrics were not clear enough for them to grade consistently. This is consistent with previous work in which students' primary concerns in their TA positions was with grading and providing feedback (Moon et al., 2013). In follow up interviews, students found that grading had become somewhat easier, however they felt that grading and providing feedback was still difficult and inconsistent. For future iterations of this course one should consider including grading practice. To be consistent with the course intent of preparing graduate students for multiple roles, it may be beneficial to assign students to grade research article-style reports in order to expose them to grading using rubrics as well as exposing students to the general structure of research articles.

Limitations

Due to the ongoing COVID-19 Pandemic classes were moved online and remained online for the remainder of the 2020-2021 school year. Therefore, the course was redesigned to meet the needs for online teaching including how to use Zoom video conferencing software and how to promote classroom engagement online. This also had an impact on data collection as all interviews were conducted via Zoom. In addition, interview recruitment was done through survey administration via email listservs and there was no opportunity for in-person or in-class recruitment. This likely had a major impact on the response rate for all surveys and interview inquiries. In addition, there were limitations of the student interview pool due to the small size of the course. Course enrollment was a total of 14 students and the pool of students interested in interviewing was a smaller portion of that further limiting the participant pool. Due to the voluntary nature of the interviews, students who are active in their graduate students roles were

likely self-selecting into the study so this group is likely not representative of all first-year chemistry graduate students.

It should be noted that the redesigned course is the first iteration and is meant to serve as a starting point for sustainable change through incremental modifications (Stoddard & Brownfield, 2020). As well, the course is meant to provide a context to study identity development situated in an authentic experience. More work is needed to further assess the impact of the course alone on identity development as the course, teaching, research and other experiences collectively influenced identity development.

Discussion and Implications

Graduate student training courses vary widely among institutions and even departments and often do not include sustained training and support in teaching. The absence of the consideration of teaching roles for graduate students has been exposed in graduate student identity research. Previous work acknowledges some conflicts between student and scholar (researcher) identities and briefly mentions the importance of teaching in later work, but teaching identity is largely ignored (Baker & Pifer, 2014; Pifer & Baker, 2016). In the context of life sciences and chemistry graduate programs, there is emerging work on the conceptions of teaching and teaching identity development of doctoral students and GTAs (Lane et al., 2018; Zotos et al., 2020). In these works, the focus is placed on teaching identity and the affordances and constraints of teaching identity development, but intersections with other identities like researcher identity are not addressed. Historically, graduate students, particularly in chemistry, are responsible for a large amount of teaching duties while conducting research, thus looking at isolated experiences in teaching discounts the research-heavy context. This study begins to bridge this gap to understand how graduate students develop teaching and research identities and

their intersections in the context of the graduate student training course. Identity is a relevant metric to gauge graduate student success and development as a stronger identification with a particular community or identity is directly related to persistence in the field (Carlone & Johnson, 2007).

To answer research question 1, regarding the extent of identity development and perception of intersection in the context of the graduate student training course, three distinct themes emerged: a) a well-developed perception of research and teaching intersection, b) recognition of potential intersection, and c) dismissal of intersection. First, students with well-developed research identities but differing levels of teaching identity development demonstrated an understanding of the intersections of research and teaching. In particular, the two students in this category asserted that teaching skills are important and relevant for research and are fundamentally useful despite one student in the category not identifying as a teacher. The student with emerging teaching and research identities did not articulate specific connections between research and teaching, but noted that teaching probably helps with lab work in some way. Here the student in this category displayed that he has room to grow and may better understand the connectedness of his roles as he develops each identity further. The two students in the final category did not see connections to teaching and research and asserted that teaching experiences were only important if one's intention was to be a professor with a teaching role. They connected teaching experience with one specific career path and did not find teaching to be beneficial for other careers like industry. Interestingly, the two in this category did not share the same level of research identity development, but both identified as teachers to some extent. Despite their interest in teaching and recognition as good teachers, they did not have aspirations nor did they find teaching skills to be important. Previous studies show that departmental culture plays a

major role in how graduate students see themselves as teachers (Lane et al., 2018; Zotos et al., 2020). Graduate students often do not see themselves as teachers because the departmental culture minimizes the importance of teaching and their commitment to teaching is often limited based on time constraints, despite interest and success in teaching. The findings demonstrate that being recognized or recognizing oneself as a good teacher is not always sufficient for developing integrated teaching and identities and that there is a need for explanations of how teaching training and experience can be beneficial outside of a teaching career.

To answer the research question 2, regarding the valued components of the redesigned course, students found the teaching-related modules and reflection assignments to be the most useful. It was especially important that students were trained to teach over Zoom and were able to practice those skills in a low-stakes environment with constructive feedback. The reflections also provided an additional space for students to make connections between the course content and practical applications of the content. Previous studies posit that opportunities for reflection for GTAs is a vital source for professional development (Dragisich, Keller, Black, et al., 2016; Zotos et al., 2020). In summary, the relational (peers and instructors), ideational (discussions and reflections on holding multiple roles), and material (teaching modeling and practice) resources provided within the course were generally well received by students and in part contributed to identity development as researchers and teachers. However, despite best efforts to incorporate the needs of students, important topics such as grading were not address and as such should be incorporated into future iterations of the course.

Conclusions

The results of this study demonstrate that there is a need to explicitly state the importance and purpose graduate student roles and to be intentional about the ways in which graduate

students are enculturated into the communities of teaching and research. It is vital that graduate students understand how and why teaching is important to their education more broadly and how students can leverage teaching opportunities and subsequent skill development for their own career interests. That being said, a course alone is not necessarily sufficient for identity development. Mentors outside of the course, like faculty and staff, also play a large role in identity development (Pfund et al., 2016) and influence students' perceptions of teaching and research outside the course, thus departmental climate should also be studied alongside graduate student identity development. To expand on the current study, longitudinal research on graduate student identity development after the completion of training courses should be conducted to provide insight into long-term impacts of interventions that are intended to support integrated research and teaching identity development. If instructional training functions as an intentionally designed professional development experience that is relevant to multiple career trajectories, this could further disrupt the notion of a teaching-research tradeoff and better justify the employment of graduate students as teaching assistants.

Chapter 5, in part is currently being prepared for submission for publication of the material. Corrales, Adriana; Komperda, Regis. "Exploring Chemistry Graduate Student Identity Development and the Intersection of Multiple Sub-Identities". The dissertation/thesis author was the primary investigator and author of this material.

Chapter 6: Conclusions and Implications

This chapter recapitulates the findings for each research goal and sub-question. Goals 1 and 2 are discussed together and goals 3 is addressed separately. Recommendations for graduate programs and broader impacts on the field are outlined. Limitations of the study design are also addressed in addition to other constraints on data collection. Lastly, future directions and conclusions of the study are detailed.

Review of Results

Weidman and Deangelo (2020) describe graduate student socialization in stages in which graduate students develop different "states of identity and commitment." This "malleability" of identity is further emphasized in Winstone & Moore's work (2017) in which graduate students are seen as researchers, teachers, employees, and more. Baker and colleagues' work in the domain of graduate student identity has recently been expanded to include consideration of personal identities such a race and ethnicity (Griffin et al., 2020), but consideration and conceptualization of various identities and their intersections for chemistry graduate students, in particular, is still needed to understand how to effectively support graduate students. This study provides insight into the multifaceted nature of graduate student identity, expanding on work of Zotos et al. (2020), which focused mainly on teaching identity development, to look at holistic graduate student identity development and the interactions of multiple identities.

Research Goals 1 and 2

The first two research goals comprise a bulk of the analysis and results to describe overall graduate student identity development and the sub-identities therein. Qualitative data from interviews and open-ended survey questions and quantitative survey data were used for the following research questions. The two research goals and sub-questions are:

1) Understand graduate student identity development as scientists, teachers, and students throughout their graduate career.
    a) Which sub-identities do graduate students develop as a result of experiences with teaching and research?
    b) What are the trajectories of sub-identity development?
    c) What experiences and other resources contribute to the development of these sub-identities?
2) Understand the relationships between graduate students' multiple sub-identities in the context of particular institutional environments.
    a) To what extent do graduate students perceive an intersection between teaching and research sub-identities?
    b) What are the relationships between graduate students' multiple sub-identities more broadly?
    c) What resources do graduate students access in order to make sense of and sustain various sub-identities simultaneously?

The answers to these questions provide information about the types of identities that graduate students develop and how graduate students can be supported in their programs. As stated previously, research goal one and the sub-questions have been collapsed into one overarching question describing the sub-identities graduate students develop. Next, I will summarize the results for each sub-question for research goals 1 and 2.

