The Influence of Doctoral Research Experiences on the Pursuit of The Engineering Professoriate

by

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Dedication

I dedicate this dissertation to my Burt (paternal) and Houston (maternal) family. It was through your encouragement – and the conscious remembrance of the sacrifice of our ancestors – that helped make this dream a reality. Thank You!

I also want to dedicate this dissertation to my future self: “As you stumble upon this page in the future, let this dissertation serve as a reminder of your sacrifices, doubts, perseverance, and Faith in God that allowed you to complete this. Let this be a reminder that you can do anything (“I Can Do All Things Through Christ Who Strengthens Me" Philippians 4:13)!

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As an undergraduate student in NASPA's Minority Undergraduate Fellows Program (MUFP), I attended and presented at my first student affairs conference. It was at that conference where a senior administrator accepted a career achievement award and later shared some words of encouragement with me. Knowing I was interested in pursuing graduate studies and eventually earning a Ph.D., he shared with me the key to being successful in graduate school was to create a "success team." While he did not give me the magic formula who to select for my team, he did tell me that the people would have to be specific for my needs, and that the team should encompass successful models who could mentor me and provide me with a strong balance of support and challenge. I never forgot his words, and fortunately, I created the best Success Team I could have ever imagined!

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ABSTRACT

This qualitative study, of students in a chemical engineering research group at one institution, provided an in-depth understanding of what and how students learned about faculty careers from participation in their research group, and how this learning influenced their intentions to pursue the professoriate.

The key findings in this study contribute to the growing body of research and theory on engineering doctoral education. The study identified the competencies students developed through their research experiences, as well as how these experiences created perceptions of a faculty prototype and promoted certain kinds of social comparisons with peers. The faculty prototype appeared to be particularly influential when it revealed to students perceived conflicts between their personal values, traits, and the activities of successful engineering faculty. This study ends with a set of testable propositions to guide future theory development and research, and offers recommendations for research design.

CHAPTER 1: INTRODUCTION

Since its creation in the United States, the primary goals of doctoral education have been to equip students with research skills, train future purveyors of scientific knowledge, and prepare students for faculty careers (Berelson, 1960; Goodchild & Miller, 1997). It is expected that graduates who become faculty members will produce and share scholarly knowledge, mentor students, and train newer generations of scholars. Recent scholarship suggests that students' research experiences help them learn about and identify with faculty careers (Burt, 2010; Stubb, Pyhalto, & Lonka, 2012). In fact, in science and engineering fields, students spend a considerable amount of time in the research lab, making experiences within and related to the lab a critical site for learning. Additionally, research experiences are likely the predominant mechanisms through which science and engineering students are socialized to the behaviors, norms and values of a faculty career. However, our understanding of what and how students learn from engaging in research, and how this affects their identification of the professoriate and its norms and values is limited. As such, scholars are needed to improve our understanding of doctoral education – including the practices within doctoral education and interactions related to research – on students' learning, perceptions of faculty work, and their interest in the professoriate.

Statement of the Problem

Existing research on doctoral education is limited in a number of ways. One limitation is that little is known about the wide range of experiences and professional practices that contribute to preparing graduate students for faculty roles. That is, scholars tend to conceptualize doctoral education as taking place within the classrooms, departments, or between the student and faculty-advisor (Austin, 2002 & 2009; Barnes, 2009-2010; Barnes & Austin, 2009); rarely have scholars considered other important contexts where learning and identity development take place. A limited but growing body of research, however, illustrates that doctoral students in science and engineering programs spend a considerable amount of their doctoral experience in research labs (Brazziel & Brazziel, 2001; Brew & Peseta, 2009; Crede & Borrego, 2012; Pearson, Cowan, & Liston, 2009). Scholars logically argue that students' research experiences influence graduate students' perceptions of faculty work and their aspirations to and preparation for the professoriate (Crede & Borrego, 2012; Crede, Borrego, & McNair, 2010; Newstetter, Kurz-Milcke, & Nersessian, 2004; Pearson, Cowan, & Liston, 2009).

Another limitation is the overreliance on a traditional socialization lens that aims to identify "where" doctoral students acquire skills rather than examining in-depth what is learned about the field and about the professoriate through doctoral education. Often, the focus is on "who" students interact with rather than on how interactions with research supervisors, advisors, mentors, peers, and others shape learning about the field and aspirations to the professoriate. While studies ostensibly focus on professional identity, few have sought to uncover the ways in which doctoral students' identities as scholars are shaped – or not – through scholarly activities that define graduate education.

Finally, scholars often examine doctoral students across multiple disciplines and fields of study, giving us a broad landscape for how they experience doctoral education. This is a limitation of existing research because each field of study has its own set of norms, values, and practices that need to be studied to understand how they might build or impede interest in the professoriate. Research focusing on one particular discipline thus offers a more nuanced understanding of students' experiences by allowing researchers to understand how specific practices and norms influence students' aspirations and identity development (see for example Antony & Taylor, 2001; Baker & Pifer, 2011; Crede & Borrego, 2012). For example, most of the focus on why there are not more faculty of color in engineering is on recruitment into Ph.D. programs. There has been much less focus on how doctoral students of color experience engineering doctoral programs (for exceptions see Brazziel & Brazziel, 2001; Burt, 2010). To fully understand how students receive and apprehend the norms and practices of the field, researchers need to understand how students see themselves within the context of their field. In other words, more intensive investigation of the process of negotiating and navigating personal and professional (disciplinary) identities is needed.

Significance of the Study

This study contributes to the emerging literature on doctoral education by examining one critical component of the learning process of doctoral education, the research experience[1], to understand how it shapes students' understanding of, and intent to pursue, the professoriate. In addition it employs a conceptual framework that links learning and identity development to explore the role of the doctoral research experiences in shaping doctoral students' understanding of their field of study and their potential to succeed in that field.

Focus of the Study

To learn more about the nature of doctoral research experiences and how they influence doctoral students' pursuits of the professoriate, the following research question and sub questions guided this study:

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[1] For the purposes of this study, when I say "research experience" I am referring to any experience where students are engage in the process of generating scientific knowledge (e.g., individual project, collaborating in research groups, working on publications, presenting at conferences).

How do doctoral students' research experiences in an engineering research group influence their perceptions of, and interest in pursuing, academic careers? Specifically, how do research experiences influence:

a. *Doctoral students' learning about engineering and the professoriate?*
b. *Their perceptions of faculty work?*
c. *Their personal and professional identities?*
d. *Their intentions to pursue a faculty position?*

Historical Overview of Doctoral Education

The history of doctoral education in the United States reveals how our system of graduate education came to be organized as it is, who participates in graduate education, and how graduate study benefits our nation. Thus, before answering the proposed research questions related to academic careers, it is important to discuss the evolution of the professoriate in the U.S.

The ascent of doctoral education in the United States as a leader in graduate education comes with a tumultuous history (Berelson, 1960; Buchanan & Herubel, 1995; Goodchild & Miller, 1997; National Center for Educational Statistics, 2012b). This history shows periods of significant growth and periods of stagnation because of changes in the labor market, needs of the nation during times of war, and desires to compete globally as a leader in the production of new knowledge (Goodchild & Miller, 1997).

Under the influence of Europe – and based off the European model of higher education – undergraduate education in the U.S. was established in the early 1600s at Harvard, the College of William and Mary, and Yale, and further developed nearly a century later by the colonial colleges – Columbia University, University of Pennsylvania, Brown University, Dartmouth College, Rutgers University, and Princeton (Altbach, 2011; Geiger, 2011). For most of its early history, the American college offered students an undergraduate education. Americans who wanted advanced degrees attended European universities [approximately 9,000 Americans studied in Germany between 1820-1920] (Goodchild & Miller, 1997). Once they returned to the

U.S., many held faculty and administrative positions in American colleges, advocating and influencing the creation of graduate programs domestically (Berelson, 1960; Buchanan & Herubel, 1995; Goodchild & Miller, 1997; National Center for Educational Statistics, 2012b).

In 1861, Yale offered the first American doctorates in theology, classical languages, and physics (Buchanan & Herubel, 1995). Soon thereafter, other elite colleges – and some public universities – began offering doctorate degrees. Yet, it was not until the establishment of Johns Hopkins University in 1874 that the idea of merging the German and American models of graduate education, that is, the doctorate as a terminal research degree, took shape (Berelson, 1960; Buchanan & Herubel, 1995; Goodchild & Miller, 1997).

After the establishment of the American model of graduate education – led by Johns Hopkins University – many other universities "vied to establish Ph.D. programs for the purposes of prestige and intellectual respectability" (Buchanan & Herubel, 1995, p. 2). This growth in research universities was supported by the distribution of federal funds, made possible by the Morrill Land Grant Act in 1862, which gave each state money to develop state institutions that would specialize in agriculture, sciences, and classical studies. Over time, these land grants institutions gradually added graduate programs to address the growing demands for graduate education (Geiger, 2011).

The increased growth of graduate education in the U.S. led to varying degrees of quality, as some institutions were "ill-equipped to offer research programs" (Buchanan & Herubel, 1995, p. 3). As a result, calls for standardizing the requirements of the doctorate became a pressing issue. It became increasingly important for U.S. institutions to adequately train future teachers, researchers, and people going into the labor market. The creation of the Association of American Universities (AAU) in 1900 did just that, helping to solidify the requirements of the Ph.D.

(including the requirement that dissertations produce original work and the introduction of the Graduate Record Examination in 1937 as gateway for admissions), and providing quality control by determining which institutions could award doctorates (Berelson, 1960; Buchanan & Herubel, 1995; Goodchild & Miller, 1997).

From the early to mid 1900s, the United States experienced steady growth in the development of institutions and enrollments in graduate education.[2] The greatest growth appeared between the 1960s and 1970s, due in part to the passing of the GI Bill in 1944 that allowed war veterans to attend undergraduate and graduate studies. As a result of enrollment growth at the undergraduate level, colleges and universities began increasing the number of students admitted to graduate programs; administrators knew that increasing undergraduate enrollment would require more faculty members, thus, admitting more graduate students who would later become faculty members (Berelson, 1960; Bowen & Rudenstine, 1992).

The U.S. government's reaction to the launch of the satellite Sputnik by the Soviet Union also contributed to the increasing enrollment patterns. After Sputnik, federal funding of scientific research increased, resulting in increased financial support to existing science and engineering graduate programs, and increased numbers of research universities (Berelson, 1960; Buchanan & Herubel, 1995; Goodchild & Miller, 1997; National Center for Educational Statistics, 2012b).

Berelson's (1960) study of graduate education between 1876 and 1960 found that 60% of students who enrolled in doctoral programs completed their degree, while 40% of dropped out. Despite his suggestion that the 40% attrition rate did not warrant panic, Berelson argued the need for reform. He asserted that there would be greater costs for graduate attrition; graduate students stay in school longer before dropping out, which has negative implications for faculty members,

[2] Between 1900-1909, approximately 3,654 doctorate degrees were conferred. From 1930-1939, nearly 26,000 doctoral degrees were conferred. By 1950-1959, 82,689 graduate degrees were awarded; see Appendix A (National Center for Educational Statistics, 2012).

the institution, and society that needs trained doctorate holders to fill specialized industry jobs. A similar trend of was observed between 1960s and 1980s: 50% of students who entered doctoral programs completed their degrees; the biggest factor attributed to doctoral attrition was the increase of time-to-degree (Bowen & Rudenstine, 1992).

Between the 1970s and the present, research on doctoral education shifted from focusing on the expansion of doctoral education, to better understanding access to doctoral education, improving retention rates, understanding completion and attrition, and preparation for post-graduate careers (Bowen & Rudenstine, 1992; Nettles & Millett, 2006). Additionally, current research also looks at the different experiences of doctoral students by discipline/academic fields of study (Antony & Taylor, 2001; Austin, 2002; Austin & McDaniels, 2006; Gardner, 2009 & 2010; Golde, 2005; Nettles & Millett, 2006).

Finally, it is estimated that nearly 2.5 million doctoral degrees were conferred in the United States between 1977 - 2010; in 2010 alone, approximately 159,000 doctoral degrees were awarded (National Center for Educational Statistics, 2012a). It is unclear, however, how many of these graduates pursued faculty careers.

CHAPTER 2: THEORY and LITERATURE

In a sociocultural perspective, learning not only takes place within larger social, cultural, and historical contexts, learning is also believed to be strongly shaped by these contexts (Baker & Lattuca, 2010; Cobb & Yackel, 1996; Lattuca, 2002; Rogoff, 1990; Wertsch, del Rio, & Alvarez, 1995). Sociocultural perspectives seek to not only understand how what one learns is linked to these contexts, but also how what one learns influences his or her identity (Wertsch, del Rio, & Alvarez, 1995). How doctoral students' identities as potential faculty members are shaped by their research experiences, and an enhanced understanding for how doctoral students are prepared for the professoriate, are gained when using this theoretical perspective.

This chapter will achieve three goals: provide an overview of sociocultural perspectives; discuss the existing literature on doctoral research experiences; and, draw linkages between students' research experiences and preparation for the professoriate. To achieve this, I will use the concepts of sociocultural perspectives as a framework to help organize the existing literature. To start, I discuss the prevailing framework scholars use when researching doctoral education – socialization theory – and offer a critique from the sociocultural perspective; by first presenting the research on socialization, I am better able to explain – and contrast it with – sociocultural perspectives on learning. Next, I describe sociocultural theories by briefly providing a discussion of their evolution and explaining the main concepts through contemporary applications of the theory; these concepts guide my presentation of the literature on student research experiences. I conclude this chapter with an illustration of how the four sociocultural concepts work together, as well as critiques of the theory.

Socialization in Doctoral Education

The concept of "socialization" explains how individuals adjust to a new environment by investigating the strategies that organizations implement to aid newcomers, and explores how newcomers respond to the strategies used by the organization (see for example Carden, 1990; Chao, 1997; Chao, Walz, & Gardner, 1992; de Janasz & Sullivan, 2004; Jones, 1983; Van Maanen & Schein, 1979). Traditional theories of socialization are conceptualized as a linear, stage-based process in which newcomers enter the organization and begin to make sense of the context to understand their role and boundaries. Organizations selectively reinforce particular norms, values and behaviors that they want to perpetuate (Tierney, 1997; Van Maanen & Schein, 1979). In subsequent stages, newcomers become more familiar with the rewards and consequences that result from certain behaviors, and, finally, they navigate the organizational context by either continuing to conform or reject the organization's standards and normative behaviors (Bragg, 1976; Van Maanen, 1976; Van Maanen & Schein, 1979).

Socialization theories and graduate education.

Socialization is the dominant framework higher education scholars use to discuss graduate education. In this line of research, doctoral students, particularly in the early stages of their programs, are considered "newcomers" who are being socialized into an academic and disciplinary community. Socialization theory describes the mechanisms of how doctoral students (and new faculty members) learn and adapt academic and institutional norms and behaviors (Antony & Taylor, 2002; Austin, 2002; Austin & McDaniels, 2006; Tierney, 1997; Weidman & Stein, 2003; Weidman, Twale, & Stein, 2001). For example, Weidman, Twale, and Stein (2001) extended previous conceptions of socialization by presenting a new framework illustrating how the socialization process promotes graduate students' "identity with and commitment to professional roles" (p. 49). These scholars describe the process of socialization as occurring through four stages (i.e., anticipatory, formal, informal, and personal) whereby newcomers gain increasing knowledge about their field of study and think about – and are prepared for – their future career by interacting with the university, personal and professional communities, practitioners. Embedded in each of these four stages are core elements of socialization (i.e., knowledge acquisition – the process of acquiring role-specific knowledge and becoming specialized; investment – the act of personally committing to a role by dedicating something personal to the role, for example, one's time and energy; and, involvement – the act of participating in one's new professional role). Taken together, as newcomers progress through the stages, and interact within various communities and individuals, their identification with and commitment to a role becomes solidified.

Drawing upon the work of Weidman, Twale, and Stein (2001), other scholars demonstrate how the reconceptualized framework helps to explain the socialization strategies departments implement to prepare graduate students for academic careers. Austin (2002) interviewed 79 graduate students at two "research-oriented, doctoral granting" institutions across humanities, science, social science, and professional fields to understand how students are socialized to academic careers (p. 101). Her study was guided by a socialization framework in which socialization occurs when newcomers interact and engage with others. Austin found that while students received preparation in some aspects of the faculty career (i.e., research and publishing), they were less prepared for – and less knowledgeable about – other aspects of the faculty career (e.g., grant writing, teaching, curriculum design, service). Her findings suggest a disconnect between the socialization strategies of the departments/institutions, students' perceived socialization (e.g., knowledge acquisition) to the academic career, and the actual skills and norms needed by future faculty.

Antony's (2002) socialization framework offers a slight – yet important – amendment to that of Weidman, Twale, and Stein (2002). Antony and Taylor (2004) studied 12 Black students at six institutions who were interested in pursuing faculty careers in the field of education. Through interactions with and observations of faculty and peers in their departments, all students came to understand the norms and values and of their department. Despite knowing these norms and values, every student did not adopt them. In fact, some students felt that pursuing an academic career conflicted with their personal values; becoming a faculty member would require them to compromise their own research interests, values, and integrity. Antony (2002) argues that previous socialization frameworks assumed that students must assimilate and adopt norms and values (of their department, institution, etc.) in order to be considered socialized. Further, he suggests that acquiring the knowledge of their field does not and should not require the adoption of all its norms and values.

While socialization theory has been regularly used (Antony, 2002; Antony & Taylor, 2001; Antony & Taylor, 2004; Austin, 2002; Austin, 2009; Austin & McDaniels, 2006; Gardner, 2008a & 2009; Weidman, Twale, & Stein, 2001), there are several limitations, especially when applied to doctoral students and their preparation for the professoriate. These limitations are discussed in the next section.

Limitations of socialization theories for studying doctoral student learning, identity, and preparation for the professoriate.

The conceptualization of the socialization process suggests that the focus is on adaptation to the organization (Van Maanen, 1983). Typically, socialization theories posit that newcomers learn from knowledgeable insiders (Carden, 1990; Chao, 1997; Chao, Walz, & Gardner, 1992; de

Janasz & Sullivan, 2004), and "reproduce an existing cognitive and social order" (Wertsch, del Rio, & Alvarez, 1995, p. 16). In other words, the theory provides us with an understanding for how newcomers transition into, evolve within, and preserve the behaviors of an organization.