1. Graduate Student Identities. The identities that were most salient for participants of this study were research, teaching, and student identities, respectively. Research is the primary identity that most students are in the process of developing, likely due to the departmental or

institutional emphasis on research as their primary role. This is a common mindset in the STEM departmental culture (Luft et al., 2004; Stachl & Baranger, 2020) and is also reflected in the consideration of all other identities as secondary. Research identities are developed through the proficiency in certain skills such as writing scholarly articles and performing laboratory tasks. These skills are the main gatekeepers for identity development and the support in these skills are highly variable across student participants. Beyond proficiency in the laboratory, graduate students in this study consider themselves to be scientists when they are given agency in developing projects and perform studies that have a high impact on the science community. Students in this study want to know that their work will make a difference and previous work shows that this is often the case (Carlone & Johnson, 2007). Graduate students are less likely to consider themselves to be students and prefer the term learners or life-long learners. They are learning in settings outside of the classroom and thus see their role as continual learners rather than students, despite the presence of "student" in the name. The student identity is often described as a scientist-in-training and could be more of an extension of the research identity. Lastly, teaching identity development is supported by content knowledge, agency in facilitating courses, and opportunities for mentoring. Graduate students in this study often see themselves as facilitators or babysitters as is consistent with previous work (Zotos et al., 2020). However, when granted more control over their teaching graduate students developed more salient teaching identities and considered teaching integral part of how they viewed themselves as graduate students.

2a. Intersections of Research and Teaching. When considering how research and teaching identities overlap for graduate students, Gilmore and colleagues (2014) have proposed a need for a qualitative study on the intersections of these roles. For participants in this work, just

under half of students surveyed perceived an overlap between the two roles, while 89% of students interviewed demonstrated this notion in some way. This indicates that the graduate student participants in this study self-selected for those that have considered their multiple roles in the past and are aware of intersections between research and teaching. Overall, conceptions of research and teaching intersections do exist, but more work must be done to facilitate deeper connection for graduate students. Means for facilitating these connections will be discussed later. Interview participants conveyed that teaching was often useful for improving their research skills but did not mention how research could benefit their teaching, proving further evidence that research holds primacy. This is consistent with previous work in which many students demonstrated a unidirectional connection between roles but a bidirectional connection between teaching and research skills was not common (Gilmore et al., 2014).

2b. Research and Personal Identity Intersections. While some interview participants explicitly stated that their personal identities were not relevant to their research identities, others did describe personal identities that interacted with the research identity. Some graduate students reported that their personal identities conflicted with their research roles. For example, one student had difficulties with developing and conceptualizing her personal identity outside of the lab and that led to a great deal of turmoil regarding her overall perception of herself. Others had conflicts due to their socioeconomic status as graduate students are often not paid a living wage, but are expected to work long hours. As well, international students struggled with acclimating to a new lab as well as a new country away from their support systems. Others reported feeling a sense of belonging because their personal identities were supported and valued. This included having representation of one's personal identity on dissertation committees and at conferences as well as mentors creating space for expression of students' personal identities.

2c. Resources for Reconciliation and Support. The results above demonstrate the need for support for sub-identities other than research. Students enter graduate programs as people and should be supported as whole people. Students devote long hours to their programs and social support from their departments are clearly needed (Close et al., 2016; Rockinson-Szapkiw et al., 2017; Wilkins-Yel et al., 2021). This includes support for teaching through legitimate peripheral participation and apprenticeship in teaching, which is increasingly more common (Kendall et al., 2013) and support for personal identity development through whole-person style mentorship as well (Gross et al., 2015; Wilkins-Yel et al., 2021). As long as support is only provided for certain types of students, students of color, first-generation, neurodivergent, and other people who are consistently excluded and unsupported in academic spaces will not have the affordances to succeed. It is on the onus of institutions to provide this support if they are truly committed to diversity and inclusion in their graduate programs (Harshman, 2021; Sharpe et al., 2018; Stachl & Baranger, 2020; Wilkins-Yel et al., 2021). Anything less is merely performative.

Research Goal 3

The third research goal was designed to demonstrate a practical application of the above ideas and how it can be used to evaluate a course tailored to support identity development. Data from the case study subset of interviews, course evaluation surveys, and classroom artifacts were used for this portion of the study. Research goal and sub-questions are as follows:

3) Redesign an existing GTA training course using best practices from the literature such as feedback and reflection, and evaluate the impact of the course on graduate student identity development.
    a) How does teaching experience and a first year graduate student training course contribute to the teaching and research identity development for graduate students?

b) Which components from the course do graduate students value? Specifically, to what extent do students value the feedback and reflection components of the course?

Identity development for five students participants, themes across student cases, and overall takeaways from the course are presented next.

3a. Identity Development through a Graduate Student Training Course. Similarly to the larger graduate student interview population in Chapter 4, the case study participants in the graduate student training course displayed different levels of identity development as researchers and teachers and perceptions of intersection. The student cases fell into three categories of overlap: teaching is a part of being a scientist, teaching and research may be related in some way, and teaching skills are not important for becoming a researcher. These three themes display the common conceptions of teaching from the MRTS open-ended question data and previous work from Gilmore and colleagues (2014). While there were trends in perceived overlap, the extent of identity development for each student's sub-identities did not show a definitive trend. Some students had strong research and teaching identities, but did not perceive overlap, while others did. These results indicate that more must be done to facilitate development of student conceptions of research and teaching intersections and that while a 14-week course can be beneficial, longer-term support is needed to develop and sustain these ideas.

3b. Valued Components of the Redesigned Course. Specific components of the redesigned course that students reported as useful were the teaching-related modules and reflection assignments. Most students in the course were teaching for the first time and all students were teaching online for the first time. Students found that the abundance of resources in the form of teaching demonstrations, in class discussions, presentation practice, and reflection assignments enriched their knowledge of teaching and communicating and were beneficial to

their development. This aligns with current literature on graduate teaching assistant (GTA) training as sustained support, practical teaching experience and discussion and reflections on teaching are the current known best practices for instructional training (Dragisich, et al., 2016; Zotos et al., 2020).

Summary

In summary, the results from each of the three research goals provide insight into the experiences and development of chemistry graduate students who have persisted in academia thus far. Graduate students in this study recognized their roles, but may not have been provided the tools or opportunities to recognize the intersections or benefits of the overlap. In this study, students reported placing their research identity above all else, even beyond their personal identities as people and often reported struggles due to that. Contrastingly, students of color reported positive experiences in which their personal identities were valued; however, this is likely reflective of the nature of the study design and recruitment process as the participant pool consists of students currently situated in graduate programs. By following people who have persisted we can speculate about what may have happened to people who are not in this data set, for example students who did not receive the positive support from advisors and peers would likely be excluded. For example, Wilkins-Yel et al. (2021) describe cases in which women of color in graduate programs felt unsupported in their personal identities and lacked psychosocial support such that they discontinued their STEM doctoral programs. This study provides further evidence that intentional support for students of color, disabled students, non-traditional students, etc. is vital to promoting persistence and success.

As well, being intentional in conveying to students why their multiple roles, such as teaching, are beneficial in many contexts can contribute to more well-rounded students who can

leverage their skills across communities. Students are enculturated into an academic community that involves research, teaching, learning, mentoring, and being human and in turn institutions and the stakeholders within them are obliged to intentionally support them as the multi-faceted people they are. Providing a space for graduate students to pursue their interests and be fully themselves is integral to identity development and belonging and should not be considered extra.

Conclusions and Recommendations

While there has been progress in improving graduate education through calls for better mentoring and understanding diverse graduate student experiences (Byars-Winston et al., 2020; Harshman, 2021; Sharpe et al., 2018), these innovations and improvements often occur on a smaller scale such as within programs or departments. What should be recognized is that enduring change must be promoted through changes in the academic systems within which programs and departments operate (Kezar et al., 2018; Reinholz & Apkarian, 2018). This means that while small scale studies such as the current dissertation are useful for understanding how improvements can be made at the student, faculty, and staff levels, higher level stakeholders must uphold and mirror these improvements as well. Therefore, this section outlines recommendations for graduate programs and the institutions in which they are situated in order to promote meaningful improvements in graduate education. The recommendations, organized by research question and subsequent findings, are as follows: a) provide incentives for students to pursue legitimate teaching roles and opportunities for reflection on the utility of those roles, b) humanize graduate students experiences and validate intersectional identities through incentivization of excellence in mentoring the whole person, and c) design graduate student training courses that are relevant to the student population and address the intersecting nature of graduate student roles.