The linear stage models posited by traditional socialization theorists do not account for variability in what is learned, when it is learned, and how it might be differently learned at different points in time. In graduate education, doctoral students learn different things (i.e., knowledge, skills, attitudes) at different times. For example, a doctoral student may learn through coursework about engaging in qualitative research. Yet, after being in the field collecting data – and revisiting course readings – his understanding about qualitative research is significantly deeper. The inability to provide a recursive conceptualization of learning is a limitation of socialization theories as frameworks for studying doctoral education (for a discussion see Weidman et al., 2001).

Another important critique is that socialization theories typically parse out students' learning from their identity development, which suggests that the processes of learning and identity are unrelated rather than interrelated. As discussed by Baker and Lattuca (2010), two examples illuminate how learning and identity are often dissected in socialization research. First, in Bess's (1978) study of 236 newly admitted graduate students, he aimed to understand if new – relatively unsocialized – graduate students' interests in the faculty career were similar to the interests of current faculty members (e.g., asking both new graduate students and faculty members how important it is to perform service duties?). Bess conceptualized "socialization" as one of two processes that influence students' understanding and preparation for academic roles. Bess identifies "professionalization" as learning the skills, behaviors, and values of the profession, and "socialization" as adopting the learned skills, behaviors, and values of the profession; a similar distinction is observed in Antony and Taylor's (2004) study above. Second, according to Antony and Taylor (2004), all of the doctoral students studied were aware of the norms and values of the professoriate based on their observations and interactions with peers and faculty members but did not necessarily adopt them. Antony and Taylor (2004) concluded that being socialized does not guarantee uncritical adoption of the norms and values. They suggest that learning and identity (in this case, the adoption of norms and values) are two distinguishable and separate processes. According to Baker and Lattuca (2010), the separation of identity from knowledge is problematic because the norms and values of a field are intertwined with the knowledge of the field. Thus, as one gains knowledge about his or her field, he or she simultaneously develops an identity characteristic of the profession, that is, one that is largely consistent with the norms and values of the field. It is impossible to parse out the identity of a professor from the norms and values of the academy and the field because being a faculty member requires one to not only know what the role entails, but to accept the basic norms and values that undergird the profession. From this perspective, learning and identity development are not only simultaneous they are interrelated and inseparable.

A final critique relates to the research designs of studies employing socialization theories. Most studies of doctoral education employ samples of students from a variety of disciplines (for an exception, see Crede & Borrego, 2012). These studies take a broad view of student socialization across multiple disparate fields of study and thus do not provide the nuanced understanding of how students in a particular field of study come to understand and adopt the norms and values of their field. Other studies primarily focus on the experiences taking place in the classroom, department, or in the student and faculty-advisor relationship (Austin, 2002 & 2009; Barnes, 2009; Barnes, 2009-2010; Barnes & Austin, 2009). These common research designs provide insights into how these settings and relationships influence doctoral education but tend to neglect the research experiences that are critical to success in the professoriate. In addition to what is learned in the classroom, a reconceptualized framework would holistically study the research experience as a context where learning happens through professional activities outside the formal academic program (e.g., conferences, symposia, departmental colloquia), and even through social functions that involve graduate students and/or faculty in a particular field of study. Baker and Lattuca (2010) note the importance of understanding how the local context (e.g., department and institution) and larger sociocultural contexts (e.g., economy, demographic shifts, cultural understandings of race) interact and influence learning during doctoral study. The research group itself, however, is a context for learning that deserves study.

Finally, sociocultural theories press researchers to understand how the social identities of individuals influence their future identity development (e.g., professional identity). A more holistic perspective would suggest that researchers studying doctoral education understand the overlapping social identities (race and gender for example) that graduate students bring to the doctoral experience to understand potential variations in doctoral students' experiences, post-graduate intentions, and participation in activities that prepare students for the professoriate (e.g., research).

Sociocultural Perspectives: A Holistic Framework for Studying Doctoral Education

From a sociocultural perspective, the process of learning is not just about reproducing one's knowledge through behavior (Wertsch, del Rio, & Alvarez, 1995). Rather, learning occurs through the co-construction of knowledge and interactions with others within a given community of practice (Baker & Lattuca, 2010; Wortham, 2004). Sociocultural perspectives link individuals' learning with identity development, which both result from participating in the social activities of a particular community of practice[3] (Lave & Wenger, 1991). Through interactions with community members, individuals develop "physical and conceptual artifacts – words, tools, concepts, methods, stories, documents, links to resources…" (Wenger, 2010, p. 1). For instance, in an engineering department, there are common conferences that faculty and students attend, understood steps for acquiring conference funding, departmental acronyms and vernacular, and even shared stories of faculty tensions. From a sociocultural perspective, only members within the community of practice have access to and can draw upon the knowledge built within the community. That is, within a community of practice, members co-construct the learning that take place and artifacts used and produced; members' understanding of the community's practices and artifacts help to guide the organization (and participation) of group members (Wenger, 2010). How members view themselves – their identities in the context of the community – are tied to their learning.

Evolution of sociocultural perspectives.

Understanding the evolutionary nature of sociocultural perspectives – and the concepts that comprise the theory – will help illustrate how existing research has used the theory, albeit sometimes using different terms to describe the phenomenon. In the section that follows, I describe how we have arrived to our current conceptualization of sociocultural perspectives, from the early work of Piaget, Dewey, and Vygotsky, to that of contemporary scholars who utilize this theory in their research.

Prevailing learning and developmental theories from Jean Piaget posited that what and how one learns and develops is based on the individual and not solely related to factors external to the individual (John-Steiner & Mahn, 1996; Phillips, 1995). Piaget argued that what

[3] Scholars often use the metaphor of an apprenticeship to capture the social interactions that enable learning to take place within particular social practices (see Lave & Wenger, 1991 for myriad examples of communities of practice).

individuals come to know, and how they come to know it, is related to their own creation of knowledge, generally described as a result of maturation and/or genetic and intellectual capacity (Confrey, 1995; Phillips, 1995). Conceptualizing knowledge in these dichotomized ways (i.e., knowledge influenced either internally or externally) prompted John Dewey and Lev Vygotsky to hypothesize how learning and development could be interrelated (John-Steiner & Mahn, 1996). Both Dewey and Vygotsky believed that learning is inherently social and occurs when learners interact with others (Phillips, 1995; Phillips & Soltis, 1998). The important distinction, however, is that Vygotsky strongly argued that one's learning takes place within contexts that are shaped by larger social structures. In the paragraphs that follow, I further contrast Vygotsky from Piaget and Dewey and explain how Vygotsky's contributions led to sociocultural perspectives on learning.

Both Piaget and Vygotsky contributed to the field of psychology, primarily through their studies of children. Piaget claimed that children's development was largely a process of individual learning and development, predicated on pre-determined stages of maturation (Confrey, 1995; John-Steiner & Mahn, 1996). Vygotsky's work, however, contrasted and challenged that of previous developmental scholars. He stressed both children's ability to individually problem solve as well as to solve problems when interacting with more knowledgeable others (e.g., teachers) (John-Steiner & Mahn, 1996). Vygotsky called this the "Zone of Proximal Development," defined as:

> "…the distance between the actual development level as determined through independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86, cited in John-Steiner & Mahn, 1996, p. 198).

Further, his research suggested that there was an irreducible relationship between the individual and his or her context; that is, the interactions with one's environment – and the people therein –

shape what one learns and how he or she develops (Cobb, 1994; Cobb & Yackel, 1996; Confrey, 1995; John-Steiner & Mahn, 1996; Wertsch, del Rio, & Alvarez, 1995). The second distinction for Vygotsky was that his work argued that learning is not purely an individual task, and is more complex than the internal versus external binary offered by Piaget. Vygotsky concluded that to fully understand how people learn and develop, we must consider how interactions with others influence what we learn.

A third point of distinction of Vygotsky's work is the identification of "how" individuals learn and develop. He considered the role that accepted "symbols" (e.g., history, location, and time) played in individuals' development and argued that much of what individuals learn is passed down generationally through these symbols (Wertsch, del Rio, & Alvarez, 1995). "Culture," as Vygotsky described it, encompassed one's sociohistorical, political, economic, and other environments that shape an individual's context (Wertsch, del Rio, & Alvarez, 1995). His concept of "culture" was adapted by Wertsch, del Rio and Alvarez (1995) and replaced with the term "context."

Since Vygotsky's (1978) work that linked learning and development with social context, several contemporary scholars have extended his work to further explain how learning and context – plus social interaction – influence one's development. These perspectives go by several names: situated cognition (Brown, Collins, & Duguid, 1989); guided participation/apprenticeship (Rogoff, 1990); situated learning (Lave & Wenger, 1991); and, cognitive apprenticeship (Collins, Brown, & Holum, 1991). These scholars further considered the roles that social interactions played in the development of knowledge and identity. Although they each has nuanced differences, from this point forward, I will use "sociocultural perspectives" as an umbrella term to represent Vygotsky's beginning considerations of learning and the expansions contributed by the contemporary scholars mentioned above.

Contemporary applications of sociocultural perspectives.

Contemporary scholars employing sociocultural perspectives as theoretical frameworks aim to understand how "context," "mediation," and "participation" affect the learning and identity development of those within a given community of practice. For the purposes of this study, the three key concepts are defined as: context (the surrounding structures and the relationships within communities of practice); mediation (interactions with members of the community of practice and with the cultural tools – for example, its language, books, or equipment – that make it possible to engage in the community's practices); and, participation (the engagement in the activities associated with the community of practice) (Lattuca, 2002; Wertsch, del Rio, & Alvarez, 1995).

When scholars employ a sociocultural perspective, they "…locate learning in co-participation in cultural practices" (Cobb, 1994, p. 14), and their research designs focus on communities of practice so they can "look at change at different levels of analysis and organizations" (John-Steiner & Mahn, 1996, p. 204). As individuals participate within a community of practice, they may develop an identity consistent with that community (Baker & Lattuca, 2010; Brown & Kelly, 2007; Crede & Borrego, 2012; Crede, Borrego, & McNair, 2010; McAlpine & Amundsen, 2007; Stinson, 2008). By observing how change takes place at different levels (e.g., contextual change, group change, and individual change), the unit of analysis is broad (Cobb, 1994; Cobb & Bowers, 1999; John-Steiner & Mahn, 1996). Unlike research conducted using a sociocultural lens, much existing research focuses on the individual "or" the organization as “the” unit of analysis, which neglects how the individual and/or the organization interact with and are influenced by larger contexts (for an exception see Tierney, 1997).

Two main outcomes are often associated with research employing sociocultural perspectives of learning: what individuals know (epistemological or cognitive change) and how individuals change as a result of new knowledge (ontological or identity change) (Baker & Lattuca, 2010; John-Steiner & Mahn, 1996). As an example for how epistemological change takes place, Cobb and Yackel (1996) considered a mathematics classroom where the teacher and student play equally vital roles in students’ learning of math; both participants share their understanding and negotiate meaning. Through the process of scaffolding, the teacher mediates students’ learning by leveraging what students already know and carefully guiding them to new knowledge. In other words, “the teacher and the student co-opt or use each others’ contributions” to give meaning and “the teacher negotiates with students in order to mediate between their personal meaning and established cultural meanings” of mathematics (Cobb & Yackel, 1996, p. 14).

In another example, Brown and Kelly (2007) illustrate how both epistemological and ontological change occurred among high school students on a baseball team as they learned more about both baseball and the science of the sport. The baseball coach (who was also a science teacher in the high school and the primary researcher for this study) wanted members of his baseball team to see the connections between baseball and physics. The coach expected his students both to learn scientific concepts and to communicate their knowledge of baseball using scientific vernacular. The challenge arose, however, because the ethnically diverse Californian students were not exposed to scientific language in their everyday lives, so using a scientific lexicon was not practical. The coach mediated students’ learning by helping students understand the physics behind throwing curveballs, and implementing baseball drills that required students to practice throwing curveballs. In addition to the assistance from the coach, the more knowledgeable members on the baseball team helped scaffold learning by demonstrating how to use both scientific terms and the everyday language of novices on the team. Moreover, knowledgeable peers on the team provided an environment where learning about – and practicing – scientific vernacular on the baseball team was both acceptable and expected. By participating in these exercises, students' were increasingly able to use the concepts from physics to explain the science behind curveballs. Along with this epistemological change, the students' sense of their own identities also changed; by linking the act of throwing curve balls with the practice of explaining the science behind the curveball curving, students increasingly appreciated "being a baseball player," that is, their meanings of what it meant to be a baseball player was deepened as a result of understanding – and being able to explain – the science behind the sport they played.

Integrating Theory and Literature.

The research experience has been identified as one – if not the – central most experience in doctoral education because it cultivates students' research-related skills, shapes their perceptions and understanding of faculty roles, helps them transition to that of independent researcher[4] (Baker & Pifer, 2011; Baker, Pifer, & Fleminon, 2013; Gardner, 2008b; Lovitts, 2005), and aids in students' preparation for the professoriate. For instance, a doctoral student in engineering who engages in a research experience will interact with – and learn from – a research supervisor and members of the research group (Pearson & Brew, 2002). The doctoral

[4] The transition from student to independent scholar – facilitated by one's research experience – is an important step in the preparation for the professoriate because this transition marks once a student begins to accept and "enact the academic career" (Baker & Pifer, 2011, p. 5). Furthermore, it signals students' transition from "consumers of knowledge…to creators of knowledge" (Gardner, 2008b, p. 328)

student might run experiments, write journal articles, and present at conferences. Through participating in research-related practices – with members in the community of practice – the doctoral student may adopt the same values and norms as the members within the community of practice. Thus, the research group – as a community of practice – affects students' understanding, further highlighting that learning – at least from a sociocultural perspective – is both an outcome and a process. Investigations of students' experiences with research can help us understand how they learn, not only in students' areas of specialization, but about the professoriate as a career path.

From a sociocultural perspective, the key concepts (i.e., context, mediation, participation, and identity) are interrelated; the concepts are meant to work together. For example, one's institutional context can mediate their learning and shape their identity change; identity change cannot be described without discussing context and mediation. In this section, I will use the concepts of sociocultural perspectives as a framework to discuss the empirical literature related to doctoral students' research experiences – recognizing that describing these concepts separately is artificial.

Context.

Sociocultural theorists accept Vygotsky's (1978) argument that "…to understand the individual, one must first understand the social context in which the individual exists" (Lattuca, 2002, p. 714). To that end, contexts are embedded within structures (e.g., historical, political, economic, cultural, and institutional environments), and these structures contribute to the shaping of individuals' learning and identity (Wertsch, del Rio, & Alvarez, 1995). By examining students' contexts, we place some level of responsibility on the contexts and remove sole responsibility from individuals (McAlpine & Amundsen, 2007). As it relates to students' pursuits of the professoriate, looking at one's contexts is important because the contexts can shed light onto how students view themselves as future faculty. For example, if a Black male doctoral student in science or engineering attends a prestigious predominantly White institution – where he is one of few other Black males because the institution and/or department does not have a strong record of recruiting or retaining Black doctoral students – he may describe his experiences as isolating and hostile (Fries-Britt, Burt, & Franklin, 2012). Because it is common for Black males to be underrepresented in departments, institutions, and within the field writ large, it is unlikely that he will have Black male science or engineering professors as mentors modeling the professorial role (Fries-Britt, Burt, & Franklin, 2012; Gasman & Spencer, 2012; Palmer & Gasman, 2008). The nature of students' educational context can thus influence their career goals (as well as other outcomes). Because these various contexts play a role in students' preparation for the professoriate, they must be examined.

Levels of contexts related to research experiences.

With the exception of research labs as a context where students and their faculty supervisor engage in collaborative research, the empirical literature on doctoral research experiences often describes "context" in terms of institution, discipline or field of study, department, and the culture of science. While these contexts are interrelated, the academic department – embedded within the larger structures of college/school, institution, disciplines, and culture of science – is charged with interpreting and implementing policies and practices that most closely affect students (McAlpine & Amundsen, 2007); the academic department (as a context) links students with the "norms, expectations, trends, and ways of working" of the discipline and institution (Anderson, 1996, p. 310). In the sections that follow, I discuss how scholars examine "contexts" in students' research experiences, and how these contexts influence students' preparation for the professoriate.

Discipline, institution, and academic department.

The ways in which students experience research are related to their department's approach – and interpretation of their institution and discipline/field of study's approach – to research. In addition, academic departments influence what students learn about their field of study (i.e., "…concepts and principles associated with a field, its methods of inquiry and its criteria for assessing and validating knowledge,") and help cement students' academic identities (i.e., how students see themselves fitting within their particular academic community) (Baker & Lattuca, 2010, p. 812). For instance, in Gardner's (2009) study of 40 students in chemistry and history departments at two institutions, she reported that students in chemistry receive greater support from peers in the research lab, which aides in their transition to being independent scholars. She argued that the disciplinary context plays a role in students' transitions because in science fields – like chemistry – engaging in research within a community of practice is common. Similarly, in her study of students and faculty in four fields (i.e., chemistry, civil engineering, microbiology, and sociology), Anderson (1996) found that the disciplinary context influenced the academic department. In chemistry and microbiology, participants described their interactions to include "conflict, competition, and favoritism," whereas, in civil engineering and sociology departments, where collaborative research experiences are more common for the participants in this study, respondents reported greater collegiality and preparation for academic careers. While we do not know the proportion of students involved in these two studies who ultimately pursued academic careers, we can surmise that students who perceived having preparation for research careers were more likely to pursue the professoriate than students who did not feel comfortable with their research experiences.

In addition, when these two studies are taken together, they illuminate how students' research experiences can differ based on the disciplinary, institutional, and departmental contexts. More specifically, in Gardner's (2009) study, chemistry students were engaged in collaborative research experiences, whereas, the chemistry students in Anderson's (1996) study had more individualized research experiences. There is no set disciplinary requirement that chemist must learn in collaborative research groups. Thus, when juxtaposing these two studies, it is not surprising that we see chemistry students differently engaging in research because the decisions for how students best learn research were made at the departmental levels rather than dictated by the institutions and disciplines.