Providing Legitimate Teaching Opportunities

Teaching is often not valued in STEM departments such as chemistry (Stachl & Baranger, 2020) and interest in such domains is either passively or even actively discouraged. These sentiments are noticed and taken up by graduate students, which often leads to a devaluing and lack of recognition of the benefits that teaching can provide, which is in alignment with the findings as teaching was considered as less important and not necessary for professional development. Even students interested in teaching or who recognized that they are good teachers did not value teaching or perceive benefits outside of a direct connection to a teaching career. To combat this, graduate programs, departments, and institutions as a whole must be intentional in how they enculturate graduate students to teaching, how they frame responsibilities of teaching, and how these skills are useful outside of pursuing a teaching career (Weidman & Stein, 2003). Specifically designed courses, modules, workshops or trainings related to teaching and their utility for professional development beyond GTA responsibilities are needed. Within this study, the graduate training course is a start to this, but further sustained mentorship and training is still important. While students in this study reported that the course was useful, outside sources of support such as mentorship and legitimate teaching experiences were also large factors. If institutions must rely on GTAs for education, then efforts must be made to train them in ways that do not harm undergraduates at the least and benefit graduates and undergraduates at best.

Specific actions include: a) providing monetary awards for excellence in teaching for graduate students, faculty, and staff, b) allowing graduate students to pursue teaching interests without guilt due to negative departmental perceptions of teaching, and c) including teaching as a legitimate part of apprenticeship rather than additional work that is placed upon students in addition to research demands. Similar strides in prioritizing instructional training for GTAs can

be seen in mathematics education (Pilgrim et al., 2021) in which GTAs are exposed to mathematics pedagogy and are specially trained and supported long-term to teach a certain subject in mathematics.

Humanizing Graduate Education

In addition to including teaching as a legitimate part of graduate student professional development one must also consider the following: graduate students are people. In the academy, we promote the idea that research is paramount and all else is secondary including one's own personal identities and needs, as was seen in the findings of this study. Students can lose their sense of self, may encounter mental health issues (Afonja et al., 2021; Sharpe et al., 2018), or lack a sense of belonging because they must hide parts of themselves for a large portion of their daily lives (Brown, 2016). Thus, it is important that graduate programs make concerted efforts to humanize graduate education to prevent these deleterious outcomes for students. This has been called for in recent work from Santa-Ramirez (2021) in which holistic mentoring and humanization of graduate student experiences were key features of positive mentoring relationships and student outcomes. In practice, programs must examine the ethics of how graduate students are treated and departments must incentivize excellence in mentoring in order for graduate students to be better supported as people (Sharpe et al., 2018).

Specific actions include a) including mentoring and service in tenure decisions, b) providing monetary awards for excellence in mentoring, c) providing time and money more faulty to attend professional development workshops in mentoring. This would directly address the current needs of graduate students who report that they require more support from their advisors (Kuniyoshi et al., 2021) and in turn promote sense of belonging (Griffin et al., 2020) and potentially persistence in chemistry graduate programs.

Meeting the Professional Needs of Graduate Students

To better address the professional needs of graduate students, it is recommended that a) faculty work directly with graduate students to elicit their feedback and perspectives and incorporate these ideas into training course designs and b) explicitly address the intersecting nature of graduate students roles. The first recommendation serves to demonstrate that graduate students are legitimate members of the community, which can promote a sense of belonging (Wenger, 1998). This is consistent with findings in this study as students found feedback and reflection components of the training course to be useful and provided specific suggestions for future iterations of the course including adding training in grading assignments. The second recommendation leverages the opportunity for graduate students to develop multifaceted professional identities which include research and teaching. Graduate student sub-identities would ideally intersect and strengthen one another, in turn dispelling the common notion of a teaching-research tradeoff (Shortlidge & Eddy, 2018). Graduate students with the guidance of more experienced others such as faculty, staff, and near-peers would have the opportunity recognize the importance teaching roles regardless of their intended career trajectories and how to leverage teaching experiences in their professional development. Specific actions to this end include a) placing graduate students as leaders and change agents in their programs, b) explicitly acknowledging feedback and how it has been considered and addressed, and c) leveraging student feedback in existing graduate student training courses to meet the specific needs of a cohort.

Contributions

This work adds to the literature by documenting, analyzing, and describing stories of success and persistence through the lens of identity for different types of students in two

chemistry graduate programs and the types of resources that have been efficacious for their success and persistence. It also builds upon previous work in studying chemistry graduate students to include explicit examination of the intersections of multiple identities (Brown, 2016; Tran, 2011; Santa-Ramirez, 2021; Wilkins-Yel et al., 2021). As well, this work demonstrates the potential for chemistry graduate students to understand the intersections of research and teaching identities, which in turn could serve to better prepare them for a variety of careers inside or outside of academia.

Future Directions

This work describes resources and experiences that support graduate student identity development and how chemistry graduate programs can improve education and training. While the mixed-methods approach incorporated a variety of data sources, the qualitative data was emphasized in making claims and formulating themes. Further studies from this particular work would be to administer the Modified Teaching and Research Survey to a larger population across more than two institutions to elicit a greater amount and variety of responses. With a larger pool of responses, comparative statistics could be run to glean more information from the survey data as well as validating the survey using appropriate statistical tests (Arjoon et al., 2013). Improving the survey through additional iterations of implementations, modifications, and validation would strengthen the utility of the survey. The survey could then be used as one tool to monitor progress and success in making meaningful changes to graduate courses or overall programs.

As well, the graduate students training course is a starting point for scaffolding the valued knowledge in graduate apprenticeship and professional development, but more can be done to improve this course, namely to run the course in person and include teaching tools for in-person discussion sections and lab. Furthermore, resources outside of and that extend beyond the course

are needed because while 14 weeks is an extend period of time it cannot be considered “on going” support as is recommended by previous literature (Dragisich, Keller, Black, et al., 2016; Dragisich, Keller, & Zhao, 2016). It should be noted that the course is the first iteration of course transformation and is meant to serve as a starting point for sustainable change through incremental modifications (Stoddard & Brownfield, 2020). As well, the course is meant to provide a context to study identity development situated in an authentic experience. More work is needed to further assess the impact of the course alone on identity development as the course, teaching, research and other experiences collectively influence identity development. Additionally, more research can be done on the specific differences between researcher and scientist identity in the context of graduate education and how students conceive of these concepts in order to strengthen claims about identity development.

Lastly, it is still unclear how programs can convey and strengthen the connections between research and teaching identity and as such further implementations of the survey and studies in additional contexts can provide information on how to build and reinforce those links. More knowledge on this front could greatly improve the utility and value of graduate education and potentially lesson the cognitive load on students.

For future research more broadly, there is a need for work to examine and implement systemic changes in the way that graduate programs are designed and run. There is still a need to elicit student experiences, but in a way that promotes change for the better to prevent contributing to the ever-growing gap gazing (Gutiérrez & Dixon-Román, 2010) literature that points out inequities but often does not contribute to improvements or transformational change, though there are emerging studies that examine program climates and incorporate feedback to implement meaningful change (Stachl & Baranger, 2020). In addition, stakeholders at

institutions of higher education should reexamine the goals of graduate education and how the current structures in their academic systems do or do not serve their student populations and surrounding community. If institutions continue to admit students, both graduate and undergraduate, to learn and develop as professionals, then more must be done to demonstrate commitment to those goals through evidence-based and intentional change at all levels.

Appendix A: GTA Bootcamp Schedule

Monday, August 19th

11:00 — 12:30	TA information on policies, ethics, and getting ready for your TA-ship **CSL 526**
12:30 — 1:00	Break out into groups to discuss Ethics
1:00 — 3:00	Safety Meeting in **GMCS 305**
3:00 — 4:00	Blackboard Training
4:00 — 5:00	Going over how to present to students

Tuesday, August 20th

11:00 — 11:30	Introduction to the Coordinators and Stockroom Technicians in **CSL 529**
11:30 — 1:00	Safety in the Laboratories, Presenting in the Laboratory Room, and other Important TA information
1:00 — 3:00	Titration Experiment (PPE will be required) **Note: Please refer to Experiment titled Volumetric Equipment and Standardization of NaOH in the Chem 200 Lab Manual. You will need to bring with you: Proper lab PPE: closed toed-closed heeled shoes, pants (no holes), T-shirt that covers your shoulders, lab coat or lab apron, and lab safety glasses.**

Wednesday, August 21st

11:00 — 3:00	Chem 100 & 200 10 minute presentations in **TBD**
3:00 — 4:00	Current TA experiences
4:00 — 5:00	Open Discussion

Appendix B: Fall 2019 TFU Course Syllabus

Chemistry 695: Graduate Education in Chemistry and Biochemistry

Location: GMCS 306

Instructors: Redacted

Course Catalogue Description:
Skills and knowledge needed for success in chemistry graduate program to include techniques for successful teaching, key safety protocols, ethical issues in teaching and research, department research programs, effective means of finding and communicating chemical information.

Scope and Purpose:
This class is designed for new graduate students and will cover teaching strategies, lab safety, ethics in science, searching for chemical information, useful software, and tips for presenting and manuscript writing. It will also include presentations of SDSU Chemistry faculty on their research.

Office Hours: e-mail Prof. Name for an appointment

Course Information: Available on Blackboard

Grading:

Class and seminar attendance, participation, faculty interviews	100 Points
Make a CV (Due 09/13)	100 Points
TA/Lab skills	100 Points
Student presentations	150 Points
NSF proposal (Due 12/1)	200 Points
Total	*650 Points*

Grading Scale: A = ≥ 92.5%
A- = 89.5-92.4%
B+ = 87.5-89.4%
B = 82.5-87.4%
B- = 79.5-82.4%
C+ = 77.5-79.4%
C = 72.5-77.4%
C- = 69.5-72.4%
D+ = 67.5-69.4%
D = 62.5-67.4%
D- = 59.5-62.4%
F < 59.4%

Students with Disabilities:

If you are a student with a disability and believe you will need accommodations for this class, it is your responsibility to contact Student Disability Services (SDS) at (619) 594-6473. To avoid any delay in the receipt of your accommodations, contact SDS as soon as possible. Please note that accommodations are not retroactive, and that accommodations cannot be provided until you have presented your instructor with an accommodation letter from SDS. Your cooperation is appreciated.

Lecture	Date/Time	Topic(s)	Location
1	8/19 11 am-5 pm	TA Bootcamp	
2	8/20 11 am-5 pm	TA Bootcamp	
3	8/21 11 am-5 pm	TA Bootcamp	
4	8/22 9 am–1 pm	Welcome, Group Selection; Presentations; Lab Record Keeping;	GMCS 306
5	8/23 1:30-4 pm	Research Presentations by faculty	GMCS 306
6	8/30 12-4 pm	Research Presentations by faculty; Making CV; How to read papers	GMCS 306
7	9/6 12-4 pm	Research Presentations by faculty; Writing Papers; Writing grant proposals;	GMCS 306
8	9/13 12-4 pm	Research Presentations by faculty; Computer Resources (SDSU library, Pubmed, Scopus, SciFinder, Paper Organization Tools, Feedly, Data backup, graphing tools)	GMCS 306 ***Bring your laptop!***
CV due on 9/13			
9	9/20 12-4 pm	Ethic; Science Careers my IDP; Networking in San Diego;	GMCS 306
10	9/27 12-4 pm	Student Presentations	GMCS 306
11	10/4 12-4 pm	Student Presentations	GMCS 306

Lecture	Date/Time	Topic(s)	Location
Faculty interview sheet due on 10/14			
NSF proposal due on 12/1			

Student Outcomes:
Upon completion of this course students will be able to:
1) Teach undergraduates successfully in laboratories.
2) Perform safely in a laboratory both as a student and as a researcher.
3) Evaluate ethical situations associated with research and know the appropriate steps to take in order to maintain high ethical standards.
4) Be knowledgeable of the diversity of research within the department in order to make an appropriate choice of research for their graduate study.
5) Search efficiently for the chemical information they will need for their course and research work.
6) Use popular chemistry software.

Textbook (required):
On Being a Scientist: A guide to responsible conduct in research 3rd edition. Available free online at: http://www.nap.edu/catalog.php?record_id=12192

Other resources:
http://en.wikipedia.org/wiki/Scientific_misconduct
http://en.wikipedia.org/wiki/MSDS (and references therein)
http://tlt.psu.edu/plagiarism/student-tutorial/
http://www.sciencegeek.net/Chemistry/chemware/chemware.shtml
http://bionumbers.hms.harvard.edu/
https://pymol.org/edu/?q=educational/
https://www.ncbi.nlm.nih.gov/pubmed/

Appendix C: Fall 2020 TFU Course Syllabus

Course Sessions:

Fridays (Virtual) 12 pm – 4 pm (Tentative) Zoom link available in Canvas

Instructors: Redacted

Welcome to Chem 695! This course is designed to introduce new graduate students to the department and the variety of roles and responsibilities included therein. In this course we will develop academic skills as scientists, instructors, and students. This will include presentation skills, classroom management and lab safety, research and teaching ethics, grading and providing feedback, scientific reading and writing, use of online resources, networking, and career planning. This course is designed to support YOU as a new graduate student, therefore we will work together to make this class useful for everyone. Our mission is to set you up for success and provide the community structure to support you long-term.
Students are provided with an SDSU Gmail account, and this SDSU email address will be used for all communications. Per University Senate policy, students are responsible for checking their official university email once per day during the academic term. For more information, please see Student Official Email Address Use Policy here.
All communication regarding this course should occur through official SDSU email accounts. The course instructors will be available via email to answer questions or to schedule office hour appointments. Please allow 24-48 hours for a response, longer over weekends and holidays.

Course Catalog Description

Skills and knowledge needed for success in chemistry graduate programs which include techniques for successful teaching, key safety protocols, ethical issues in teaching and research, department research programs, effective means of finding and communicating chemical information.

STUDENT LEARNING OUTCOMES

Upon completion of this course students will be able to:

- LO1) Teach undergraduates successfully in laboratories.
- LO2) Perform safely in a laboratory both as a student and as a researcher.
- LO3) Evaluate ethical situations associated with research and know the appropriate steps to take in order to maintain high ethical standards.
- LO4) Be knowledgeable of the diversity of research within the department in order to make an appropriate choice of research for their graduate study.
- LO5) Search efficiently for the chemical information they will need for their course and research work.
- LO6) Use popular chemistry software.

COURSE MATERIALS

On Being a Scientist: A guide to responsible conduct in research. 3rd edition. Available on course Canvas page and free at: http://www.nap.edu/catalog.php?record_id=12192

All other required readings will be made available through Canvas (https://sdsu.instructure.com/).

Class Resources/Links:
http://en.wikipedia.org/wiki/Scientific_misconduct
http://en.wikipedia.org/wiki/MSDS (and references therein)
http://www.sciencegeek.net/Chemistry/chemware/chemware.shtml
http://bionumbers.hms.harvard.edu/
https://pymol.org/edu/?q=educational/
https://www.ncbi.nlm.nih.gov/pubmed/

COURSE DESIGN

Equity, Inclusion, and Diversity:
In this course, we are committed to creating a safe space for people of all views and backgrounds. We may cover difficult topics in this course regarding social issues that you may encounter while teaching or at some other point in your teaching career. It is our intent to present materials and activities that are respectful of diversity: gender identity, sexual orientation, disability, age, socioeconomic status, ethnicity, race, culture, perspective, and other background characteristics. Suggestions about how to improve the value of diversity and inclusion in this course are encouraged and appreciated.

Community Building:
This is a course designed to build community among the graduate student cohort and beyond. The course instructors are committed to your success and we intend to support the formation of a community among your peers to expand that support. Formation of a graduate student community can be an integral part of your success and this course will lay the framework for such a community.