Culture of science.

Defining the "culture of science" (not to be confused with the "discipline" of science) is subjective, and interpretations may vary by discipline, institution, and department. Nonetheless, there is empirical literature that suggests the culture of science includes prestige, competition, hard work, and rewards (e.g., monetary/grants or symbolic awards) (Reskin, 1979). Embedded within the culture of science are norms and traditions of academic research (Anderson & Louis, 1994)[5]. This broader context extends beyond that of discipline, institution, and department, yet undergirds their policies and practices.

Scholars rarely investigate the culture of science, except when attempting to understand how students identify (or do not identify) with their respective discipline or field of study (see

[5] Drawing from the work of Merton (1942), Anderson and Louis (1994) present four norms of academic research: universalism (based on accepted standards merit, scientists evaluate research); communality (scientists disseminate new knowledge); disinterestedness (scientists are motivated by gains in knowledge, not personal gains); and, organized skepticism (scientists consider all new knowledge – in their varied forms).

Identity section below). While understanding students' science identities is an important line of research – because how one identifies with science can influence students' post-graduate career plans such as pursuing the professoriate – it is equally important to understand how the culture of science represents a context that influences other contexts, and ultimately, students' learning. For instance, Reskin (1979) aimed to understand how faculty members' research productivity influenced their students' academic careers; she hypothesized that students' career outcomes (i.e., securing and succeeding in tenure-track jobs) related to the level of productivity of one's advisor[6]. With a sample of 238 chemists, she tracked the number and citations of participants at three times (i.e., before receiving the Ph.D., three to five years after their first postdoctoral tenure-track job, and at the end of their first decade). She found that students who worked with productive faculty were more productive at the predoctoral level, that is, there were direct effects between faculty productivity and predoctoral productivity. However, in their first postdoctoral tenure-track job and a decade later, there were no direct effects of faculty advisor on publication record; at both later times, students' publication records were significantly affected by the caliber of the department in which they worked.

Reskin's findings – similar to those of Anderson (1996) and Gardner (2009) in respect to how advisors mediate students' preparation for the professoriate (through engaging in collaborative research) – highlight how the departmental and institutional contexts in which advisors are situated – influence students' productivity and ultimately their ability to secure and succeed in faculty careers. Reskin argues that because of the scientific reward structures and prestige of certain departments at certain institutions, institution and departmental contexts

[6] Students' faculty advisors (or "sponsors" as she refers) were identified by the "American Chemical Society's Directory of Graduate Research" (p. 134). Faculty productivity was measured by the following variables: prestige of the Ph.D. department; number of postdoctoral fellowships held and their prestige; number of awards received and their prestige; number of honorary degrees; age; academic rank; and, number of federal science committees they served during the time their student was working on the Ph.D. (Reskin, 1979, p. 135).

(situated within the larger culture of science) likely yield indirect effects for students. In other words, institutions and departments are deemed "prestigious" for a number of reasons, one being their historical adherence and successful practice of what is expected in the culture of science. As a result, prestigious institutions and departments often have greater resources than less prestigious institutions and departments. These more prestigious institutions and departments attract the most productive faculty, who recruit talented students who, by virtue of the nature of the departmental context, are more likely to engage in the research practices of their productive faculty advisor. By historically engaging in the practices – characterizing the culture of science – prestigious institutions and departments are more likely to prepare and produce future faculty members than institutions that do not have similar traditions. In this example, the culture of science – that is, prestige, competition, hard work, and awards – plays a role (at least in part) in faculty productivity and their students' preparation for the professoriate, as well as how national and international scientific cultures influence universities and their constituent departments. While different contexts play a role in students' preparation for academic careers, the interactions and learning that take place within the contexts are equally important to understanding preparation for faculty careers; interactions within one's contexts mediates learning.

Mediation.

"Mediation" is a process that links individuals to the communities of practice they are attempting to join (Cobb & Yackel, 1996; Lattuca, 2002; Wertsch, del Rio, & Alvarez, 1995). The concept of "mediation" often focuses on the appropriation of "cultural tools" – generally rooted within cultural, institutional, and historical traditions – that enable individuals to engage with others in specific contexts (Cobb & Yackel, 1996; Wertsch, del Rio, & Alvarez, 1995).

Some examples of cultural tools that could help bridge a newcomer to an existing community are language, acronyms, customs, religious practices, attire, decorum, etc. Such cultural tools in and of themselves do not force individuals to behave in specific ways. Rather, individuals are not able to fully act as a member of a community of practice until they have acquired – at least to some extent – the cultural tools central to the activities of that community of practice.

Mediation influences behaviors as cultural tools are acquired and used. For example, an incoming doctoral student in engineering may not be able to fully engage in their community of practice (i.e., research group) until he or she understands both the nature and scope of the research undertaken, which materials or resources are needed, and where to find those materials or resources. In this example, the incoming doctoral student would learn the norms and values of this local community of practice by observing, interacting with, and conducting research with its members.

Mediation in research experiences.

From a sociocultural perspective, all learning is mediated; mediation takes place through our direct interactions with others and/or through the tools that humans have created in order to interact with one another. In the empirical literature, scholars describe three primary methods in which mediation transpires for doctoral students: interactions with faculty advisors, peers, and research groups.

Faculty-advisors.

Pearson & Brew (2010) argue that the impact of the research experience on student learning is largely related to the role of the faculty-advisors[7], "For it is part of the responsibility of the supervisor to provide the intellectual and professional leadership and facilitation of

[7] While not always the case, students' faculty-advisor usually serves as the supervisor of their research experience. I will be using advisor and supervisor interchangeably.

research students' learning within the workplace…" (p. 140). The roles of faculty-advisors are extensive and vary by department, but research suggests that advisors should serve as sources of information, liaisons to the department, dissertation supervisors, agents of socialization, role models, mentors, and career coaches (Antony & Taylor, 2001; Austin & McDaniels, 2006; Barnes & Austin, 2009), and all of those components contribute to students' learning and identity. Bluntly put, the faculty-advisor "can make or break a Ph.D. student" (Lee, 2008, p. 1).

In Reskin's (1979) study, she asserts that faculty transmit to their students "scientific knowledge, technical skills, and professional values," and how students engage in their own research and faculty careers are direct results of the mediation from their faculty advisor (p. 131). Anderson and Louis (1994) extend the work of Reskin (1979) by investigating which faculty tasks mediate students' learning about research, and how those tasks shape students' scientific values. Particularly, they find that faculty tasks such as providing feedback (e.g., the level of detail provided to students' when their work is evaluated), contact (e.g., the amount and quality of time spent with one's advisor), and mentoring (e.g., provides consistent criticism, teaches students good research practices, shares relevant research with students, expresses interest in one's progress, and helps students learn how to navigate the field) relates to students' adoption of counternorms[8].

Faculty members also mediate students' learning – and preparation for the professoriate – by guiding students to the norms and behaviors of members within their community of practice. For instance, Pearson, Cowan, and Liston (2009) describe how a student engages in the publishing process with his faulty advisor. The student describes meeting with his advisor to

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[8] Drawing from the work of Mitroff (1974), Anderson and Louis (1994) present four counternorms of academic research: particularism (scientists evaluate new knowledge based on the reputation and past productivity of the researcher(s); solitariness (research is guarded to ensure priority in publishing, patenting, and disseminating; self-interestedness (scientists compete for recognition and awards); and, organized domatism (scientists engage in research to advance their own scientific agendas).

discuss the results of an analysis and negotiating how to parse out data for future manuscripts. Their findings align with those of Barnes and Austin (2009) who find that faculty members blend students' content expertise with the faculty members' understanding of the research process in order to publish research. By working together, both student and faculty advisor contribute to the manuscript, but more importantly, the student gains a better understanding of the process of research.

Peers.

Because much emphasis is placed on the myriad ways faculty members mediate student learning, less consideration is given towards understanding how students help mediate the learning of their peers. Despite this relatively small body of literature, students learn a great deal about research through interactions with their peers. For instance, when some newcomers prepare to present at their first conference, they turn to their peers for help (Baker and Pifer, 2011). The advanced doctoral students help their peers understand how to navigate the conference and the expectations of conference participants, how to present research, and offer practice questions that might arise from the audience. These interactions with peers are important to students' learning about and practicing research because students often serve as next-in-line experts when the faculty-advisor is not present (Crede & Borrego, 2012). In addition, some students feel more comfortable asking questions of their peers than they do asking their advisors; with peers, there is a feeling of safety, instead of a feeling of shame if the student does not know something the advisor thinks she should know (Burt, 2010). The growing line of research on peers extends previous conceptions of the doctoral experience that positions the student and faculty-advisor role as the sole link to doctoral students learning about research.

Research groups as mediational means.

Scholars studying doctoral education often focus on either the faculty member or the student; some studies will look at the dyadic pairs of faculty "and" students (Ives & Rowley, 2005; Sweitzer, 2007). However, only rarely do scholars examine the interactions of students and the members within their communities of practice (for exceptions see Crede & Borrego, 2012; Pearson, Cowan, & Liston, 2009). Viewing students within their communities of practice (e.g., research groups, departments, fields of study) provides researchers opportunities to better understand how the meditational means (e.g., a given community's language, behaviors, community norms) are used to interact within communities and how meditational means shape members' learning. For example, Crede and Borrego (2012) provide an improved understanding of what takes place – and the benefits of working – within research groups compared to engaging in research in isolation. The authors note that such benefits resulted from weekly meetings with faculty advisors and frequent exchanges of emails with faculty members. Students' learning, however, was also mediated by peer-to-peer interactions. While Crede and Borrego's findings suggest that size of the research group influences the scope and type of mediation (e.g., students in larger groups have more interactions amongst each other, whereas, students in smaller groups have more interactions with the faculty supervisor), the nature of research experiences organized in research groups mediate students' learning.

Research groups are embedded in institutional and departmental contexts that also mediate students' learning about research. Pearson, Cowan, and Liston (2009) provide a narrative for how a student in Immunology participates in a journal club, and how her participation in that community of practice influences her learning. The participant articulates how attending the journal club allows her to witness how scholars present research (e.g., hypotheses, results) and respond to critiques. Similarly, Golde (2007) describes how journal clubs mediate students' learning about research by providing both newcomers and older students with opportunities to learn about the field and research in ways that are not taught within the general curriculum. More precisely, she argues that these local communities of practice help students stay current with research, encourage students to discuss and critique research, and help students make interdisciplinary connections between their field of study and the larger scientific community.

Participation.

Individuals participate in the activities of the communities of practice they wish to join by activating the meditational means of those communities. As described by McAlpine and Amundsen (2007),"Communities create the occasion for interactions. They are the locations (imagined and real) where purposes, roles and tasks are enacted based on often tacit rules and practices" (p. 65). Participation, then, occurs when newcomers and community members interact with one another to create a shared meaning or understanding (Cobb & Yackel, 1996; John-Steiner & Mahn, 1996).

Scholars researching doctoral students often look to the academic department or research group because those are, in a sociocultural view, communities of practice. In some research groups, advanced doctoral students practice the roles of future faculty by facilitating group meetings, managing lab supplies, and taking lead roles in papers (Turner, 2006). As members of their academic programs, students attend departmental symposia, present research at conferences, and publish scholarly work because those are the kind of activities undertaken in their communities of practice (Barnes, 2009-2010). Using engineering students as an example of a community of practice, newcomers participate in the activities of engineers to learn what engineers do. Through this participation, engineering students acquire the tools used in the field that help them, for example, design research and run experiments. Consequently, they learn to think, speak, and act like an engineer. By investigating how individuals participate in their local communities of practice, researchers learn the norms and values of that community of practice, and make sense of how participation mediates students' learning and identity development.

Identity.

Sociocultural perspectives on learning suggest that in addition to shaping what one knows, learning also shapes who one is; identity development cannot be separated from the process of learning ((Baker & Lattuca, 2010; John-Steiner & Mahn, 1996; Lave & Wenger, 1991; Wertsch, del Rio, & Alvarez, 1995; Wortham, 2004). Therefore, what one knows and who one is are interconnected as outcomes of learning. When applied to doctoral education, identity is important to understand because it can influences how students experience research, as well as whether they will pursue the professoriate upon graduation.

Identity is both a process and an outcome. Existing empirical literature on doctoral students' research experiences distinguishes between identity as a process (a means for establishing who one is) and as an outcome (the identity one assumes); for example, as a result of participating in research (process), students may see themselves as scientists and holding an academic career (outcome). Myriad variables (e.g., race and ethnicity, nationality, gender, origin of baccalaureate degree, parents' educational, socioeconomic status) are often considered to be "background characteristics" when scholars examine doctoral students' research experiences. From a sociocultural perspective, these "background characteristics" are considered forms of "identity." They are not just about how others view students, these characteristics provide information about how students view themselves and how they have come to be. Because the process and outcome of identity are interrelated, it is not always easy distinguishing between the two. In the sections below, I explore how scholars have discussed identity development in relation to research experiences.

Identity characteristics mediating students' learning.

How individuals interact with others within the research experience can be – at least in part – attributed to their identity characteristics (e.g., race, ethnicity, gender), learned prior to college, and shaped by one's environment (e.g., growing up in a racially diverse city, growing up wealthy). For instance, some women and students of color have challenges adjusting to and adopting the identities of scientists because they feel like science is not welcoming (Carlone & Johnson, 2007; Green & Glasson, 2009; Museus et al., 2011). Three predominant explanations are that: 1) scientific research is not generally framed in altruistic ways; 2) science is taught from a limited perspective; and, 3) the culture of science provides barriers to accepting a science identity.

The first argument posits that women and people of color often enter science with the intent of helping their communities, yet as they continue through the science pipeline, they are not shown how remaining in science will allow them to meet their goals (Carlone & Johnson, 2007). The second argument focuses on how teaching from male-dominated Eurocentric traditions and norms[9] of science makes it difficult for women and students of color to adjust to and identify with science (Fries-Britt, Burt, Franklin, 2012; Green & Glasson, 2009). Moreover, women and students of color are underrepresented in the models of exemplary scientists used to describe scientific theories and contributions. While the first two explanations are – in part – related to how women and students of color interact with "individuals" of power in science (e.g.,

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[9] Within scientific settings, Socratic pedagogies (i.e., debate-style teaching and discussions) are often utilized. Research suggests that these pedagogical methods to teaching and learning are detrimental to women and students of color remaining in science. In fact, these methods have been attributed to "weeding out" students from science courses (Fries-Britt, Burt, Franklin, 2012; Green & Glasson, 2009).

college professors, high school teachers) – generally White men – a final explanation suggests that students' disidentification with science is related to the historical perpetuation of the "culture of science" that maintains the traditions and norms of science from a Eurocentric male perspective. For instance, if a student is having a bad research experience due to a strained relationship with his or her research supervisor, one perspective suggests that the strained student and faculty interaction is an interpersonal relationship issue between individuals. Another perspective suggests that how the faculty-advisor interacts with – or conducts research and teaches – the student is reflective of his doctoral preparation and identification with science (Lee, 2008; Pearson & Brew, 2002; Strauss, 1961), which likely stems from a lineage of White men in science. In the latter explanation, the culture of science (not the individual) is the culprit in the student's disidentification with science, because the culture of science maintains science-related behaviors that are not congruent with the student's learning needs.

In Conefrey's (1997) observation of a life science laboratory, she details the lab experience of a female member of the research group – Lilly – who is scheduled to run the meeting and give an update on her research. During this meeting, Lilly is belittled, frequently interrupted, ignored, and not included in advanced science (and sports-related) side conversations during her presentation. While this behavior could occur with any member in the group, Lilly is an Asian woman (one of only two women in the group) and one of the newest members of the team. At times during the meeting, the research supervisor tries to help her get back on track, and other times, the supervisor contributes to derailing her presentation. According to Lilly, that meeting was a defining moment where she felt disconnected from the team and disconnected from science. In this example, not only is Lilly's science identity is being shaped - or not – by the research experience, she ultimately decides not to remain in science and the authors argue that the context of the research lab – embedded within a culture of science marked by White male dominated, aggressive and competitive forms of communication did not provide a nurturing environment for a young woman researcher. From a sociocultural perspective, the lack of congruence between Lilly's interactional practices and the practices of the research lab influenced her decision to stop participating in science. When participation in a particularly community of practice ceases, so does the development of an identity based in that community.

Scientific (and academic) identity.

Another form of identity that does not particularly fit with students' background characteristics relate to students' science identity. This characteristic relates to how students view themselves in the context of science (e.g., being a scientist, doing what scientist do, believing in one's abilities to engage in science). This identity is important, particularly for those interested in pursuing the professoriate, because for an individual to engage in a career of academic research, one must first understand the culture of science, what it takes to engage in academic research (e.g., securing grants, conducting research, disseminating information), adopt these norms and values, and then participate in the profession.

Stubb, Pyhalto, & Lonka (2012) illuminate how individuals identify with their discipline in a study of doctoral students in three disciplines (natural science, behavioral science, and medicine) attending a Finnish university. They find that a majority of the students sampled characterize the nature of their research experiences as a personal journey that influences their personal development, learning, and understanding of the role of researcher. In fact, one student describes him or herself in terms of science, "The 'science me' and the person I am in general, they are not separate things. Of course not. What I am as a researcher builds me as a whole" (p.

9). According to the authors, when these doctoral students engaged in research experiences, their scientific identities evolved, and as a result, a majority of respondents not only saw themselves as scientists but as researchers. In this example, the outcome of identity change was inextricably linked with the process of learning (participating in research and engaging in the roles held by researchers).

In another example, Gonsalves & Seiler (2012) show gender influencing how a doctoral student locates herself within physics. In this study, however, her experience is not mediated by the members of her research group. Rather, as she attempts to acquire the skills of physicists in her lab by participating in the experiments they are running, she is unable to access the tools. More specifically, to run her experiment she must use an oversized microscope which is difficult for her to maneuver. When talking with the researcher, she mentions that many of the tools needed to run experiments require her to stand on stools or get assistance from lab mates (most of them men), highlighting the gendered nature of physics. In this example, although interactions with the people in her research group did not negatively mediate her learning and development of a science identity, the culture of science (e.g., science as constructed and practiced by men) reminded her how hard she must work to succeed in science.