Assignments:

Class and seminar attendance, participation	200 points
Faculty interviews	100 points
Student presentations + peer feedback	100 points
Reflections (submitted to Canvas)	100 points
Assignments (submitted to Canvas)	200 points
Total	**700 points**

GRADING POLICIES

Grading Scale:

	A = ≥ 92.5%	A- = 89.5-92.4%
B+ = 87.5-89.4%	B = 82.5-87.4%	B- = 79.5-82.4%
C+ = 77.5-79.4%	C = 72.5-77.4%	C- = 69.5-72.4%
D+ = 67.5-69.4%	D = 62.5-67.4%	D- = 59.5-62.4%
	F < 59.4%	

SCHEDULE

Tentative Schedule (check Canvas for any updates): *Unless otherwise told by the instructor, all assignments are due in Canvas at 10 pm on the Thursday before class.*

Class #	Date/Time	Topic(s)	Assignment(s) Due BEFORE Class	Learning Outcome
N/A	8/18 12 - 4pm	• Introductions to key personnel • Preboarding		LO1, LO2
N/A	8/19 1 - 5pm	• Technology for graduate students: Canvas, Blackboard, Zoom & Gradescope		LO1
N/A	8/20 12 - 4 pm	• Policies, ethics, and lab safety		LO1, LO2
N/A	8/21 1:30-2:30pm	• Panel with experienced GTAs		LO1
1	8/28 12 - 4 pm	• Discuss first week of class • Finding a research group • Faculty research presentations	• Zoom link • Introduction slide or video	LO1, LO4
N/A	8/28 4 - 5 pm	Department Seminar/Additional Faculty Research Presentations		LO4
Class #	**Date/Time**	**Topic(s)**	**Assignment(s) Due BEFORE Class**	**Learning Outcome**
2	9/4 12 - 4 pm	• Overview of campus resources • Discussion of Canvas CTL M1 • Preparing and giving presentations	• Canvas CTL M1 • Reflection • Canvas Profile	LO1, LO4
N/A	9/4 4 - 5 pm	Department Seminar/Additional Faculty Research Presentations		LO4
3	9/11 2 - 4 pm	• Deliver prepared presentation • Provide feedback to peers	• Presentation	LO1
4	9/18 2 - 4 pm	• Issues related to equity, diversity, and inclusion	• Canvas CLT M3 • Reflection	LO1

			• Implicit bias test	
5	9/25 2 - 4 pm	• Responsible Conduct of Research (RCR) • Ethics case studies	• Reflection	LO3
6	10/2 2 - 4 pm	• Difficult classroom situations	• RCR Complete	LO1
7	10/9 2 - 4 pm	• Mid-semester check-in • Select elective CTL module	• Reflections • Faculty Interviews	LO1
8	10/16 2 - 4 pm	• Software, online and library resources	• Canvas CTL module	LO5, LO6
9	10/23 2 - 4 pm	• Finding funding opportunities	• Reflection	LO4
10	10/30 2 - 4 pm	• Managing literature and citations • Reading and writing academic articles	• Funding plan	LO4
11	11/6 2 - 4 pm	• Networking and career planning	• Reflection	LO3, LO4
12	11/13 2 - 4 pm	• Mentoring • Individual Development Plans	• Reflection	LO4
13	11/20 2 - 4 pm	• Deliver prepared presentation • Provide feedback to peers	• Presentation • IDP/Mentor Map	LO1
14	12/4 2 - 4 pm	• End of semester discussion • Catalyze! Board Game	• Final Reflection	LO1

Appendix D: Reflection Prompts

Implicit Bias and Microaggressions

1. Reflect on your implicit bias test results. Is this what you expected? Were you familiar with this term before?
2. What comes to mind when you see the term microaggression? Were you familiar with this term before?
3. Which strategy(ies) from the inclusive classroom module would you find most useful as a student and why?
4. Which strategy(ies) do you think you could personally implement as a TA and why?

Equitable Teaching Practices

1. Reflecting on the discussion in class on [Date], has anything changed about your understanding of implicit bias and microaggressions?
2. Do you see any opportunities to apply what we discussed to situations in a research or teaching context?

Mid Semester Check-in

1. How is your teaching going? How is your research/group selection going?
2. How are your classes and other responsibilities going?
3. Do you have any questions or concerns regarding your workload? Do you have any questions or concerns regarding teaching or research?
4. Reflecting on topics we've covered in 695 so far, have you implemented any of that knowledge? How?

Week 11 Check-in

1. How are you feeling about your teaching responsibilities for the rest of the semester? Are there tips you can share with your peers, or things you'd like to ask their input on?
2. How are you feeling about your classes for the rest of the semester? Are there things that are working well for you that you'd like to share, or things you would like to ask your peers for help with?
3. How are you doing with your research responsibilities? Any positives you'd like to share? Any issues you'd like to ask for help with?

Final Reflections

1. How were you able to manage your workload this semester? Looking back, what are you most proud of and what would you change about the way you managed your responsibilities?
2. How, if at all, have your teaching or presentation skills changed over the course of the semester? Do you feel that your ideas about teaching or presenting have changed at all this semester?
3. How has your transition into research been? You can address positive aspects and challenges and how you've managed them.
4. Reflecting on topics we've covered in 695, have you implemented or do you plan to use any of that knowledge? How?

5. What are you most excited about for next semester and why?
6. What are you most nervous about for next semester and why?

Appendix E: Start Codes for the Pilot Interview Analysis

Code	Description	Example Discourse
Competence		
Joint-enterprise	Component to which members are accountable. What are we all trying to do?	For a teacher or researcher this could be as simple as "we want to communicate science effectively."
Mutuality	How norms/competencies are established.	The course coordinator has guidelines regarding how GTAs should present lab lecture.
Shared-Repertoire	The shared knowledge and resources to which members should have access.	GTAs have access to grading rubrics for their class. I talk to my PI (resource) about issues with my research.
Belonging		
Engagement	How one participates.	I make sure to give meaningful feedback to my students. I work in lab every day.
Imagination	How one see themselves (now or in the future) in a community.	I see myself as a researcher with teaching responsibilities.
Alignment	How one's perspectives, ideals, and goals align with a community.	I want to be a professor who focuses on research.
Nexus of Multi-membership		
Connectedness	The degree to which one feels a part of a community. Influenced by the components of belonging. Includes recognition by others.	I don't talk to the other GTAs outside of TA meetings.
Expansiveness	The degree of multi-membership.	I use presentation skills from teaching when giving talks at conferences.
Effectiveness	The degree to which participation influences identification.	I use the GTA discussion board to troubleshoot problems in my class and I now I feel more confident in my teaching.
Identity		
Competence/Performance	One's belief in their ability to understand content specific	I'm a social person so presenting in front of others is easy for me.

	information and perform required tasks.	
Recognition	Whether and how one is seen as a type of person by oneself and by others.	My PI says I am a diligent researcher.
Interest	One's inclination to think about and understand content in a domain.	I like to read education research articles in my spare time.
Resources		
Material	Tangible resources for identity development.	The instructional training course was helpful for me to develop my skills as a teacher.
Relational	Relationships with others that influence identity development.	My PI was supportive in my goals to pursue research interests in chemistry education research.
Ideational	Ideas (values, beliefs, narratives, etc.) that (dis)connect someone (from)to an identity.	Researchers don't have time to focus on teaching.
Trajectories		
Inbound	The goals is to become a full member.	I participate in…
Insider	A full member who negotiates novel roles, practices, and norms in a community.	I organize…
Outbound	The movement out of a community and often into another.	I don't feel welcome in…
Boundary	A member who operates at the boundary of multiple communities.	I strive to connect my skills in multiple domains.

Appendix F: Pilot Interview Protocol

*Before Interview: Present the participant with a copy of the consent form (via email) and the electronic form to sign.

Hello my name is Adriana Corrales and I am a 3rd year PhD candidate at SDSU studying mathematics and science education. I am conducting this interview to get a sense of the ways in which graduate students see themselves and their roles in a graduate program. In addition, intend to use this information to improve future versions of the Chemistry and Biochemistry GTA training program. This interview is entirely confidential and the information will be anonymized for future analysis. Do you have any questions for me before we get started?

Background Questions

1. What year are you? Major/research focus?
2. What were you doing before grad school? (education, other jobs, etc)
3. How/why did you become interested in science?
4. What are your goals after you graduate?

Science Identity

1. What is the role that science plays in your life?
2. When you think of a scientist what comes to mind?
    a. What kinds of activities do scientists engage in?
    b. Responsibilities?
    c. Who (someone you know or know of) do you see as scientists?
3. Do you see yourself as a scientist?
    a. Why or why not?
4. What experiences have contributed to your identity as a scientist? Anything that has encouraged or discouraged you in science?
    a. Has ANYONE encouraged/discouraged you in science?
    b. How did your identity change or develop over time based on these experiences?
5. Have you ever felt that you don't belong in science?
    a. Explain with examples
6. Do you think other people see you as a scientist (chemist)?
    a. Your peers?
    b. Your professors/supervisors?
    c. Your family?
    d. Anyone else?
    e. If yes, does this tend to be more common with people who you share a stronger or weaker personal connection with?
7. Are there aspects of your skills as a scientist (or grad student) that you feel you need/want to improve? (skill-based)
    a. What are they?
    b. What steps do you feel you need to take to improve these skills?
    c. What will the development of those skills do for you?
8. Do you see yourself as a learner of science? Why or why not?

    a. Do you see yourself as a successful science student/learner? (could incorporate into #13 depending on the answers)
9. Are there others who you look to for advice, guidance, etc. to become a better scientist (grad student)? (self-based) - may omit depending on how they answered #7 in professional goals
    a. Try to get at any mentoring experiences, can ask:
        i. What are the qualities of a successful/good mentor?