Putting the Sociocultural Pieces Together

To connect the four concepts identified in this review – context, mediation, participation, and identity – and to suggest how sociocultural perspectives can be used to understand the experiences of doctoral students learning to do research I turn to an example. In describing the experience of a Black male engineering doctoral student, I note in brackets how sociocultural concepts can be combined to present an analysis of learning and identity development in graduate education.

Alphonso is a Black male engineering doctoral student from a lower middle-class socioeconomic background and who attended a racially diverse K-12 school system [*social identity characteristics*]. He is currently enrolled at a prestigious predominantly White research institution [*context*]. Because he always showed interest in science – and because both of his college-educated parents valued and understood the importance of academic enrichment – they allowed him to watch science shows on the public broadcast station, regularly took him to the local science museum, and bought him chemistry experiment sets [*mediation*]. Because of the support from his parents, he was able to overcome barriers such as being called "geeky," "nerd," and "not Black" because of his interest in science. As he continued along the science pathway, he became increasingly aware that he was one of few Blacks in his classrooms. Continuing through college and graduate school, most of his peers and research colleagues were White or non-Black international students, which contributed to his feelings of isolation. He felt as if his peers did not think he was smart enough to be in science (or assumed he was admitted because of Affirmative Action [*sociohistorical context*]). Thus, his peers were reluctant to study and/or engage in research with him [*context*]. After passing his qualifying exams, he identified a dissertation topic, a new faculty-advisor, and began engaging in research (albeit within a research group, he was in a non-experimental group where students work on individualized research projects) [*mediation*, *participation*]. Now, having a more positive research experience where he has support from a new, nurturing faculty-advisor [*mediation*], he gets his first paper accepted to a conference, and soon after, a manuscript is accepted for publication [*participation*]. While he did not describe positive experiences with peers, his initial faculty-advisor, or the academic department [*context*], once he began having positive experiences with research, he began envisioning himself as capable of being an engineering professor [*identity*].

According to Burt (2010), several social identity characteristics helped shape how this Black male doctoral student engages with research and views himself as a future scientist. One salient example is how parental education played a role in his acceptance of his growing interests in science. Instead of dissuading the student to pursue other interests, the parents encouraged him by providing him with enriching activities that nurtured his interests in science; this encouragement was also important to help counteract the negative influences of peers. His early interest in science helped foster an identity of scientific creativity; creativity is one characteristic existing research suggests is important for scientists and future professors who will have their own research groups (Strauss, 1961). His science identity was threatened by the negative experiences with his first advisor and the peers within his academic department. Fortunately, after switching to a more supportive advisor, he now participates in research, and believes in himself as a scientist because he participates in the activities of scientists.

Critiques of Sociocultural Perspectives

Although sociocultural perspectives of learning improve our knowledge of how individuals learn and develop their identities, they are not without limitations. Some scholars suggest that sociocultural perspectives are viewed as a cure-all for improving learning across a number of spectrums (Anderson, Reder, & Simon, 1996). For instance, Anderson, Reder, and Simon (1996) agree that there are contexts in which learning might be best facilitated in social environments, but they argue that more important than the social context is the way in which learning is facilitated through some form of instruction. In other words, they explain that regardless of the context, learning requires thoughtful scaffolding to insure that intended learning outcomes are met. In addition, they assert that while one's context may provide an optimal learning environment, there is no guarantee that what is learned can be transferred to another context. This critique suggests that what is most important is “what” is learned rather than “where” and “how” it is learned.

Another critique suggests that like other models and theories where one learns from the expertise of knowledgeable others (e.g., socialization theory), in a sociocultural perspective, individuals also learn from passed down accounts; Cobb & Yackel (1996) point to this as a “transfer-of-knowledge model” that leads to imitation (p. 186), or the “transmission” of culture from previous generations. In response, John-Steiner and Mahn (1996) acknowledge that sociohistorical events provide contexts for individuals’ learning and identity development, but that Cobb and Yackel (1996) provide an oversimplification for the “mutuality of learning and its interpersonal and intergenerational dynamic” (John-Steiner & Mahn, 1996, p. 197). Despite these critiques, sociocultural theorists unapologetically hold that individuals’ multiple contexts shape what they know and who they are. Thus, while individuals’ current understanding of themselves may be shaped by sociohistorical events, their evolving identities are mediated by acquiring new knowledge and participating with their communities of practice. Sociohistorical context, then, is only one piece of holistically understanding an individual.

Chapter 3: METHODS

This chapter begins with a review of my research questions. Next, I describe the pilot study I conducted to prepare for this work. This leads into a discussion of the research design for this dissertation, which includes data collection, data analysis procedures, and limitations (see Appendix B: Dissertation Timeline). I conclude with a reflection on my role as a researcher and the steps I took to ensure the quality of this study.

Research Questions

To learn more about the nature of doctoral research experiences and how they influence doctoral students' pursuits of the professoriate, the following research question and sub questions guide this study:

> *How do doctoral students' research experiences in an engineering research group influence their perceptions of, and interest in pursuing, academic careers? Specifically, how do research experiences influence:*
>
> *a. Doctoral students' learning about engineering and the professoriate?*
> *b. Their perceptions of faculty work?*
> *c. Their personal and professional identities?*
> *d. Their intentions to pursue a faculty position?*

Pilot Study

To prepare myself for my dissertation research, I conducted a pilot study to determine: 1) the feasibility of answering the research questions I posed using ethnographic methods; and, 2) to familiarize myself with the research experience in engineering doctoral programs. During the pilot, I engaged in weekly observations of one engineering research group's meetings for seven months (September 2012 through April 2013). I also conducted six one-on-one semi-structured interviews with members of the research team (three doctoral students, two faculty members, and one lab supervisor) using IRB-approved interview protocols that were based on a priori research findings and the sociocultural theoretical perspectives that informed the study (see Chapter 2: Theory and Literature). In addition to these formal interviews, I also gathered data through informal interviews while in the field, for example, while attending meetings or at the group's periodic social gatherings.

The pilot study provided information on the composition of the research group, how the group was organized, how it functioned, the specific roles held by group members, the nature of students' research projects, and students' interests in post-graduate careers (e.g., academic, industry, research, other). It further provided information on the appropriateness and comprehensibility of the interview questions and the protocol's ability to elicit rich data. Below I describe the research design and methodological choices that shaped my pilot, and offer the preliminary findings and pilot reflections that informed the dissertation study.

Pilot Research Design

Between September 2012 and April 2013, I conducted a pilot study that afforded me the opportunity to observe the research group for an entire academic year. In addition, because I do not have a science and engineering background, I needed to devote an extended amount of time within the research site.

Data collection procedures.

The goal of a sociocultural analysis is to understand how one's learning and identity development are influenced by the context(s) in which one learns, interactions with others in the setting, and participation in a given community's practices. Because contexts play a major role in shaping how individuals learn and view themselves, as well as sets the tone for how individuals within a community of practice interact, the choice of a research setting and data collection strategies are critical methodological choices.

Selecting the institutional site.

Cross-referencing multiple lists of the top engineering graduate schools in the United States (US News and World Repots, 2012; NACME, 2008) reveals that Model University's (pseudonym) School of Engineering is consistently rated as a top-ranked institution. While Model University has a top-ranked engineering college, its locale provided the research with both a cost-efficient and methodologically sound option for the extensive amount of fieldwork required for this ethnographic study. Finally, professional connections to individuals in the School of Engineering eased access to the research group.

Selecting the research group.

To select a research group for this study, I consulted with a high-ranking engineering administrator, who is also an engineering professor. Several factors went into the selection of the research group. The research group had to include a diverse group of students (e.g., race, gender, nationality) because of a desire to understand how social identities and professional identities intersect for doctoral students. After identifying research group options, I considered the engineering discipline and the type of research that takes place in the research group. More specifically, I considered the approaches to research that would provide different kinds of understandings of how students are prepared for the professoriate (e.g., "experimental" research may include more collaborative group and research projects, whereas, "non-experimental" research projects may entail more independent work yet still feed into the larger group project) (Traweek, 1992). Finally, I prioritized groups led by a faculty member from the U.S; this choice was considered to help minimize cultural differences that could influence the nature of students' research experiences.

After the criteria were established, potential research groups were identified and ranked. After IRB approval, I emailed the faculty supervisor of the first identified group. The recruitment email briefly described the project, and I encouraged an in-person conversation to answer questions about the study (see Appendix C: Faculty Supervisor Recruitment Email). I received an agreement to study the first group I contacted from the faculty supervisor, so I did not have to contact the remaining identified research group supervisors.

I introduced myself and the study to student group members via email (see Appendix D: Student Recruitment Email). Despite reaching out to students, at the beginning of the study, student group members were reluctant to sign the consent form, that is, until they became comfortable with me and better understood my study. Nonetheless, after gaining consent from the faculty supervisor I was able to observe the research setting. But, before individually talking with any student, I obtained his or her consent.

Pilot Fieldwork.

In ethnography, the primary methods of data collection are observations and interviews (Emerson, Fretz, & Shaw, 1995; Fetterman, 2010; Van Maanen, 1988; Wolcott, 1994). Observations allowed me to understand the culture[10] in which participants operated, and how their culture shaped their perceptions of the professoriate. I took extensive fieldnotes during observations to ensure that I was capturing the cultural tools (e.g., acronyms, engineering-specific vernacular, symbols of praise and correction, rituals) used by participants in the research

[10] In this study, I adopt Van Maanen's (1988) definition of culture as the "the knowledge members ('natives') of a given group are thought to more or less share; knowledge of the sort that is said to inform, embed, shape, and account for the routine and not-so-routine activities of the members of the culture" (p. 3).

group (Emerson, Fretz, & Shaw, 1995; Fetterman, 2010; Van Maanen, 1988). Once I had an understanding for how the research group functioned and members were comfortable with me, I conducted six in-depth, semi-structured, one-on-one interviews. "Judgment sampling" was used to determine whom to interview; this technique required that I observe the research group until I had a sense of how the group members worked together and who might be key informants (Fetterman, 2010). Three students were receptive to interviews, and two of the three were specifically targeted due to their interest in pursuing faculty careers. The research group leadership team (i.e., faculty supervisor, professor emeritus, lab manager) were also interviewed. All interviews took place at a location away from the research lab (Marshall and Rossman, 1999) (see Appendix E: Fieldwork Schedule). During interviews I was able to ask specific questions about what was happening in the research setting, and members' interpretations of group practices, activities, and interactions (see Appendices F & G: Interview 1 Protocols). After each interview, I wrote reflective memos detailing salient aspects of the interview (e.g., body language, affect, long pauses from participants). Consistent with recommendations from Emerson, Fretz, & Shaw (1995) and Fetterman (2010), I also used memos to consider the appropriateness of interview questions and how to best adapt questions for greater clarity to the engineering students. Finally, memos allowed me to begin speculating on what I was learning about participants' research experiences.

During interviews with the three doctoral students, I became aware of the difficulty they were having answering some of the semi-structured questions. Although I adapted questions, I needed another tool that would allow participants to understand what I was asking them. As a result, I created two drawing exercises as aides to help them think about the research group, situate themselves within the group's structure, and their future career interests. The first drawing exercise required participants to sketch the research group. I tried not to lead participants into thinking of this exercise as a hierarchical organizational chart, as there could have been alternative interpretations of the group. Nonetheless, most participants drew organizational charts. The second exercise included a blank sheet of paper with an arrow in the middle extending from left to right. On the left side of the continuum read “unlikely career” and on the right side of the arrow it read “likely career.” Participants were asked to indicate on the continuum “faculty, industry, researcher, and other” career options. If they wrote “other” they were asked to describe what “other” included. After drawing, each participant was better able to articulate his or her responses to my questions, and we were able to use the drawing as an aide throughout the remainder of the interview.

I used a digital recorder to record all formal one-on-one interviews, which were then transcribed verbatim; I checked each transcription against its audio recording. Informal interviews – which were documented through fieldnotes – allowed me to check for understanding, triangulate received information, and seek disconfirming evidence. It should be noted that fieldnotes were the only form of data collection for research group meetings and other observations of group members. All transcribed interview data and field notes were uploaded into the qualitative research software program HyperResearch for coding and data management.

Preliminary findings from the conclusion of the pilot study (April 10, 2013).

Because the pilot study became the dissertation study, this methods section will not include many findings from the analysis. Instead I present the preliminary findings – based on fieldnotes and memo data – that were included at the end of my pilot study.

Preliminary findings from my pilot study showed how certain practices in this particular research group influenced students' research identities and preparation for research careers. The School of Engineering at Model University has a reputation of generating scholarly knowledge, securing funding, and producing engineering faculty. Doctoral students admitted to Model University are required to take courses, join a research group, serve as a graduate teaching assistant for at least one semester and publish article(s) before graduating. The established requirements shed light onto the research group's emphasis on research, presentations, and publications.

Within the research group I studied, the faculty supervisor established an environment of shared responsibility in which students were expected to contribute to the day-to-day operations of the group. This freed the faculty supervisor to spend more time guiding the overall work of the group (including securing external funding to support his labs). The shared responsibilities also provided students with the opportunity to practice balancing research, with other related-research tasks, which is important to learn in a research career or as a faculty member managing his or her own team (some examples of other research-related tasks were: taking inventory of needed materials and tools; creating safety procedures; and organizing group celebrations).

Each student was required to understand what work was being done in the field and by members of the group. In addition to understanding the scope of existing research, students in the group learned how their individual project was situated within the group's research program. Overall, the expectation was that students' work provides both scholarly knowledge and scientific advancements. Along with the creation of knowledge, there was an expectation that students present their research at national conferences. Students prepared for conference presentations through weekly group and subgroup meetings. During meetings, students received feedback on their research methodologies, and received help with troubleshooting (e.g., interpreting data, creating research protocols, determining next steps for failed projects, strategizing ways to better present the research). After meetings, students returned to the lab to address any problems and move their work forward. The process of engaging in research and receiving weekly feedback helped to promote students' transitions to independent scholarship; by the second year, some student group members felt comfortable designing and running new experiments.

Reflections on the pilot study.

One of the goals of the pilot study was to learn about the nature of an engineering group to glean practices that can improve and increase the engineering pipeline, vis-à-vis preparing more engineering professors. Preliminary data from this pilot study provided some evidence of apparently successful ways to prepare engineering doctoral students to become professors. For instance, in addition to the group's shared responsibilities, the organization of the group also influenced student collaboration. Specifically, students were engaged in independent research, but each project is interrelated and draws upon the work of other students within their respective subgroup. In addition to the collaborations among doctoral group members, advanced doctoral students (and one post-doctoral student) were expected to help manage the experiences of undergraduates and master students in the group. The opportunity to manage others gave students additional opportunities to practice managing a pseudo research group.

It took a bit more than a semester to build rapport and gain the confidence of the doctoral students. After I demonstrated consistency by attending weekly meetings, I was invited to the Group's annual holiday party, and began interviews with some students at the conclusion of the

Fall 2012 semester. During this time, I also conducted my first formal interview with the faculty supervisor.

I intended to provide participants with incentives (i.e., $25 gift cards) as a courtesy for their time interviewing with me. I realized, however, that the students in the group worked long hours in the lab. Instead of offering incentives after the study concluded, I decided to invite them to interview with me during lunch or dinner – the times when they give themselves breaks from their research – and pay for their meals. As a result, I was able to get students to interview with me for at least one hour (most interviews lasted one and a half to two hours).

At the conclusion of the pilot, two doctoral students self-disclosed an interest in pursuing faculty positions. In our interviews and interactions, they described the importance of having their own lab and students in the future, as well as how participation in the practices of the research group helped to solidify their pursuit – and improve their understanding – of the professoriate. Specifically, they excitedly explained the importance of engaging in research, receiving regular critical feedback, and utilizing the research group as a laboratory to make and learn from mistakes. For them, the time to make mistakes was now – within the safety of the research group – rather than in their own research labs when they become faculty members.

The pilot study provided a preliminary understanding for how this research experience prepared two students for academic careers, but more data and analysis were needed to understand how the research experience was shaping group members' identities as potential future faculty members. As such, the pilot study yielded ideas for future fieldwork (e.g., how many sites to visit, how many research groups to investigate, how much fieldwork would be adequate to build rapport and gain an understanding for the research experience).

Dissertation Research Design

A key question considered for the extended dissertation study was how many institutional sites to include in this study. Studies in a single site often raise questions about the representativeness of that site. Such questions presume that generalizability is a goal of the research. In contrast, studies that seek to develop in-depth understandings of individuals' experiences and outcomes to inform future work may be better served by intense study of a single site or phenomenon (Small, 2009). Since the purpose of this study was not to assess engineering research groups to generalize my findings to all research settings, but rather to generate a grounded understanding of the role of research experiences in shaping perceptions of the professoriate among engineering doctoral students, a more focused approach was appropriate and desirable.

Data collection procedures.

Acting on the recommendation of my dissertation committee, and with permission from the pilot research group's supervisor, I stayed with the same research group for the dissertation research. During the seven months of my pilot study, I gained greater access to group members and acceptance into the group; learning from the pilot, it would likely have taken a similar amount of time to gain similar access to another group. Also, the pilot research group may or may not be an exemplar of a particular type of research group that is common in engineering, and to some extent in other science fields.

Extending the data collection period.

I extended data collection for six additional months (April 2013 – October 2013) for a number of reasons. First, I needed to further my understanding of the experiences of group members. Second, participants informed me that their heaviest period of research activity took place during the summer months and I wanted to observe members' rigorous summer work schedule (including members' supervising summer undergraduate researchers and collaborating with visiting scholars). Third, I wanted to see new students transition into the group during the beginning of the Fall 2013 academic year. Finally, this extended period of data collection provided me with opportunities to longitudinally observe and engage with the group members. During this period of data collection I was able to focus on how members' research skills, aspirations, and scholarly and professional identities were developing.

Dissertation Fieldwork.