Teaching Identity (Teaching - another aspect of your grad student life that is often required of you)

10. When you think of an instructor/educator/TA/faculty what comes to mind?
    a. What kinds of activities do educators engage in?
    b. Responsibilities?
11. Do you teach currently or have you taught, in any capacity, in the past? Explain.
12. If they say TA: What do you see as your role as a TA?
13. Do you see yourself as a successful TA? Why or why not?
    a. Are there any salient teaching experiences that you have had in the past that have encouraged or discouraged you?
14. What are the qualities of a successful TA?
    a. Why do you think that? Where did you get these ideas about teaching from?
15. If they mention TA training:
    a. What did you use from your TA training? What was salient to you?
16. Do you see yourself as an instructor/educator in general?
    a. Why or why not?
    b. To what extent?
17. Do you have any interest in teaching (beyond grad school)? In being an instructor/educator/faculty?
    a. Why or why not?
    b. What sparked this interest?
18. Do you think other people see you as an instructor or teacher? Why?
    a. Your students?
    b. Your peers?
    c. Your professors/supervisors?
    d. Your family?
    e. Mentees?
19. Are there aspects of your skills as an educator/instructor/mentor that you feel you need to improve? (skill-based)
    a. What are they?
    b. What steps do you feel you need to take to improve those skills?
    c. Why do you think that? Where did you get these ideas about teaching from?
    d. If applicable: Where do you derive this motivation to implement innovative teaching techniques/be a better teacher?
20. Are there others who you look to for advice, guidance, etc. to become a better educator/instructor/mentor? (self-based)
    a. Who? Explain.
21. Do you feel supported in your teaching/instruction/mentoring efforts?

    a. Why/why not?
    b. By whom?
    c. If they don't bring it up: How is your relationship with the faculty or course coordinator you TA for? Do you feel supported by them? How?
22. Do you think that teaching experience is necessary or important in your field (as a grad student)?
    a. Why or why not?
23. Are there ways in which you have benefited from your teaching experiences?
    a. Explain with examples.
    b. Try to get at any mentoring experiences, if you haven't yet:
        i. What are the qualities of a successful/good mentor? (may come up earlier)
24. What are other members of your department or institution's attitudes toward teaching?
    a. Faculty
    b. Peers
    c. Mentors
    d. Staff
    e. Other?
    f. How do you feel about this?

Closing

25. Are there any other aspects of your identity that you feel contribute to/color your experience as a graduate student?
    a. Explain with examples
26. If applicable: How do you handle managing all of these roles (TA, researcher, student, etc.)?
27. Is there anything else about your graduate school experience that you would like to add? Anything salient to you that has contributed to your development as a scientist, student and/or researcher?

Demographic Information

1. Gender
2. Race/Ethnicity
3. Year in graduate school
4. MS or PhD
5. International Student?

Appendix G: Main Study Interview Protocol

*Before Interview: Present the participant with two copies of the consent form: one to keep and one to sign.

Hello my name is Adriana Corrales and I am a 4th year doctoral candidate at SDSU studying mathematics and science education. I am conducting this interview to get a sense of the ways in which graduate students see themselves and their roles in a graduate program. In addition, intend to use this information to improve future versions of the Chemistry and Biochemistry GTA training program. This interview is entirely confidential and the information will be anonymized for future analysis. Do you have any questions for me before we get started?

Background Questions

1. What year are you? Major/research focus?
2. What were you doing before grad school? (education, other jobs, etc)
3. How/why did you become interested in science?
4. What are your goals after you graduate?

Science Identity

1) What is the role that science plays in your life?
2) When you think of a scientist what comes to mind?
   a) What kinds of activities do scientists engage in?
   b) Responsibilities?
   c) Who (someone you know or know of) do you see as scientists?
3) Do you see yourself as a scientist?
   a) Why or why not?
4) What experiences have contributed to your identity as a scientist? Anything that has encouraged or discouraged you in science?
   a) Has ANYONE encouraged/discouraged you in science?
   b) How did your identity change or develop over time based on these experiences?
5) Have you ever felt that you don't belong in science?
   a) Explain with examples
6) Do you think other people see you as a scientist (chemist)?
   a) Your peers?
   b) Your professors/supervisors?
   c) Your family?
   d) Anyone else?
   e) If yes, does this tend to be more common with people who you share a stronger or weaker personal connection with?
7) Are there aspects of your skills as a scientist (or grad student) that you feel you need/want to improve? (skill-based)
   a) What are they?
   b) What steps do you feel you need to take to improve these skills?
   c) What will the development of those skills do for you?
   d) Do you see yourself as a learner of science? Why or why not?

8) Do you see yourself as a successful science student/learner? (could incorporate into #13 depending on the answers)
9) Are there others who you look to for advice, guidance, etc. to become a better scientist (grad student)? (self-based) - may omit depending on how they answered #7 in professional goals
    a) Try to get at any mentoring experiences, can ask:
        i) What are the qualities of a successful/good mentor?

Teaching Identity (Teaching - another aspect of your grad student life that is often required of you)

1) When you think of an instructor/educator/TA/faculty what comes to mind?
    a) What kinds of activities do educators engage in?
    b) Responsibilities?
2) Do you teach currently or have you taught, in any capacity, in the past? Explain.
    a) If they say TA: What do you see as your role as a TA?
3) Do you see yourself as a successful TA? Why or why not?
4) Are there any salient teaching experiences that you have had in the past that have encouraged or discouraged you?
5) What are the qualities of a successful TA?
    a) Why do you think that? Where did you get these ideas about teaching from?
    b) If they mention TA training:
        i) What did you use from your TA training? What was salient to you?
6) Do you see yourself as an instructor/educator in general?
    a) Why or why not?
    b) To what extent?
7) Do you have any interest in teaching (beyond grad school)? In being an instructor/educator/faculty?
    a) Why or why not?
    b) What sparked this interest?
8) Do you think other people see you as an instructor or teacher? Why?
    a) Your students?
    b) Your peers?
    c) Your professors/supervisors?
    d) Your family?
    e) Mentees?
9) Are there aspects of your skills as an educator/instructor/mentor that you feel you need to improve? (skill-based)
    a) What are they?
    b) What steps do you feel you need to take to improve those skills?
    c) Why do you think that? Where did you get these ideas about teaching from?
    d) If applicable: Where do you derive this motivation to implement innovative teaching techniques/be a better teacher?
10) Are there others who you look to for advice, guidance, etc. to become a better educator/instructor/mentor? (self-based)
    a) Who? Explain.
11) Do you feel supported in your teaching/instruction/mentoring efforts?
    a) Why/why not?

b) By whom?
c) If they don't bring it up: How is your relationship with the faculty or course coordinator you TA for? Do you feel supported by them? How?

12) Do you think that teaching experience is necessary or important in your field (as a grad student)?
    a) Why or why not?
13) Are there ways in which you have benefited from your teaching experiences?
    a) Explain with examples.
    b) Try to get at any mentoring experiences, if you haven't yet:
        i) What are the qualities of a successful/good mentor? (may come up earlier)
14) What are other members of your department or institution's attitudes toward teaching?
    a) Faculty
    b) Peers
    c) Mentors
    d) Staff
    e) Other?
    f) How do you feel about this?

Closing

1) Are there any other aspects of your identity that you feel contribute to/color your experience as a graduate student?
    a) Explain with examples
    b) If applicable: How do you handle managing all of these roles (TA, researcher, student, etc)?
2) Is there anything else about your graduate school experience that you would like to add? Anything salient to you that has contributed to your development as a scientist, student and/or researcher?

Demographic Information

1. Gender
2. Race/Ethnicity
3. Year in graduate school
4. MS or PhD

Appendix H: Follow-up Interview for Case Study

Hello again! This is a follow up to our previous interview to see how you have progressed over time. This interview is entirely confidential and the information will be anonymized for future analysis. Do you have any questions for me before we get started?