Consistent with my pilot research design, I continued with weekly observations of the group's research experiences (e.g., weekly meetings) and after building rapport and gaining trust, I was able to interview the remaining core group members. Using the same interview protocol as during the pilot[11], I conducted ten additional one-on-one semi-structured interviews. These interviews – which I will refer to as "Interview 1" – ranged from forty-five minutes to nearly two-hours; the variation was based on the participants' ease with the interview and their availability (i.e., how long they could spare being away from the research lab). The questions in Interview 1 were broad in nature, allowing me to gain an understanding of students' career interests, their individual research project, and how their project are situated within the group's work. These interview questions were far ranging because I was not certain that participants would be receptive of a follow-up interview, so I needed to gather as much information as I could during the first interview. Consistent with the pilot study, I continued to use the two drawing exercises to help students in the group reflect on the groups' organization and their post-graduate career interest.

[11] As a result of memo-ing, some questions on the interview protocol were adapted for clarity purposes. However, the nature of the questions remained the same.

After analyzing pilot data (fieldnotes and interviews) and the remaining Interview 1 transcripts, I developed a second set of semi-structured interview questions stemming from my memos and designed to explore emerging hypotheses. I conducted 15 one-on-one semi-structured follow-up interviews with all core group members[12] (see Appendices H & I: Interview 2 Protocols). The questions in Interview 2 focused on members' perceptions of faculty careers and self-assessments of their capabilities of being successful in faculty roles. The purpose of these interviews was to address any discrepant evidence from prior interviews or observations, search for disconfirming evidence, and obtain members' reflections on my emerging hypotheses. I continued to reflect and memo after each interview from the first and second rounds. Memo-ing changed over time as I was no longer reflecting on the nature of the interview questions but rather on the meaning of participants' responses. In addition, I was more aware of discrepancies among participants' answers and given the longitudinal nature of this study, the evolving viewpoints of individuals. Thus, during memo-ing, I was able to explore hypotheses about what students were learning, how they perceived faculty careers, and the mediating factors that were contributing to their intentions to pursue the professoriate.[13]

As in the pilot phase, all transcribed interview data and field notes were uploaded into the qualitative research software HyperResearch for coding and data management.

Data analysis.

Due to the longitudinal nature of data collection and the extent of data collected, I started the coding process after the first round of interviews. An advantage of analyzing data as they were collected is that I would be able to manage the volume of data resulting from interviews

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[12] One group member graduated and relocated. Thus, there is one less 2nd round interview than there is in the 1st round of interviews (i.e., 16 – 1st round interviews; 15 – 2nd round interviews).

[13] Throughout this study, I use faculty and professoriate synonymously. Additionally, the term "professoriate" is used to refer to tenure-eligible faculty positions, but not to academic positions such as research scientists or instructor/lecturer positions.

and weekly fieldnotes from observations. Another advantage of coding in phases is that I could ask clarifying and confirming questions in subsequent formal and informal interviews. The potential disadvantage of coding while simultaneously collecting data was that I might become convinced of the goodness of existing codes and understandings rather than remaining open to emerging understandings of student experiences in the research site.

I analyzed data relative to the three waves with which data were collected (i.e., after the Fall 2012 and Winter 2013 semesters (pilot), Spring/Summer 2013, and Fall 2013) (Figure 1 presents a visual of this study's Data Analysis Procedures). This helped me manage the volume of data, and develop preliminary understandings of what I was learning from my study. As a result, my understanding of what group members were learning about research and the engineering professoriate evolved as data collection and analysis progressed.

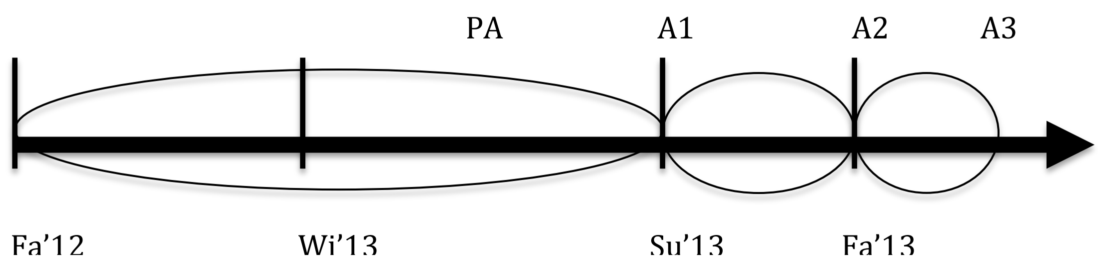


Figure 1: Data Analysis Procedures

PA = Pilot Analysis; A1 = Analysis 1; A2 = Analysis 2; A3 = Analysis 3

Pilot Analysis.

After seven months of data collection in weekly research group meetings, I had a small group of research team members willing to interview with me (i.e., the leadership team, one second year male doctoral student, and two first year male doctoral students). Although I had a small subset of the research group at this point, it was still important for me to make sense of the collected data[14]. I began reading typed fieldnotes and transcripts from interviews and reflecting on what I was seeing during observations and hearing from interviews with participants. These reflections resulted in initial understandings that could be treated conceptually rather than purely as descriptions of events and interactions. These are the kinds of theoretical memos that Fetterman (1995) suggests can identify what were initially thought to be unrelated issues within the data, and speculate on possible patterns that offer explanation of the phenomenon studied.

Analysis 1.

At the conclusion of the pilot study (i.e., Winter 2013 academic term), I began the first concerted wave of data analysis with all collected data from the pilot study. Like other scholars who employ ethnographic data collection methods (Emerson, Fretz, & Shaw, 1995; Fetterman, 2010), each wave of data analysis included grounded theory techniques; analysis began with open coding, inductively identifying chunks of data from my interviews and fieldnotes that captured important information about research group practices, students' interactions, and student learning. These chunks of data were identified by the repetitions of words, phrases, and ideas that appeared to address my research questions about the nature of research experiences, what and how students learn about research and the professoriate, and their intentions to pursue faculty careers.

After coding within individual interviews and fieldnotes, I used the constant comparative technique to determine whether codes were similar or potentially different across interviews and fieldnotes. This process was an iterative one and as a result, codes were expanded or collapsed to

[14] I was only able to interview a small number of the student group members during the pilot because it took time to build rapport with students (see "Reflections on a pilot study" section for more information). Also adopting the technique of judgment sampling (Fetterman, 2010), I needed time to determine which students would be most appropriate for interviewing (see "Pilot Study" section for more information).

form other codes. Next, I identified similar dimensions or properties across my initial codes and continued to compare and refine these dimensions (Merriam, 2009).

At this point, my analysis included data collected for an entire academic year. I ended this wave of analysis with a theoretical memo in which I reflected upon the patterns I identified during the coding process. For example, based on some of the codes that were identified (e.g., “seating at group meetings,” “power dynamics,” “group hierarchy,” “other research-related tasks”), I hypothesized how members’ engineering identities were developing based upon their levels and kinds of participation in the research practices of the group. I also noticed patterns related to the hierarchical nature of the group (e.g., how members’ participated in weekly group and subgroup meetings, members designated roles within the group, and where members sat within the group’s conference room). I speculated that students who were more engaged in the various group practices were also more likely to be interested in pursuing faculty careers than those whom did not participate in group practices at high levels.

During theoretical memo-ing I also took into consideration how my methodological choices during fieldwork influenced the type of data that I was receiving (e.g., adjusting interview questions to be clearer for participants, including drawing exercises as a technique to help participants better respond to questions, identifying those in the research group who should be furthered interviewed again).

Analysis 2.

After the summer 2013 term concluded, I engaged in the second main wave of data analysis. Recall that the between May and August 2013, students were engaged in their heaviest period of research activity, and several student group members supervised undergraduate students. While this period of data collection continued to focus on group practices (i.e., individual research in the laboratory, weekly group and subgroup meetings), the expectations for students to produce research results were greater. As a result, students were in the lab for longer hours, some students worked on multiple projects, and some even supervised other students within the group. Such differences in practices observed in the second round of data collection suggested that my analysis would have to account for the possibility of new understandings of research group practices, students' interactions, and student learning. Accordingly, I chose to continue to use open coding of new interviews and fieldnotes instead of engaging in selective coding (i.e., using existing codes and searching for data that fits within those parameters). Some of the existing codes from the first wave of analysis were applied to data during the second wave of analysis, but I remained open to new insights throughout the second wave of analysis. I was cognizant that the adjustments I had made to clarify my interview questions might have shaped interviewees' responses. In addition, after the post-pilot study, I was more focused in my observations on specific interactions between core group members rather than using the broad scope employed during the pilot. For these reasons, I could not rely exclusively on existing codes identified in the previous wave of analysis. Several new codes were thus identified during this wave of analysis.

As in the first wave of analysis, after open coding, I employed the constant comparative technique. This time, however, I took a different approach. I ran frequency reports – a function in the qualitative software Hyperresearch – to help see which codes were applied the most (and least) throughout the 10-months of analyzed data. After identifying the most frequently used codes, I engaged in constant comparison to make sure that codes were distinctly different. When a code could not be easily distinguished from another, I re-analyzed those data, and assigned a more appropriate label to identify the code. At this point I gained confidence that my study was reaching saturation as no new codes were identified in the data (Merriam, 2009).

Because the final wave of data collection and analysis would be focused on hypothesis testing and searching for disconfirming evidence, my theoretical memo-ing during this wave of analysis were more nuanced as I had more data with which to draw speculations. In preparation for theoretical memo-ing I employed additional analyses to aid in hypothesizing the data. Specifically, I looked for codes with the greatest intensity. By "intensity," I was looking for codes – and the quotes attached to these codes – that answered, shed light on, or complicated my research questions. For example, students confidently discussed their abilities to do research and participate in the research practices of the group. While looking for intensity, however, I began noticing that while not equal in the frequency of codes, students consistently described a concern for research practices for which they do not feel comfortable (e.g., grant funding, crafting a research agenda).

Since I was gaining deeper understandings of research group practices, students' interactions, and student learning, I wrote another theoretical memo to help the process of interpretation. This new theoretical memo forced me to recalibrate what I thought I understood about doctoral students' learning based upon the new information from interviews and fieldnotes, as well as the comparisons between data analyzed between the first and second wave of analysis. For instance, I speculated on the relationships between the intensity of codes (information that complicated the research questions) and the frequency of top codes (how often different constructs were mentioned). For example, what were the relationships between one of the most frequent codes "project management" and the intensity of "grant funding," or the frequency of the code "faculty interest" and the intensity of "gender or racial identity"? Pairing codes in speculative forms prompted me to interrogate the data and create hypotheses in preparation for the final wave of data collection.

Analysis 3.

After the final period of data collection, I had an additional month (September 2013-October 2013) of observational fieldnotes, and 15 additional interviews (second round interviews with core group members). I had chosen to observe the group after the conclusion of the summer because I wanted to see if and how existing student group members transitioned into their more senior roles in the team as well as how new student members transitioned into the group. In particular, I wanted to observe if new members' transitions were similar to or different from what I observed at the beginning of data collection in September 2012. I was willing to add new codes, but none were identified from fieldnotes. However, new codes were identified from the second round of interviews because the follow-up interview focused on members' self-assessment of their research skills and interests in the professoriate, topics that were not deeply explored in the previous interview. Again, I utilized the constant comparative technique to ensure that new codes were unique from existing codes and that they had their own defined properties.

Next I employed axial coding, which allowed me to create clusters of codes (i.e., groupings) by identifying relationships between and among codes. During this process, I looked for patterns across as well as dimensions within clusters until no new clusters could be developed. This constant refining of groupings depended on elaborating the relationships between codes in a cluster, the cluster as a whole, and how one cluster was related to another cluster. For example, "group meeting" and "subgroup meeting" could be considered separate clusters, with distinctive codes that helped describe the research practices that take place within the group and subgroups, as well as the research competencies that result from those meetings.

Thereafter, themes – resulting from grouping clusters – were created to help describe the major findings of this study, address the research questions, and to generate theoretical propositions (hypotheses) for future research (Corbin & Strauss, 2008). These propositions aided in the construction of a substantive theory[15] that helps to explain how engineering research groups influence doctoral students' learning and identity development and their aspirations to the professoriate.

Researcher stance and sensitizing concepts.

Because I believe that much of what individuals come to learn stems from how they make sense of their experiences and their social interactions with others, I take a constructivist research stance that privileges the meanings that my participants make of their experiences. However, sociocultural concepts served as "sensitizing concepts" rather than limits on how I analyzed and interpreted the data; I remained open to challenges or expansions to the sociocultural interpretation of the data. This stance is consistent with recent approaches to grounded theory that acknowledge we cannot bracket all of our prior experiences and knowledge in our research and must instead recognize when the data do not fit our framing theories and thus put the theory aside (Corbin & Strauss, 2008).

Sociocultural theories stress the critical role of contexts in the learning, and the impossibility of separating the experiences of individuals from the contexts in which those experiences occur. Some sociocultural theorists therefore define the unit of analysis in sociocultural studies as "person-in-context" to express this inescapable interaction (Cobb, 1994;

[15] Substantive theories produce mid-range theories that are based on a limited number of observations.

Shanahan, 2009). Consequently, the experiences and understandings of my focal students (i.e., core group members) must be understood as resulting, at least in part, from their experiences in the research group and in relation to the experiences and understandings of other students of the research group.

Choosing participant pseudonyms.

Given the racial and ethnic diversity of this study's participants, a major consideration related to choosing participant pseudonyms. I considered several factors in this process. While I wanted to provide authenticity by choosing names that would honor the culture of participants, I did not want to compromise the confidentiality of study participants. I also considered allowing participants to choose their own names. But I did not want to suggest to participants that they would be the focus of the study.

Ensuring quality.

Ethnographic work lends itself to several validity strategies. First, engaging in fieldwork for an extended period of time allowed me to gain the trust of participants, which facilitated formal and informal data collection and enhanced the quality and depth of data. I was also able to observe patterns of behavior, change, and even consistency in participants because of the time spent working in the field. Second, by taking extensive fieldnotes and transcribing interviews verbatim, I was able to provide thick descriptions and quotes, giving power to the voices of my participants (Fetterman, 2010).

Third, I collected and analyzed multiple sources of data (e.g., observations, formal interviews, casual conversations) and triangulated findings. Triangulation allowed me to bring several sources of data to bear on key experiences and build explanations from these sources of information (Merriam, 2009). This was particularly helpful when I received discrepant or disconfirming evidence of research group practices, students' interactions, and student learning (Merriam, 2009; Patton, 2002). Finally, I employed several steps to ensure accuracy of the data. For example, I typed and expanded upon my hand-written field notes immediately following each observation. I also wrote a memo after each formal interview. The goal of all of these strategies was to gain a deeper understanding of students' research experiences and learning about both research and the professoriate through their work and interactions in the research group.

An audit trail was used to make the study procedures transparent (Merriam, 2009). Before, during, and after engaging in fieldwork, I wrote memos and reflections detailing the decisions I made. This audit trail allows future researchers to learn from my decisions, bypass my mistakes, understand how this study was conducted, and conclusions drawn.

Limitations of the study.

There are many characteristics that make research groups different (e.g., faculty supervisor's orientation to research, number of students in the group, student composition of the group, departmental and institutional policies). Thus, because this study examined only one research group, it is not evident if this group is an exemplar and its research practices are best practices for preparing students for faculty careers. However, since the goal of the study was to generate propositions for future research, concerns about the representativeness of the research group was less of a concern than it would be in a study with different goals, such as defining exemplary practice.

Observations and interviews focused on what members considered the dominant research practices of the group. There may have been additional contexts where learning about research and the professoriate took place that I did not examine, for example, students' learning in the classroom, interactions with networks outside of the research group (e.g., friends, undergraduate mentors, alumni), or other contexts in which faculty work might be evident or discussed (e.g., doctoral student orientation, graduate teaching assistant training).

Most of data collection involved observing group meetings and interviewing with student members of the research group. More interview time with the research supervisor would have made his intentions in promoting particular research group practices evident.

A final limitation is related to the time frame in which I collected data. While I was able to formally and informally interview students over 13-months, I was not able to longitudinally follow students from entry into graduate school to graduation to fully understand how their understandings of and intentions regarding careers may have changed over time, for example, students' career interests at the time they entered their doctoral programs and how they might have changed over the duration of study. In addition, by the end of data collection, I cannot confirm whether or not students will act on their stated intentions to enter either industry or the professoriate. My intention is to continue this study longitudinally after the dissertation period.

Role of the researcher.

In qualitative research, an attitude of **r**eflexivity encourages the researcher to be aware of how his or her "worldview" can shape all aspects of a study (Merriam, 2009). A reflexive attitude can elucidate biases that may affect the researcher's interpretations of data. For instance, there were several assumptions that influenced how I approached this study. As a doctoral student myself, I was aware that there may be students in the research groups who did not share my understanding of graduate school, research, or career possibilities of doctorate holders (e.g., faculty, industry, administration, policy). Also, as an advanced doctoral candidate, I was conscious of the challenges of participants in the earlier stages of the doctoral process. This was especially true when considering times to interview. Students in earlier stages were taking classes in addition to their research responsibilities; as the researcher, I had to adjust to participant's schedules to ensure my ability to gain access.

My own identities also influenced how I viewed the participants of the study. First, in science and engineering fields, it is common for students to enter doctoral programs immediately following their undergraduate studies. Thus, several of the participants in the study were younger than me. Acknowledging our age differences, and reflecting on my earliest years in graduate school, I was able to understand participants' uncertainty of their future career goals. Second, my interpretations of international students and how they make sense of their academic experiences were shaped by my citizenship status. Acknowledging my American culture around schooling, I did not assume that international participants' shared the same perspectives. The semi-structured nature of interviews allowed me to ask questions until I had a better knowledge understanding for how one's country of origin, culture, schooling, and goals shaped participants' thinking about career choice. Additionally, there were language barriers that affected my communication with some international student participants. By being patient when communicating, and using drawing exercises during formal interviews, I was able to engage in mutually rewarding dialogues. Finally, I was cognizant that while there could be common experiences shared between the Black group members and myself, I did not assume that the Black participants' experiences mirror mine simply because we share the same race.

Being both cognizant and reflexive about my identities encouraged me to consider when and how my subjectivity came into play (Peshkin, 1988) and to acknowledge and try to control these biases and assumptions during observations, interviews, and data analysis. Throughout this study, I continually reflected how my position as researcher, both emic (insider) and etic (outsider) affected the quality of data I collected (Cooper, Jackson, Azmita, and Lopez, 1998; Fetterman, 2010; Merriam, 2009).

Although it is normal to have some influence on the research environment, especially longitudinal qualitative research (Fetterman, 2010), the goal for researchers is to minimize their influence on participants and the environment. I tried several strategies to limit my presence and potential influence on the group. For instance, during weekly group meetings, I sat in the corner of the conference room as to not seem like an integral member of the group (the exception to this was my first day of observation when I did not know what to expect, how many people would be in attendance, and thus, did not know where to sit). I also attempted to blend in with how students dressed; jeans, t-shirts, and Model University apparel. With all of these strategies, my goal was to be as inconspicuous as possible. For the most part, being inconspicuous worked; by the end of 13-months of data collection, some students admitted that they assumed I was a regular member of the research group. Because this study is ethnographic, and part of my methods included interviewing, students routinely asked me what I was learning about the group, and I sometimes caught them discussing topics from our interviews with fellow group members.

Chapter 4: SETTING, RESEARCH PRACTICES AND COMPETENCIES DEVELOPED

The Setting

The focus of this study is on one research group – and the student members[16] within this group – embedded within the chemical engineering department in the School of Engineering at Model University. In this chapter, I introduce the research group (from this point forward referred to as the "Houston Group") that is central to this study. Before describing the group and its various contexts in which students in the community work and learn, I set the stage by describing the academic environment that gives rise to the practices and activities of the Houston Group. This chapter will thus address my research questions on the nature of the research experience, and doctoral students' learning about engineering and the professoriate.

Model University, the School of Engineering, and the Chemical Engineering Department.

The School of Engineering at Model University is consistently considered as one of the Top 25 engineering schools by the U.S. News and World Reports. In the 2012-2013 academic year, student enrollment in the School of Engineering was approximately 6,500, which included almost 5,000 undergraduates and nearly 1,500 graduate students (master's and doctoral).

The well-established practices of the School of Engineering guide the activities of the Houston Group. Specifically, all graduate students are expected to participate in a research group starting in their first year of study and throughout their graduate career. By graduation, students

[16] From this point forward, I use "students" and "members" interchangeably to denote the student members of the Houston Group.

at Model University's School of Engineering will have spent more time engaging in research than they have in coursework. Acknowledging the ratio of research experience to coursework reinforces the reputation that students who graduate from Model University are experts in their respective area of research.

The Houston Research Group is part of the highly ranked chemical engineering department. The department has a storied history, dating back over a century. Like Model University, the chemical engineering department is internationally known for producing cutting-edge research. In addition, their graduates serve as leaders who influence the engineering workforce, solidifying the national and global reputation of the chemical engineering department at Model University.

The emphasis on the development of research skills is also clear in the departmental graduation requirements. In addition to working in research groups throughout their doctoral tenure, chemical engineering students are expected to publish at least one scholarly, peer-reviewed work and present at a conference. Most students of the Houston Group will have multiple publication and conference experiences upon graduating. Preparing for conference presentations and writing strong papers is a staple activity of the Houston Group, often resulting in group members winning "best student presentation awards."

While much focus at Model University is on doctoral students' mastery of research, the chemical engineering department also requires that each student serve as the graduate teaching assistant for one undergraduate course. With so many students teaching for the first time, the university – and the School of Engineering – established a Learning and Teaching division that prepares and supports graduate students through their teaching experience. This teaching requirement can be completed at any point before graduating, however, many Houston group members fulfill the requirement while balancing coursework and research obligations.

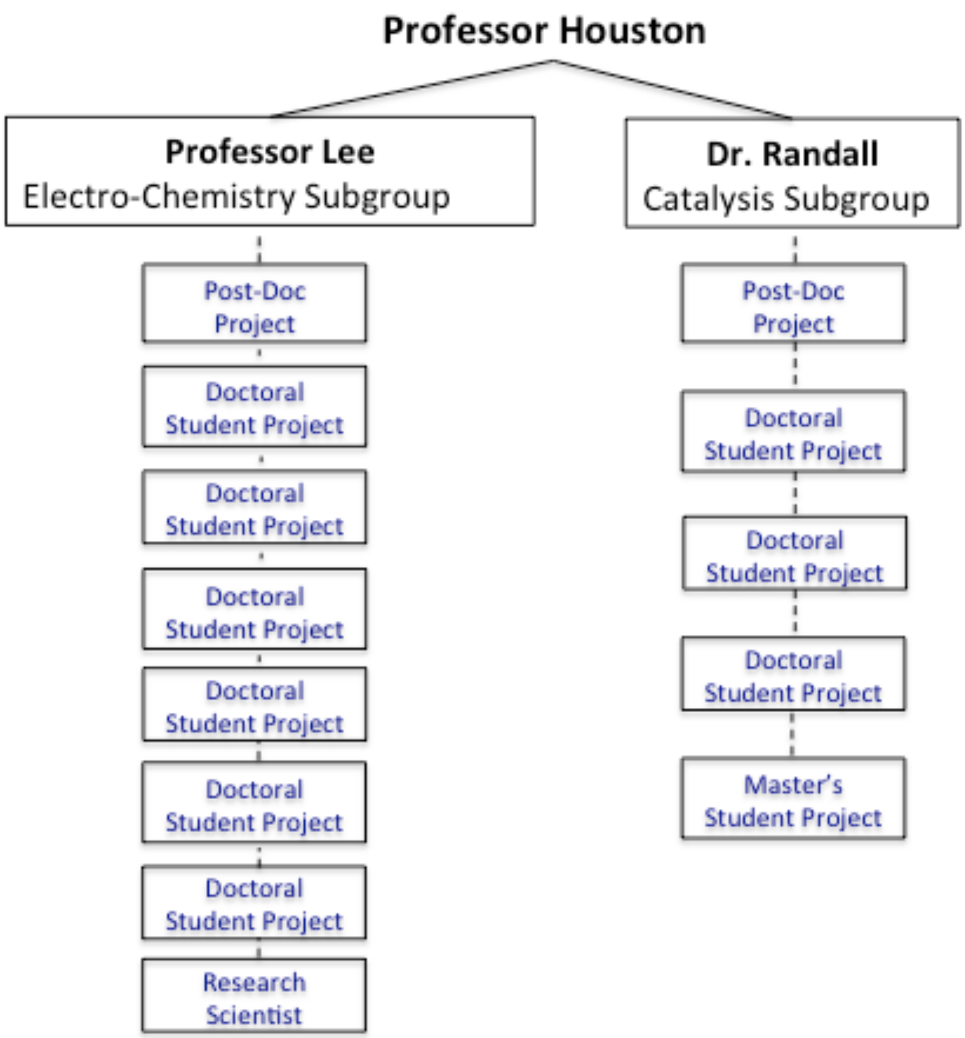
The Houston Group.

The study of climate change, land conservation, and sustainable energy are part of a research agenda aimed at reducing our dependency on fossil fuels. In fact, during President Obama's administration, increased research efforts seek to better understand – and improve our capacity to utilize – renewable alternative energy sources such as wind, water, and sun (White House, 2011). While there are many in research and industry sectors whom have taken on the challenge of addressing our needs for alternative energy, chemical engineers are one set of players involved in leading the charge and creating viable options towards sustainable energy. Chemical engineers combine their knowledge of materials with the practice of developing useful products. The Houston Group is a research group that has been focusing on renewable alternative energy sources for decades. It is considered a leading group in this research area based on the quality of work (evidenced by the group's publication record), research grants, and number of graduate students in the group.

Organization of the Houston Group.

The 20-person Houston Group is organized around student members' research projects. Under the leadership of Professor Houston (research supervisor and students' academic advisor), Professor Lee (professor emeritus of chemistry working part-time with Professor Houston), and Dr. Randall (lab manager and alum of the Houston Research Group), students are divided into two subgroups based on the processes, methods, and techniques they use to improve the performance of alternative energy sources to reduce reliance on fossil fuels. Within these subgroup affiliations, each student works on an independent research project – loosely related to others in their respective subgroups. Yet, each project is related to Professor Houston's overarching research agenda. For the purposes of this study, "Subgroup A" studies electro-chemistry[17] and "Subgroup B" focuses its research activity on catalysis. [18] Figure 2 (below) depicts this organization.

Figure 2: The Houston Research Group[19]



[17] "Electro-chemistry" refers to a process of storing energy for longer and more efficient performance.
[18] "Catalysis" refers to a technique of quickly converting one form of energy into another.
[19] This figure includes only the core group members. Visiting scholars and undergraduate summer researchers are not included in this figure because they are short-term and transient.

Table 1: Profile of Study Participants

Pseudonym	Status*	Co-Advisement	Teaching Experience	Career Intention+
Leadership Team				
Professor Houston	Research Supervisor			
Professor Lee	Professor Emeritus/part-time			
Dr. Randall	Lab Manager			
Core Group Members				
Lloyd	Post-doctoral researcher	N/A		Uncertain
Emma	Post-doctoral researcher		X	Industry
Brielle	Ph.D. graduate, industry worker		X	Industry
Gloria	Fourth year Ph.D. student	X	X	Uncertain
Tiffany	Fourth year Ph.D. student		X	Uncertain
Allen	Third year Ph.D. student			Faculty
Erik	Third year Ph.D. student		X	Industry
Danny	Fourth year Ph.D. student		X	Industry
Sherman	Second year Ph.D. student	X		Industry
Vince	Second year Ph.D. student	X		Uncertain
Ralph	Second year Ph.D. student	X		Faculty
Louise	Second year Master's student		X	Industry
Kelcy	Engineer	N/A	N/A	Industry

* "Status" refers to a member's academic status at the end of data collection
+ "Career Intention" refers to member's career intentions (or uncertainty) at the conclusion of data
collection

Biographical sketches of the Houston Group.

The brief biographies below describe the core members of the Houston Group (Table 1), beginning with the leadership team and post-doctoral researchers, and then moving to the doctoral students (candidates and pre-candidates) and other group members (e.g., master's students). Those included below were present when data collection began in Fall 2012 and played a consistent role in the group's interactions and operation.

Leadership Team.

- The Houston Group is led by *Professor Houston,* a full professor who holds a named chair in chemical engineering, who has received numerous national research awards and University and School of Engineering awards for teaching excellence. In addition to his faculty career, Professor Houston also owns a private engineering company.
- *Professor Lee* is a professor emeritus of Model University's chemistry department. Being retired, Professor Lee works part-time in Professor Houston's private company and with the Houston Research Group. In the group, he primarily works with the students in the electro-chemistry subgroup, but he also provides research support to all students at the group meetings, and helps to manage the group when Professor Houston is away.
- *Dr. Randall* is the lab manager; he and Professor Lee lead the group when Professor Houston is away on travel. As an alumnus of the

Houston Group himself, Dr. Randall answers students' research questions, signs off on equipment purchase requests, and provides career advice to students. While much of his time is spent in the research group supporting Professor Houston, his primary job is to direct Professor Houston's private company.

Post-doctoral researchers.

- *Lloyd* is a post-doctoral researcher who started working with the Houston Group in Fall 2012. Prior to that, he held a post-doctoral position at an American automotive company. Lloyd has participated in research (both independent and collaborative) since earning his Ph.D. in December 2010 from a top-75 engineering school.
- *Emma*, an alumnus of the Houston Group, earned her Ph.D. from Model University in spring 2013 and then transitioned into a post-doc role in the Houston Group. She came to Model University as an international student who previously held a full-time industry position at a well-known automotive company. When she started her Ph.D. in 2007, Emma was the only woman in the Houston Group.

Advanced doctoral students (candidates).

- *Brielle* is an international student and by the end of data collection had earned her Ph.D. At the beginning of data collection, Brielle was one of the senior-most and most well-respected members of the group. She was routinely described as a "leader," "scholar," and "expert." Upon graduating, she began a career in a global electronics company.

- *Gloria* is a candidate who, because she is co-advised by Professor Houston and another professor of engineering, splits her time between two lab groups. In the Houston Group, she volunteered for the leadership role of safety officer, a position usually reserved for the senior-most students. She is passionate about outreach efforts to improve participation of women and underrepresented minority students in STEM fields.
- *Tiffany*, also a doctoral candidate, is a member of Gloria's cohort. Tiffany holds two undergraduate degrees, one from Model University in chemical engineering and another in mechanical from her home institution in China. As an undergraduate at Model University, Tiffany participated in research with the Houston Group.

Doctoral students (pre-candidates).

- *Allen* is an international student who came to the United States to pursue higher education. Upon arriving in the States, he attended a community college in the south, and then transferred to an Historically Black College and University to complete his undergraduate studies in chemical engineering.
- *Erik* is a member of Allen's cohort. Both of Erik's parents have Ph.D.s in organic chemistry and work in industry. He is considered the group's "handyman" because of his ability to fix faulty equipment. He also informally helps acclimate new members and visitors to the group. As

the group's jokester, Erik has developed a playful (yet respectful) relationship with Professor Houston.

- *Danny*, a Black male, is also an international student who attended a prestigious liberal-arts-focused research university in the U.S. for his undergraduate studies. Based on the number of years in graduate school, Danny is an advanced doctoral student, but because he switched to the Houston Group to gain hands-on experience, he is classified as a pre-candidate.
- *Sherman,* who transitioned from first to second year student during data collection, worked full-time in industry prior to beginning graduate school. He attended a private technology-focused university for undergraduate studies in chemical engineering.
- *Vince* is a member of Sherman's cohort. Vince is co-advised by Professor Houston and another professor of engineering. As an undergraduate at Model University, Vince participated in summer research experiences in engineering and was involved in a student organization advised by Professor Houston, which is how he connected with the Houston Group.
- *Ralph,* an international student, is also co-advised by Professor Houston and another professor of engineering. Both of Ralph's parents have graduate degrees from U.S. institutions and both parents work in academe.

Other group members.

- *Louise*, a master's student in the Houston Group, is an international student who collaborated on research projects at the beginning of data collection in order to help her decide on whether she wanted to pursue the Ph.D. upon graduation.
- *Kelcy* was originally hired to work on commercial spin-off projects in Professor Houston's private company. But at the end of data collection he described himself as working part-time in the private company and with the Houston Research Group. Kelcy participated in undergraduate research before receiving his bachelor's degree in mechanical engineering. He indicated that he is not interested in graduate education, and anticipates remaining in industry.

Group research practices.

During data collection, I observed students engaged in various research practices that contributed to graduate students' development of specific research competencies and professional identities. The Houston Group's research practices were in large part influenced by policies and expectations of Model University, the School of Engineering, the chemical engineering department, and the engineering field. As suggested earlier, the dominant practices included participating in individual research projects within the lab, and weekly group and subgroup meetings. Before describing the competencies learned within these dominant practices, I discuss the various research practices in which Houston Group members engaged. While graduate students surely learn in other places and through other practices, the focus of my analysis is the learning that occurs within the dominant research practices within the group.

Dominant research practices.

Individual research projects in the lab.

Professor Houston and other members of the leadership team agree that students need to learn how to independently do research. Professor Lee claimed that the Houston Research Group is not based on an apprenticeship model where students learned by imitating their faculty advisor. To encourage students' independence, all core group members have individual research projects that requires that they "get their hands dirty."[20]

The work of the Houston Group is "experimental research"; students spend a significant amount of time in the lab mixing, combining, and extracting elements from chemicals to find the right balance that will make future materials more efficient. Students receive feedback from their research supervisor, Professor Houston, and other group members during weekly meetings. Following these meetings, they return to the lab to continue working or making adjustments to their experiments[21]. In fact, when students are not in group meetings, subgroup meetings, or classes, they are in the laboratory running experiments or analyzing their data. Many students use more than one lab for

[20] There was an exception at the beginning of data collection whereby the incoming first year doctoral students started by collaborating on a similar project, then after the first semester, they branched off into more nuanced independent projects.

[21] All Houston group members are required by the university to complete a series of safety trainings. At the minimum, these trainings include certification on lab safety and blood-borne pathogens. Students are also required to learn about the emergency procedures for the lab facility and the building (largely because of the pressurized rooms, gases, and the possibility of lab explosions).

their works, which are organized primarily by types of available equipment[22]. A student would use more than one lab if equipment needed to complete his or her experiment was located in different labs. The work students do in the lab is largely self-guided.

The leadership team strategically takes a hands-off approach to members' day-to-day research activity. Dr. Randall, the lab manager, described the practice of creating independent researchers, highlighting students' leading their projects, making choices to get research results, and learning the steps for seeking help:

> Yeah, working in the lab – they are on their own. So pretty much they have to plan things or be able to plan things, order stuff they need, plan the experiment so that it's…But also these students all work in the lab, and whenever they need anything they would probably go to somebody they are comfortable with, and then if not they would come to me, and then ultimately up to Professor Houston if they get stuck. So they are kind of learning how to first overcome those issues, and then learning to work with other people as a team, and I guess better communication as well. (Dr. Randall)

Group meetings.

Engineers often have to justify the significance of their work, defend the accurateness of their findings, and substantiate the soundness of its applicability to broader contexts. The development of such skills takes place in group meetings. During the period of data collection, these meetings occurred weekly and all group members were expected to attend unless they had a class conflict. Typically only undergraduate students, first and second year graduate students, and students who were serving as graduate teaching assistants would have such conflicts. The group meetings included general announcements, followed by two conference-style 20-minute presentations by

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[22] The Houston Research Group utilized three lab spaces. Two of the spaces were on the same floor in a newly renovated building. As such, the equipment in those spaces were newer (e.g., pressurized room, temperature control, glove boxes). One student suggested, "everything is new" in the renovated rooms because the new lines of funded research (Subgroup A – Electrochemistry) required more students working on the funded projects, which also required more workspace. In the other lab space (which is located in a different, albeit nearby building), "everything is old[er] there," and fewer Houston student group members worked on that line of research (Subgroup B – Catalysis).

group members. After each presentation, Professor Houston opened the floor for 15-minutes of constructive criticism where members offered the presenter feedback on content, delivery, and other substantive issues. Presentations regularly went over the allotted as group members provided constructive criticism to presenters. Given the number of members in the group and the frequency of presentations, each group member presented their research at a group meeting three to four times per semester.