Science Identity

1. How are things for you now? Are they different from last semester?
2. How is lab work/research going? How is your relationship with your labmates and PI?
    a. Are they helpful? How?
3. Are there aspects of your skills as a scientist (or grad student) that you feel you need/want to improve? What are they?
    a. Have you been working on these skills? How has this helped you?
4. Have you found any new mentors (other than your PI) and how have they helped you?
    a. Try to get at any mentoring experiences, can ask:
        i. What are the qualities of a successful/good mentor?
5. Do you see yourself as a scientist now?
    a. Why or why not?
6. Have you ever felt that you don't belong in science while in this program specifically?
    a. Explain with examples

Teaching Identity

1. Are you TA now? Tell me about your class and how it's going.
2. Do you see yourself as a successful TA? Why or why not? Have you improved since the last time (if applicable)?
    a. Are there any salient teaching experiences that you have had in the past that have encouraged or discouraged you?
3. So the techniques that you're using right now for teaching where did those come from? Did it come from my past experiences?
4. Do you see yourself as an instructor/educator/teacher now?
    a. Why or why not?
    b. To what extent?
5. Do you have any interest in teaching (beyond grad school)? In being an instructor/educator/faculty?
    a. Why or why not?
    b. What sparked this interest?
    c. Has this changed over time?
6. Are there aspects of your skills as an educator/instructor/mentor that you feel you need to improve? What are they?
    a. Have you been working on these skills? How has this helped you?
    b. So what aspect of your teaching skills have improved over this time of being in Grad school.
7. Do you feel supported in your teaching/instruction/mentoring efforts?
    a. Why/why not?
    b. By whom?

c. If they don't bring it up: How is your relationship with the faculty or course coordinator you TA for? Do you feel supported by them? How?

8. Compared to what you've thought before, do you think that teaching experience is necessary or important in your field (as a grad student)?
    a. Why or why not?
9. Are there ways in which you have benefited from your teaching experiences?
    a. Explain with examples.

Closing

1. If applicable: How do you handle managing all of these roles (TA, researcher, student, etc)? Do you have time for yourself? Do you feel like you're able to be your authentic self in these settings?
2. Is there anything else about your graduate school experience that you would like to add? Anything salient to you that has contributed to your development as a scientist, student and/or researcher?

Appendix I : Modified Teaching and Research Survey

	Strongly agree (5)	Somewhat agree (4)	Neither agree nor disagree (3)	Somewhat disagree (2)	Strongly disagree (1)
I am a researcher. (1ID_rec)	○	○	○	○	○
Faculty and Instructors see me as a researcher. (2ID_rec)	○	○	○	○	○
There are aspects of my skills as a researcher that I need to improve. (3ID_skill)	○	○	○	○	○
I am a learner of science. (4ID_int)	○	○	○	○	○
Other people see me as a science student. (5ID_rec)	○	○	○	○	○
I consider myself a successful student. (6ID_pc)	○	○	○	○	○
There are aspects of my skills as a student that I need to improve. (7ID_skill)	○	○	○	○	○
I am an instructor/teacher. (8ID_rec)	○	○	○	○	○
Other people see me as an instructor/teacher. (9ID_rec)	○	○	○	○	○

There are aspects of my skills as an instructor that I need to improve. (10ID_skill)	○	○	○	○	○
I feel supported in my courses. (11IDa_bel)	○	○	○	○	○
I feel supported in my research. (11IDb_bel)	○	○	○	○	○
I feel supported in my teaching practice. (11IDc_bel)	○	○	○	○	○
Friends and family see me as a researcher. (12_rec)	○	○	○	○	○
I feel like I am a part of my lab. (13_bel)	○	○	○	○	○
I feel like I am part of a larger community of researchers. (14_bel)	○	○	○	○	○
For this question select somewhat agree. (CheckAgree)	○	○	○	○	○

Identity Select a choice on the scale for each statement.

End of Block: Identity Development

Start of Block: The Nature of Teaching and Research Relationship

	Strongly agree (5)	Somewhat agree (4)	Neither agree nor disagree (3)	Somewhat disagree (2)	Strongly disagree (1)
Doing research helps/will help me teach students about how research is conducted in my field. (1TRR)	○	○	○	○	○
Being knowledgeable about current research and research methods in my field helps/will help me to better design courses. (2TRR)	○	○	○	○	○
I share/will share aspects of my research with my students. (3TRR)	○	○	○	○	○
Teachers who frequently consider new perspectives while teaching generate more research hypotheses or are better able to see their research in a new way. (4TRR)	○	○	○	○	○
The same person can be an effective teacher and an effective researcher. (5TRR)	○	○	○	○	○
Through teaching, I find/will find students who are interested in research. (6TRR)	○	○	○	○	○
The connection between teaching and research depends on how close your research is to the	○	○	○	○	○

subject that you teach. (7TRR)					
I incorporate/will incorporate my students' ideas and interests into my research. (8TRR)	○	○	○	○	○
There is a disconnect between the kinds of skills that a good researcher needs and the kind of skills that a good teacher needs. (9TRR)	○	○	○	○	○
There is a disconnect between the kind of research that I do and the topics that I teach/will teach. (10TRR)	○	○	○	○	○
For this question select somewhat disagree. (CheckDisagree)	○	○	○	○	○

TRR Select a choice on the scale for each statement.

End of Block: The Nature of Teaching and Research Relationship

Start of Block: Teaching, research and academic skills

TRA This next set of questions asks you to compare the extent to which each skill relates to teaching, research, both or neither.

	Neither Teaching nor Research (1)	Usually teaching and sometimes research (2)	Usually research and sometimes teaching (3)	Both research and teaching (4)
Provides/will provide me with an opportunity to develop knowledge about my field. (1TRA)	○	○	○	○
Improves/will improve my ability to communicate about my field. (2TRA)	○	○	○	○
Improves/will improve my writing skills. (3TRA)	○	○	○	○
Encourages/will encourage me to view problems from multiple or new perspectives. (4TRA)	○	○	○	○
Improves/will improve my ability to conduct systematic observations. (5TRA)	○	○	○	○

End of Block: Teaching, research and academic skills

Start of Block: Open-ended Questions

For the following questions, we would like you to reflect on the ways you spend your time and the different responsibilities you have as a graduate student. Please write one or two sentences for each prompt.

OE1 What roles or responsibilities do you have as a graduate student?

_____

_____

_____

_____

_____

OE2 How do you manage all of these responsibilities?

_____

_____

_____

_____

_____

OE3 Do you perceive any overlap between responsibilities mentioned above? Why or why not?

_____

_____

_____

_____

_____

End of Block: Open-ended Questions

Start of Block: Background Experiences

Prior Degree What prior degree(s) do you have? Please select all that apply.

- ☐ BS/BA (1)
- ☐ MS/MA (2)
- ☐ Not listed: (3) _____

Research Exp Have you had any research experience prior to your program?

- ○ Yes (1)
- ○ No (0)

End of Block: Background Experiences

Start of Block: If yes prior research experience...

These questions ask about all of your research experiences prior to entering the graduate program.

Research Type Please indicate the general type of research that you conducted (i.e. biochemistry, organic synthesis):

_____

Research Location Where was the research conducted? Please select all that apply.

- [ ] University (1)
- [ ] Industry (2)
- [ ] Not listed (please describe): (3) _____

Research Duration How long were you involved in the research (in years)?

_____

End of Block: If yes prior research experience...

Start of Block: Background Experiences

These questions ask about all of your teaching experiences prior to and during the graduate program.

Teaching Exp Have you had any prior teaching experience?

- ○ Yes (1)
- ○ No (0)

End of Block: Background Experiences

Start of Block: If yes prior teaching experience...

Level Teach What level did you teach? Please select all that apply.

- ☐ Pre-College (Kindergarten-High School teacher) (1)
- ☐ College/University (Undergraduate Teaching Assistant/Supplemental Instructor/Learning Assistant) (2)
- ☐ College/University (Graduate Teaching Assistant) (3)
- ☐ Tutor (4)
- ☐ Not listed (please describe): (5) _____

Subject Teach What did you teach (subject)? Please select all that apply.

- ☐ General Chemistry (1)
- ☐ Organic Chemistry (2)
- ☐ Biochemistry (3)
- ☐ Physical Chemistry (4)
- ☐ Inorganic Chemistry (5)
- ☐ Not listed: (6) _____

Teach Duration How long did you teach (in years)?

_____

End of Block: If yes prior teaching experience...

Start of Block: Demographics

Race/Ethnicity Which category do you identify with?
Please select all that apply.

- ☐ American Indian or Alaskan Native (1)
- ☐ Asian or Asian American (2)
- ☐ Black or African American (3)
- ☐ Hispanic/Latinx/Chicanx (4)
- ☐ Middle Eastern or North African (5)
- ☐ Native Hawaiian or Pacific Islander (6)
- ☐ White or Caucasian (7)
- ☐ Not listed (please describe): (8) _____
- ☐ Prefer not to answer (9)

Gender Which gender do you identify with? Please select all that apply.