According to Professor Lee, because of Professor Houston's emphasis on students developing their skills in research communication, they were better able to defend their work within the engineering field:

> The Houston Group, particularly I think, devotes a lot of time to meetings and it's clear that there's an instructional purpose to that. And you've seen enough of these meetings to know the style very well. And the style is a little bit aggressive on Professor Houston's part as you've seen and I think that's intentional. He's teaching people to be able to stand up to the tough question or even the badgering questions at times. And you've seen him use this technique, which is stylistically quite different from my approach when I had a group, but he has a certain motivation for doing it the way he does it. And there's some difference between engineering and other disciplines. An engineer has to be able to answer for the things he's carrying an opinion about because things depend on it; a designed plan or a design of a plan, it's got to work. So that kind of questioning I think does serve a purpose and it's clearly deliberate. It also gives students practice in defending themselves verbally and in the presence of a group. So there's a lot of benefit there (Professor Lee)

By contrasting the Houston Group with the group he ran before retiring, Professor Lee offered insights into why the Houston Group was designed as it was. He argued that engineers needed to be experts who can strongly defend their research to an audience. Brielle, one of the senior-most Houston group members echoed Professor Lee's assertion that the group's rigorous meeting schedule helped to deepen members' understanding of their individual research and the collective work of the group: "When you go out and present your stuff, there is a huge distinction from a person who presents from our group versus from somebody else's [group] and it comes from all the crazy stuff that you get to face here…" Brielle made the observation that the depth and breadth with which students could explain their lines of research distinguished them from colleagues in other groups at conferences. It was these practices – relative to her peers in other groups – that allowed her to comparatively assert that the Houston Group practices were "crazy stuff." Vince, who was a member of two research groups, echoed Brielle's comments. He, too, agreed that it was the practice of weekly meetings that distinguished the Houston Group from his other research group. Further, he believed that because of the regular meetings, he better understood the work of other students in the Houston Group, which helped him to better situate his project within the group's larger research agenda.

Subgroup meetings.

Unlike the weekly group meetings where the emphasis was on students' oral presentation skills, the weekly subgroup meetings allowed Houston student group members to receive consistent feedback on their work-in-progress. At these smaller meetings, where members are grouped by their research projects, students sat at the conference table and one-by-one described their activities and progress during the previous week. Briefings typically included on two to three Powerpoint slides. Sherman, a second year doctoral student, stated: "[at] subgroup meetings you come in and give maybe a 5-10 minute presentation on what you've been working on for that week, and there is some give and take." He further explained that giving briefings of one's work at subgroup meetings helped to "keep yourself in check to make sure that you have done something that week."

Whereas, the group meetings were about presenting one's good and/or compelling results, in subgroup meetings Houston Group members admitted to their current difficulties and garnered help:

> The subgroup is really airing all of your dirty laundry; the main group [meeting] is more like a formal presentation and we only do two of them [two students presenting at each group meeting]. So at the subgroup, everybody says something, everybody is supposed to bring some data or something to the subgroup for our analysis. The thought is that by having more people look at it than just me, what's that saying, "Two heads are better than one." It's always better to have other people – even if they don't offer that much there is something they might offer and they might learn something. We have some younger students who learn techniques. (Professor Houston)

In the quotes above, there is a clear utility for meeting on a weekly basis; students in the subgroup are able to get feedback on their work, which helps to guide their research activity during the upcoming week. Professor Houston also emphasizes group members supporting one another rather than relying only on feedback from him as the advisor. Professor Lee suggested that because of this emphasis, students gained confidence in their abilities to do research: "they help each other (in the best situations at least) and they learn from each other and that exchange, I think, is essential in part of this gaining confidence…" Professor Houston's perspectives on support and confidence-building align with his use of the subgroup structure as a mechanism for teaching moments; all members were expected to contribute in the teaching and learning process. Or as he explained, "two heads are better than one."

Related group research practices.

Presenting at conferences.

Presenting one solo or lead-authored research paper at a peer-reviewed conference is a graduation requirement for chemical engineering graduate students in the School of

Engineering. All Houston Group members were also required to report at the following group meeting a brief summary of what they learned. This practice of sharing knowledge from conferences set the expectation that members will not only attend conferences, but will be active participants who bring knowledge back to the group to inform its collective research.

Out-of-Lab-Gatherings.

Attending these gatherings – including but not limited to holiday and summer parties at Professor Houston's house and going-away celebrations – provided additional opportunities for group members to informally interact in ways that did not necessarily occur while working in the lab environment. Out-of-lab gatherings provided the space for recognizing accomplishments of student group members (e.g., graduating, securing a job), and the collective achievements of the research group (e.g., productivity, publications, grants). It is understood – and sometimes explicitly expressed – that at these gatherings, attendees minimize work-related conversations and have fun. Thus, these gatherings reinforced the notion that there is a time to work and to play; that one can and should have work-life balance, at least once in a while.

The Houston Research Group: Research Practices and Competencies Developed

Through extensive observations of and interviews with students in the Houston Group, I identified 11 research competencies that illustrated the skills students were developing through their participation in and interactions with others in their research experiences (see Table 2 for the definitions of the research competencies described in this chapter). I submit, however, that in both weekly group and subgroup meeting contexts (where I spent a majority of my time observing), the purpose was to teach students about – and assess their abilities to conduct – quality research.

In the sections below I describe each competency including how members' acquired the skills (see Figure 3). The competencies are not mutually exclusive, but each competency contributes to the skill set for students.

Table 2: Houston Group Research Competencies

Research Competency	**Definition of Research Competency**
Solving Problems	Implementing an overall strategy that guides the group's research
Troubleshooting Problems	Iteratively (and sometimes collaboratively) working through day-to-day problems encountered in ongoing research projects
Managing Projects	Balancing tasks to make progress on one's research project
Consulting with Peers	Exchanging knowledge with others in efforts to advance one's research progress
Briefing Research	Providing short and concise updates on one's research progress
Presenting Research	Explaining one's research in accessible ways to a broad audience
Receiving and Responding to Feedback	Giving, receiving, and responding to criticism related to one's research
Contributing to Lab Operations	Performing tasks and responsibilities that help the group efficiently and effectively run
Building Equipment and Taking Inventory	Assessing the research needs (e.g., chemicals, materials, equipment) of the group or one's individual project, and when necessary, assembling equipment
Maintaining the Lab	Keeping the laboratory and equipment safe and properly functioning
Supervising Members	Guiding and mentoring the research experiences of other group members

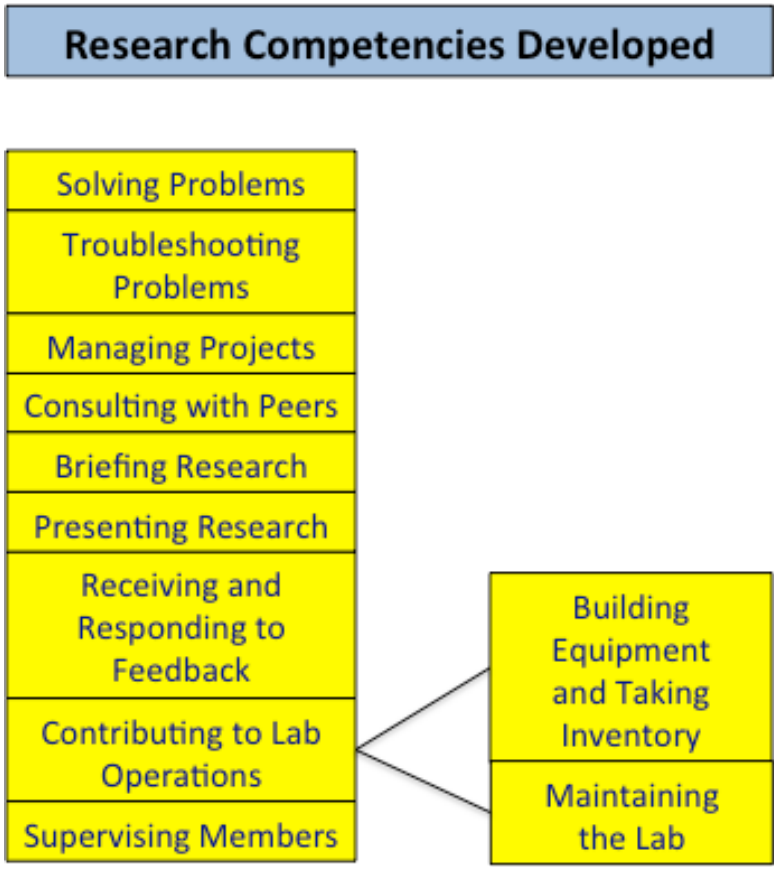

Figure 3: Houston Group Research Practices and Research Competencies

Solving problems.

Engineers are hired and expected to identify and solve problems (Anderson, et al., 2010; Jonassen, 2013). Solving engineering problems requires understanding of engineering concepts as well as professional standards (and, potentially, ethics) (Jonassen & Hung, 2006). Because experiential practice in problem solving – at the undergraduate and graduate levels – prepares students for the types of work they will do upon entering the workforce (Jonassen & Hung, 2006; Shin, Jonassen, & McGee, 2003), developing the skill of problem solving is one of the most important competencies for engineering graduates.

There is consensus that problem solving is what engineers do and that students need “experiential” hands-on practice – rather than classroom and textbook simulations – to develop this skill. Scholars (Sheppard et al., 2008) have defined problem solving (and the various forms it takes) in order to better understand the skill and how to improve students’ learning of it. For example, authors (Jonassen, 2013; Jonassen & Hung, 2006; Shin, Jonassen, & McGee, 2003) argue that problems presented in engineering textbooks and classroom settings are often formulaic, solvable, not practical, and thus considered “well structured” problems. In contrast, “ill-structured problems” are complex problems which require a host of considerations and possible solutions based on context, ethics, and involved constituents, which make them more aligned with the types of work students will encounter upon graduating and working in engineering careers.

In his synthesis of research, Jonassen (2013) asserts that problem solving is not practiced in isolation, but rather that “problem solving knowledge is distributed among team members” (p. 108). This perspective on engineering problem solving suggests that learning is an interactional process that (sometimes) occurs while participating with others in a team, and is shared by scholars such as Tonso (2006) and Anderson et al. (2010). Collectively, the authors (Anderson et al., 2010; Jonassen, 2013; Tonso, 2006) assume that the nature of teamwork and the types of engineering problems solved require engineering students to be interdependent. This form of team-based problem solving, according to Tonso (2006) helps students to better understand how their contributions fit into the larger effort, and helps students learn how to negotiate and navigate multiple personalities and work styles. Although Tonso’s (1999, 2006, 2013) work focuses on undergraduate learning in engineering design teams and Anderson et al. (2010) examines professional engineers across six firms, their larger arguments suggests that identifying with, and learning to be, an engineer (or as Tonso describes as adopting an "engineering campus identity") happens as individuals participate in engineering work with others (e.g., problem solving vis-à-vis a design team). Thus, one's identification with the engineering profession is tied to doing the work of engineering, which is generally classified as engaging in problem solving.

In the current study, problem solving appeared to be one of the central competencies germane to learning about research and how to be an engineer and scientist. The nature of the research conducted by Houston team members typifies the "ill-structured" problems described by Jonassen (2013), Jonassen and Hung (2006), and Shin, Jonassen, and McGee (2003). Student group members engaged in addressing the larger "problems" of improving battery efficiency, which relates to the goals of identifying sustainable and utilizing alternative energy sources. Many students in the Houston Group understood the importance of the problem-solving competency within their group context and within the larger field of engineering. Danny, an advanced doctoral student, suggested that "the whole field [of engineering] is problem solving and it's the way you think about problems and how you approach problems." He asserted that those who have difficulty in engineering are those who cannot solve challenging problems. Later he expressed his views of problem solving as a scientific and technical competency that was developed over time:

> …your first year, you're given a problem and you think "oh this can be solved" because I'm used to solving problems from the book and a lot of them are solvable. But you begin to see reality of what the real thing is and you have to evolve so that you can actually deal with the reality of "some of the problems are not very practical as you can see from the book." So the whole perspective changes and you begin to see the fuller picture of how science and engineering

works. (Danny)

Danny contended that problem solving competence is not mastered after a year of research experiences. The research process is arduous and may include many missteps and failed experiments. The research experiences in the Houston Group provided the space and opportunities for experimentation, failure, and growth of this competency.

Troubleshooting problems.

Unlike problem solving, which refers to the "big picture" strategy that guides a group's research work, troubleshooting focuses on attending to the day-to-day process of running the Houston group's experiments. In both the full group and subgroup contexts, troubleshooting was intended to achieve a similar outcome, demonstrate students' research progress and ensure students produce credible work. I characterized students' activities such as interrogating literature, considering societal issues, running experiments, and analyzing data as troubleshooting because these are the operational tactics students used in everyday conduct of their research. This definition is consistent with Jonassen's conceptualization (Jonassen, 2000 & 2013; Jonassen & Hung, 2006). Jonassen (2013) asserts that troubleshooting tends to be procedural, task-based, and often times is not transferable to other situations unless careful instruction is made to help students link what they are learning to other tasks. Jonassen and Hung (2006) also define troubleshooting as a cognitive task whereby individuals "isolate faults in systems and repair or replace the faulty components in order to reinstate the system to normal functioning" (p. 78). They further suggest that to troubleshoot, individuals must have various forms of domain knowledge (e.g., engineering properties), system or device knowledge, procedural knowledge (to be able to perform diagnostic tests), and strategic knowledge to iteratively search for potential solutions. Finally, the authors state that the cognitive process of troubleshooting illustrates a "shift from conceptual understanding of the system to an experiential understanding of the process" (p. 189). The designation from conceptual to experiential understanding is an important distinction because several scholars critique students' abilities to problem solve (Jonassen, 2013; Jonassen & Hung, 2006; Shin, Jonassen, & McGee, 2003), particularly because faculty in engineering classrooms tend to present "well-structured" problems that are formulaic and easily solved (Jonassen, 2013).

In the present study, the troubleshooting competency was observed in two contexts, the Houston team's full group meetings and in subgroup meetings. While I intend to emphasize how troubleshooting took place in the Houston Research Group as a whole, I offer some distinctions to demonstrate the dimensions of the troubleshooting competency. In weekly group meetings involving the full team, troubleshooting occasionally occurred when student presenters made consistent mistakes, for example, when Professor Houston noticed an underlying error in methodology or experimentation. He would then intervene, breaking the traditional presentation structure to help students work through the mistake, so that other students could learn from the presenter's error and avoid similar ones. In other instances of troubleshooting (at both full group and subgroup meetings), Professor Houston asked students to go to the white erase board – or he would go to the board himself – to draw an image of a student's machine, model, or even the formula used to arrive to a specific calculation included in the briefing or presentation. In all occurrences, Professor Houston seemed to make the occasional troubleshooting instance a teachable moment to help the presenter see where his or her mistake lay, while everyone was gathered together and students in the audience could learn from the presenter's error and avoid similar ones.

In contrast, when students ran into problems associated with their individual research projects that they could not figure out on their own, they brought their issues to the subgroup meetings where others could suggest ways to address the specific problem. In subgroup meetings, students were encouraged to admit when they did not know something, because in this context, fellow subgroup members were expected to help each other resolve issues. In the subgroup meetings, it was more common for students to ask a question or offer a suggestion rather than challenge the person giving the briefing; the goal was to understand the process and to figure out where a peer's approach went wrong. Because the subgroup meetings were organized according to the methods employed and lab equipment utilized, troubleshooting in subgroup meetings tapped individuals' research expertise. In addition, because the subgroup meetings are smaller than the group meetings, troubleshooting in subgroup meetings involved greater student-to-student interaction. The smaller meetings also seemed to allow some of the shy or soft-spoken members of the Houston Group to assert their expertise. Finally, the subgroup meetings seemed to encourage students to build collegial relationships based on similarities in their research projects, the equipment used, and specific knowledge of one another's project progress. The intimate nature of the subgroup meeting design promoted greater interactions across students, highlighting a key contrast between troubleshooting in the group meeting.

During one subgroup meeting in the fourth month of data collection, I observed members engaged in troubleshooting. The subgroup meeting on this day was pretty typical in that students spent time going around the room trying to help troubleshoot fellow subgroup members with challenges they encountered in their research. One student in particular, Tiffany (a third year doctoral student), became the central focus in the meeting because of her persistent concerns about her equipment and the findings she was presenting.

Fieldnote Excerpt 1 (Month 4):

> Today's subgroup meeting is the first meeting of the new calendar year (January 2013). As subgroup members entered and were accounted for, the updates started with Erik, then Gloria. After their quick updates recapping what they did prior to the holiday break and their research plans for the week, Tiffany begins giving her update. Unlike the other students, Tiffany is taking quite a bit of time talking about her research. Because this subgroup is small (seven people), and significantly smaller than the regular group meeting, time is being used to troubleshoot her issues, rather than "grilling" her with questions like at a group meeting. During an impasse of suggestions, Gloria gets up from her seat to go to the white erase board to draw a suggestion for how Tiffany can fix her equipment to provide better results during the next run of her experiment.
>
> After approximately 15-20 minutes spent on Tiffany's research issues, Professor Houston jumps in to make sure that the meeting is still moving. He suggests that since the group assumes there is a design flaw with her equipment, the subgroup members should examine her equipment in the lab after three final subgroup members give their research updates.

Drawing on the work of other scholars, Jonassen and Hung (2006) describe several common troubleshooting strategies. The scene I describe is similar to the "topographic" strategy whereby potential faults are isolated after engaging in a series of diagnostic checks. When Tiffany bravely explained where she was having trouble with her results, group members collectively attempted to identify potential pitfalls in her research design and pitched possible solutions to help her redesign the equipment. When no clear answers resulted from this troubleshooting, Professor Houston decided that the group would better serve Tiffany if they examined and fixed her equipment since they already speculated during the meeting that her issues lay in the design of the equipment.