- [ ] Female (1)
- [ ] Male (2)
- [ ] Non-Binary (3)
- [ ] Transgender female (4)
- [ ] Transgender male (5)
- [ ] Not listed (please describe): (6) _____
- [ ] Prefer not to answer (7)

*

Age What is your age (in years, use whole numbers)?

_____

X→

University Which University do you attend?
Please select all that apply.

- [ ] TFU (1)
- [ ] RFU (2)

X→

Program Type Specify your program type:

- [ ] MS (1)
- [ ] PhD (2)

Program Year What year are you in your program?
If you are a JDP student, please count all years in the program including the MS year(s).

- ○ First Year (1)
- ○ Second Year (2)
- ○ Third Year (3)
- ○ Fourth Year (4)
- ○ Fifth Year (5)
- ○ Sixth Year (6)
- ○ Not listed (please describe): (7) _____

Intl Are you an international student?

- ○ Yes (1)
- ○ No (0)

End of Block: Demographics

Start of Block: Participate in Interview

Interview Would you be interested in participating in a 60-90 interview on this subject as a part of this research? If yes, please provide your email address here.

_____

End of Block: Participate in Interview

Start of Block: Raffle Email

Raffle Would you like to be entered into the raffle for $20? If yes, please provide your email address here.

_____

End of Block: Raffle Email

Appendix J: Course Evaluation Survey

Chem 695 Course Evaluation Survey

Please answer the following survey questions about Chem 695.

1. Please evaluate the following class sessions in terms of preparing you for your responsibilities as a graduate student. 1 is not prepared and 5 is fully prepared.

Mark only one oval per row.

	1	2	3	4	5
Class session 1: Finding a research group	◯	◯	◯	◯	◯
Class session 2: Preparing and giving presentations	◯	◯	◯	◯	◯
Class session 3: Mini-Presentation 1	◯	◯	◯	◯	◯
Class session 4: Equity, diversity, and inclusion	◯	◯	◯	◯	◯
Class session 5: Ethics	◯	◯	◯	◯	◯
Class session 6: Difficult classroom situations	◯	◯	◯	◯	◯
Class session 7: Midsemester check-in	◯	◯	◯	◯	◯
Class session 8: Software and library resources	◯	◯	◯	◯	◯
Class session 9: Finding funding	◯	◯	◯	◯	◯
Class session 10: Program Q&A and managing/reading articles	◯	◯	◯	◯	◯
Class session 11: Networking	◯	◯	◯	◯	◯
Class session 12: Mentoring	◯	◯	◯	◯	◯
Class session 13: Mini-Presentation 2	◯	◯	◯	◯	◯

Free Response

Please answer the following free response questions about the class sessions, assignments and resources.

2. Which class session did you find most helpful? Why?

3. Which class session did you find least helpful? Why?

4. Did you find the discussion board and online resources helpful? Why or why not?

5. Did you find the reflections helpful? Why or why not?

6. Did you find the mini-presentations helpful? Why or why not?

7. Is there anything else you'd like add?

Appendix K: Updated Codebook

Below is the codebook with descriptions and examples. Use this as a guide as you code the interviews provided. Note any codes that overlap often and feel free to add any inductive codes/themes you notice in that data. For additional background, the resources codes canonically overlap with the identity codes, so they should occur together.

Code	Description	Example Discourse
Persistence	Continuing on despite challenges, larger theme that encompasses multiple codes such as ideational and relational resources, interest, competence/performance	Owen: I think sophomore year I started trying to apply to labs, but nobody wanted me. Nobody knew me. I think I got rejected by 30 different people before I finally found someone who would like, yeah, you can, you know, stick around and volunteer for a little while and then eventually they brought me on that was the term for my scope lab. Owen: I guess people who I considered to be like, who I like looked up to, you know, either like fake fantasy people or like real people in the world. I always, the one thing that they all had in common is that they never really gave up. And so I really internalize that I think when I was younger. And so I just, I don't like the idea of like getting knocked down and not getting back up, you know, and so also science is really the only job I could envision myself doing because it's the only thing that keeps me interested.
Intersectionality	The interconnectedness of social categorizations such as race, class, and gender, generally in reference to systems of power and oppression	I think I definitely felt more like a scientist and I had those identities merged together because I think that when I have them so far apart, where I felt like, who I was… like the extrovert in general was like on one side, but who I was on a scientist, I have to go into a lot buckled down do my experiments that was on like the opposite side of that spectrum. But I

		think that those two kind of merged together where it's like, you know, I can actually use how extroverted I am to advance my own career where I can network. I could talk to people... And so I think that's almost an advantage. And so it's like it's kind of like the closer and closer, those two ideas get together, they kind of merged together. (Nidiya.transcript, Pos. 184)
Confidence	To what extent does one believe in themselves	Whereas I think with a lot of women, myself included, I will always be **very cautious about what I say**. Because I, **although I think I do know a lot about my own topic and my own field. There is like an enormous amount of people that know just as much as I do, if not more** so probably much more so than I do. (Nidiya.transcript, Pos. 293-294)
Agency	To what extent does one feel in control of their trajectory, work, etc.	So the last year where all of this has been going on has actually been huge in my growth because **it's the first time I've really asked myself, "What is it that I want to study?"** and forced myself to sit down to come up with like a proposal that's waterproof. (Parker_transcript, Pos. 93-94)
Belonging	The extent to which one feels like a part of a community.	
Nexus of Multi membership		
Expansiveness	The degree of multi-membership. Leveraging experiences of one identity in another.	Steven: My cohort is pretty cool. So that's nice. They will talk about things other than science, which is always a good trait to have. I mean, there's nothing wrong with having a bit of science talk, but you know if that's your only thing about you becomes stale, a little bit quick...

Identity	*Competence and Interest often occur together but still considered separate for now.	
Competence/ Performance	One's belief in their ability to understand content specific information and perform required tasks.	Carly: I say, kind of in the middle. Like I feel like I'm doing what I need to do. But I like it's been hard to figure out like going above and beyond. Like, I like to do that with most things
Recognition (Self/ Others)	Whether and how one is seen as a type of person by oneself and by others.	Nathan: So to answer your question, like, I see myself as a scientist, I'm not necessarily, but it was like the natural way for me to go like my I guess my nature like was like going to take me towards that route.
Interest	One's inclination to think about and understand content in a domain.	Yeah, I want to have a quicker mind. I don't know how to say that I like when someone asked me a question. Sometimes I have a hard time to like analyze the question and answer it immediately. So maybe that I want to think faster because I was about to answer something that is not expected like some question that is not expected. So I want to think faster about things that I don't expect. And I also want to improve like explanation skills. I want to be able to explain things better. (Alexia_FirstInterview, Pos. 176)
Resources		
Material	Tangible resources for identity development. Ex: grades, organizations, classes, jobs, thesis/papers, scholarship/awards etc...	Owen: Yeah, yeah. So when I was in junior and senior year I needed to make some extra money so I, I joined this tutoring service and tutored two kids in like algebra and chemistry and that type of thing.
Relational	Relationships with others that influence identity development. Usually denotes the relationship with the PI.	Enrique: Yeah, I think Ron, I talked to sometimes in my classes and we TA the same class. Some of the other, the graduate students that have been here

		longer. I ask questions, too, sometimes.
Ideational (Science/Teaching/ Other)	Ideas (values, beliefs, narratives, etc.) that (dis)connect someone (from)to an identity.	Alexia: I guess what I lose more is like my personal life because sometimes you need to put it aside and be more focused on school and it's really hard when someone is asking you to like go out or have fun. You have to be focused on researching in school. So I guess that's one of the sacrifices that you make as a grad student especially I barely started but I'm sure like after some time, it will get harder. So I'll have way less time on my personal interests. But I think that I have a sense of responsibility. So when I know that I have to do something. I will do it. So I feel like, then that helps me to achieve something.
Trajectories-Larger Themes	*Use these to code the full interview	
Inbound	The goals is to become a full member.	I am not a full member yet, but I will be. Usually people use this in reference to being a "scientist in training".
Insider	A full member who negotiates novel roles, practices, and norms in a community.	I am a full member and I serve specific functions that I had agency in creating.
Outbound	The movement out of a community and often into another.	I don't feel welcome in general.
Boundary	A member who operates at the boundary of multiple communities. Usually research and teaching, but can include others.	I strive to connect my skills in multiple domains (communities).

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