Houston student group members sometimes equated doing "good research" with their abilities to troubleshoot problems in their individual research. This was likely the case because students were required to identify and address problems in their existing lines of research at subgroup and full team meetings. For instance, Emma, a Houston Group alum and now post-doctoral student in the group, expressed confidence in her ability to do good research because of her ability to troubleshoot. For her, troubleshooting related to "thinking of possibilities," and then thinking of experiments needed to "prove a hypothesis." Emma's views on troubleshooting were consistent with those of other group members. For example, Allen, a third year doctoral student, suggested that it was not only about having ideas, troubleshooting involved knowing which ideas were realistic and could be evaluated through an experiment. Allen said that he was rarely without ideas, and after his first year he had a better understanding of which ideas could be reasonably executed:

> I remember last year, my first year, I had plenty of ideas, but honestly speaking most of them didn't make sense. They were not realistic, not logical. But it was hard for me to kind of really make sense out of them. So I just sort of pitched them like "Oh, this is a good idea. Oh, I am going to try this." and then run and jump on them without taking a second to look at all the details and really make sure that these make sense and these are worthwhile pursuing…I am getting better, I know I am getting much better. (Allen)

When discussing how to solve ill-structured problems, Shin, Jonassen, and McGee (2003) state students' needs for "broad and global experience" and suggest that students should "think of global impacts" (p. 28). These instructions for problem solving were noted after the authors identified different skills students activated when solving well-structured versus ill-structured problems. To solve complex problems, according to the authors, students need to access a wider knowledge base (sometimes) beyond one's domain knowledge. While their study was based on high school students in an astronomy class, there are salient implications for the present study. Specifically, during observations of group and subgroup meetings, it was rare for students to make strong connections to the larger societal benefits of their work. Often students included one slide in their research presentations, but when students went over in the allotted time, the prevailing suggestion was to reduce or get rid of the slide highlighting the practical nature of his or her work. What was more rare were discussions about the ethical implications of one's work to society; except at one group meeting.

During a group meeting in the 13th month of data collection, there was a clear departure from the regular meeting routine. Gloria, who split her time "serving two parents" (i.e., two faculty advisors, and thus worked on two separate research projects), was presenting her work on algae as a source of green energy. During her presentation, Professor Houston interrupted her as she was attempting to link the study's motivation to societal needs for sustainability. What ensued next was a larger philosophical conversation about her research problem, ethics, and responsibilities of engineers and scientists, resulting in Professor Houston calling for Gloria to do more troubleshooting:

Fieldnotes Excerpt 2 (Month 13):

> Today's meeting and the energy in the room seems different, no one seems as rushed as they have been the previous weeks. Perhaps everyone is settling into the Fall 2013 schedule and feeling more comfortable with the new group meeting date relative to their jam-packed schedules.
>
> Gloria is presenting work that combines what she's learning from both of her research groups. Not long into her presentation, Professor Houston begins asking questions. It appears that this is no longer Gloria's presentation, it seems as if

> Professor Houston is talking out loud and pontificating or pondering random ideas.
>
> Upon further reflection, I began to think what is taking place is a larger conversation about sustainability and ethics. Professor Houston is not just nonchalantly thinking out loud, he's asking questions about Gloria's line of work situated within a broader context of one's responsibility to utilize fossil fuels. He asked a hypothetical question to Gloria and the entire group, "After we take natural resources from Earth and convert them to energy, then what? Do we replace used fossil fuels after the experiments are done? Do we put fossil fuels back into the environment?"
>
> No definitive answers were given, but after having a quizzical look on her face as if processing questions not previously considered, Gloria ended the conversation by saying "That was a good debate."

Most examples of troubleshooting during the Houston Group highlighted the diagnoses of tangible problems (e.g., faulty equipment, failed experiments, incorrect formula) that led to what students considered "bad data." The results from typical troubleshooting occurrences ended in students being encouraged to repeat failed experiments or adjust the specifications of one's equipment. But troubleshooting (and in a bigger sense, problem solving) also includes the identification of conceptual issues and ethical considerations (Jonassen, 2013). Within the teaching moment described in the scene above, broader ethical issues regarding the responsibilities of scientists dominated Gloria's research talk. Making these broader connections to larger societal issues is what Shin, Jonassen, and McGee (2003) called helping students acquire and activate skills beyond their disciplinary domain and its techniques. During their dialogue, Professor Houston scaffolded several ideas about the societal implications of Gloria's research. By the end of her presentation, he made it clear that he expected Gloria to further consider the ethical dimensions of her work when she returned to her research and during her next presentation.

The data in this study highlight the important role troubleshooting plays in the research experiences of Houston Group student members. In most scenarios, Professor Houston posed questions and engaged in teachable moments during group meetings so that non-presenters would learn [techniques] from the presenter's mistakes. It appeared as if he was publicly troubleshooting with presenters to help other students avoid similar problems. Despite his efforts, some of the same problems continued to occur, which might suggest that, as described by Jonassen (2013), troubleshooting is task-specific (i.e., student and research project specific) and does not necessarily lead to transfer of learning to other students and/or contexts.

Troubleshooting in the Houston Group was not only about working through problems. The ways troubleshooting operated differed via the group or subgroup context, and also shaped the interactions students had with each other around this competency.

Managing projects.

Houston Group members were expected to produce research results each week. In its broadest sense, "managing projects" refers to members' abilities to balance their research-related tasks. For example, Dr. Randall insisted that being a member of the Houston Group meant that research took priority over everything:

> Most of the students are here by ten o'clock and before lunch they would do the preparation work for their research, and then after lunch they would come and actually run the experiment and it could take maybe the whole day, half a day, or overnight or whatnot. While the experiments are running, they have other obligations; if you're a TA (teacher's assistant), you have to hold office hours and help the professor with their recitation. And also, all the group members have adopted equipment to make sure all the equipment is running well. So they have to be on top of that. You have to prepare for subgroup meetings, prepare for group meetings. I would say you're constantly going on first gear…So everything revolves around your research. So even your mealtime, sleeping hours, social life, everything seems to be constant. (Dr. Randall)

Because of the heavy research expectation, there were no set working hours. Rather, students were expected to stay in the lab as long as it took to complete their research goals for the week. As indicated by Dr. Randall, students staggered their research tasks throughout the day. In between preparation and experimentation, students addressed other tasks (e.g., preparing for and attending meetings, holding office hours). Work on their projects helped students learn to pace themselves, balance several responsibilities, and effectively use their time.

Houston group members shared lab space based upon the nature of their research (i.e., the various labs were designated by the types of equipment and experiments taking place in that space). Because students shared space and had a lot of research tasks that needed to be completed in order to get results, managing projects also related to the management of one's schedule in order to maximize productivity. For instance, Brielle, one of the senior-most students in the Houston Group at the beginning of data collection and now recent graduate, explained that to efficiently complete her work, she mapped out her research a semester in advance – and in consultation with Professor Houston – to help determine when she would need certain lab equipment:

> At least in my case I would always get in touch with him (Professor Houston) and I would let him know what I plan to do this semester, these are my goals and objectives and these are the experiments I've planned. I typically like to have a table with certain designs of experiments if I am trying to achieve a certain thing. (Brielle)

She also described regularly keeping him informed of her progress, beyond the regular weekly subgroup schedule.

While part of managing one's project is planning a schedule, other aspects of managing one's work include anticipating future research needs, determining when one needs to be in the lab, and organizing tasks to be productive. According to Danny, some of his work (e.g., literature reviews and analyses) could be completed at home. But he also asserted that he had to check that his experiments (and equipment) had not been tampered with:

> For me at least, I know my schedule is very variable depending on what my plans are for the week. Sometimes I have to do a literature research and I don't have to show up at the lab as much, I can do some of the stuff at home. I can come in and set up experiments for the future and make sure no one is messing around with my stuff in the lab; you have to see what's going on and you can't be gone for too long. But, let's see – an average week where I have to run off experiments in the lab, I usually come in probably like 10[am], and I set up all my stuff beforehand the previous day and then I just come in, run my experiments, make an assessment to see if my experiments are run correctly. I collect the data, clean out my stuff, and then I go home and start analyzing the data. Based on my analysis of what I collected, I can design my next experiment to see if I need to go back, redo the experiment." (Danny)

Unlike Brielle who described planning her experiments by the semester, Danny planned his work by the week, which was usually dictated by his day-to-day progress. Because students from other groups also shared the lab space, Danny wanted to ensure that nothing unaccounted for happened with his experiments. Managing his work included being aware that the lab was shared space, as his results could be (maliciously or not) influenced by others.

Consulting with peers.

Despite an emphasis on developing students' independence, students were actually interdependently-independent, meaning that while students often worked individually during the day, much of their research – and learning about research – built on the knowledge of other students in the subgroup. Students thus shared information about techniques, materials to use, operating equipment, and analysis approaches. In this sense, students often consulted with one another, but were not fully involved in partnered-collaborative research.[23] This finding aligns, but also extends, the existing literature on the nature of research groups and the work done in groups. Jonassen (2013) and (Tonso, 2006) emphasized that students' learning takes place in interdependent research and design teams where students worked collaboratively on a single problem or project. My data suggests that students can alternate between independent and interdependent problem-solving while working on separate, but conceptually related, projects; I term this as "interdependently-independent" research. Tonso observed that as the literature on research group learning increases, so, too, does our knowledge about research group dynamics, the design of groups, and the contexts and factors that influence student learning in research groups.

Professor Houston appeared to understand the important role that interactions play in student learning. While he also acknowledged his role in students' learning process, he argued that students also learn when they interact with and utilize their peers:

> …students learn from – or people learn from people they consider peers…I am trying to teach them something. But if somebody else has already seen it or done it first-hand, usually students will buy-in to that a little quicker. They believe things that I say largely based on faith. If you are talking to another student who has maybe done that experiment already, you believe it based on a belief that somebody has actually already done it recently. It's a different type of interaction, and I believe both are important. In fact, that's one reason why we structure the group the way it is so that there are these opportunities for people to learn. (Professor Houston)

Because Professor Houston believes that "two heads are better than one," his design of the research group and subgroup structures was intentional. Due to the group's structure,

[23] There were a few instances of partnered collaborations during the period when I studied the Houston Group. As described by Danny, however, these efforts appear to be "new," as if Professor Houston is experimenting with the idea of partnered collaborations within the group. Nonetheless, when there were these collaborations, they usually included first-year doctoral students, a post-doc, a senior-most group member, and visiting scholars. According to Lloyd, these collaborative projects were exploratory, in efforts to obtain preliminary findings to strengthen grant-funding applications for future independent doctoral research projects.

and the nature of students' research, students continually consult and interact with each other. Professor Houston later expressed that because of students' interactions and consulting with each other, students (particularly pre-candidates, master's, undergraduate researchers, and sometimes visiting scholars) learn how to create an innovative experiment, do the experiment, and persevere through a series of experiments, all of which Professor Houston described as steps in the research process.

Briefing research.

One of the key elements of the Houston subgroup design was the organization of students into "smaller groups focused primarily on areas that are related but not necessarily exactly the same," based on the equipment used, and/or the engineering methodological technique used to complete the research. This arrangement facilitated student support from others working on similar projects. Because each student worked on his or her own independent project, students had to clearly explain their work to peers and supervisors, and their progress to those doing similar but not identical research:

> During the subgroup meeting, people are learning what other people are doing, [they are] not totally different projects but similar to what they are doing. So that's why we have a couple of – well we used to have three [subgroups] but now we have two and one is more of a catalytic material subgroup and the other is electrochemical. So people have the opportunity to present their findings, and also get feedback, and also learn what other people are doing. Also from that they can apply it to their research and be more effective in getting to where they need to be. So the subgroup meetings are that; it's just to make sure everybody's also progressing well and getting good feedback. (Dr. Randall)

Both Professor Houston and Dr. Randall expressed a similar belief that students learn how to improve their own research from listening to and watching other group members' present and assessments of their work-in-progress.

Presenting research.

The compositional nature of the Houston Group (i.e., chemical engineers; chemists, mechanical engineers) provides students with practice describing their research to wide audiences at group meetings. The development of this competence is in preparation for future dissemination to academic and industry audiences. Erik discussed how he learned to describe his research during group meetings and the benefits of participating in this practice:

> ...part of the research experience is growing in a sense of learning how to present things and learning how to do research…[presenting in front of Professor Houston] is a good thing. That leads to you being careful, leads you to thinking of questions he's [Professor Houston] going to ask in advance. (Erik)

Learning to present and improving one's capacity to describe research to a wide audience were goals of presenting at group meetings. Because presenting in group meetings was such a dominant practice of the Houston Group, Erik related his research experiences to his developing presentation competence. Notwithstanding the nervousness that comes with presenting one's work, particularly in front of the faculty advisor "who knows so much more than you do," Erik shared that there were other benefits in presenting one's work in the Houston Group; students became more thoughtful about what they were presenting and anticipated future questions.

There was no required format for structuring one's research talk for group meetings, but because students regularly presented, it was understood that they would address "what you are doing, where you are at, what did you find, what have you been working on, [and] what challenges did you encounter...your result [however] is what is most important," (Allen). Allen explained that at minimum, presenters discussed the motivation [i.e., the problem], a brief literature review with few references, their research design and their results. These conventions for how to frame one's presentation, as well as what to include and exclude, were not written down; students – particularly student members new to the group – learned how to present in the Houston Group by watching the senior student members present and receive corrective feedback each week.

Receiving and responding to feedback.

In the Houston Group, part of learning how to describe one's research includes receiving and responding to feedback and learning to disagree. Learning this competency was not about learning to "argue," rather, learning how to justify one's claims, and anticipate future challenges to one's work. Related to this study, scholars suggest that "argumentation" (Cho & Jonassen, 2002; Tonso, 2013) and "justification" (Shin, Jonassen, & McGee, 2003) – synonymously used in existing literature – are necessary to develop communication and reasoning skills needed to address problem solving in STEM fields. Cho and Jonassen (2002) define argumentation as "the process of making claims and providing justification for the claims using evidence," (p. 5). They argue that classroom instruction – and/or face-to-face instruction – does not conclusively improve students' abilities to develop and defend sound arguments. However, scaffolding students' problem solving skill development and argumentation was successful with an undergraduate population; students who engaged in group problem solving activities were better able to make cohesive arguments and rebuttals after computer-based scaffolding. While Cho and Jonassen's study was based on undergraduates and computer-simulated scaffolding, their findings suggest that intentional scaffolding by faculty and practice in argumentation might improve problem-solving skills. Their findings also suggest that the development of the skills requires both practice and mediation of some sort (e.g., software, peers, faculty) to help students acquire these skills.

When describing the role he played during group meetings, Professor Houston explained how he scaffolds the feedback portion of presentations. He shared that he preferred to have students or the post-doc ask questions of presenters, but he first asks "a leading question that "will force you to think about things." He also engages in questioning presenters during these meetings because he wants to model for students in the audience the habit of asking questions, as much as he wants presenters to build their skills of justifying their claims. The types of questions that Professor Houston asks are similar; why a particular method, why are certain steps taken (i.e., protocol), what does the literature say about the findings (including past work completed by Houston Group alums). By priming presenters with questions, and focusing on certain kinds of questions each week, highlights a pattern of the kinds of information he feels makes a presentation and research strong. Professor Houston believes that his facilitation of the feedback portion of meetings mediated students' learning about research and their becoming scientists.

As a result of Professor Houston's attempts at scaffolding students' learning about research and argumentation, the sessions in which students received and responded to feedback were often contentious. Professor Houston acknowledged that "…we battle, battle, battle…" referring to the intense nature of the question-and-answer portion of group meetings. He explained that he incorporated constructive criticism into the group's practices because as an established faculty member, he, too, still received this kind of feedback and it helped him continue to grow:

> Criticism is an important part of growing and learning, and it's tough to take. Maybe as a faculty member, you submit proposals – and you think it's the greatest thing [sic]; the odds are it's going to be rejected. There's a one-in-ten chance that you are going to be successful with that proposal. So I've gotten used to being criticized. (Professor Houston)

Because Professor Houston sees value in critique, he believes dealing with criticism is an important competency for his students.

In the excerpt below, I describe a scene that highlights the social practices of receiving and responding to feedback. This exchange involved a disagreement between Allen and a more senior student, Brielle, as she prepared for her dissertation proposal defense:

Fieldnotes Excerpt 3 (Month 3):

> Brielle is going to present today. This time, she is preparing for her upcoming dissertation proposal defense. This meeting is important in the Chemical Engineering Department; once students pass this proposal hearing, they can officially begin working on their dissertation.
>
> During her presentation, Allen starts to relentlessly challenge Brielle. Although Allen is the less senior of the two – by three years – he continues to challenge her conceptualization and application of the word "stabilization" in her literature review. In order to get the practice presentation back on track, Professor Houston sides with Brielle and tries to explain to Allen that one can differently present research to practitioners than academicians, based on the intended audience.
>
> Not willing to concede, Allen continues to challenge Brielle's usage of the word, now citing her conceptualization relative to literature he has recently reviewed. It is apparent that he and Professor Houston disagree; Professor Houston says to Allen "I know you think you're right…" and Allen jumps in and says "I am right!" They do that back-and-forth dance one more time until Professor Houston calmly stops and describes one final time the differences between academics in engineering and practitioners. Perhaps, realizing that it is not his battle to win, Professor Houston stops engaging in the argument when he realizes that he was responding for Brielle instead of allowing her to respond to the feedback and disagreement. Professor Houston picks up his cell phone, likely to check his schedule as the meeting is running long.
>
> Back in control, and after being defended by Professor Houston, Brielle strongly stands by her use of the term "stability," loses her usual calm, cool, demeanor,

> and becomes defensive by exasperatedly retorting, "Why would I do that [change the use of her word], what's the problem?" Her response has more bite to it, her tone is harsher, she's talking faster, and is much more combative.
>
> The exchange between Brielle and Allen comes to an awkward halt as Professor Houston intervenes – after allowing it to play out for a while. This time, however, Professor Houston sides with Allen by saying to Brielle in a calm tone, "That's not a defensible response," referring to her harsh retort to Allen.

In the excerpt provided above, Professor Houston allowed Brielle to engage in discourse with Allen before he finally played mediator and reminded her that she did not have to agree with Allen's perspective, but that she cannot raise her voice at audience members who disagree with her work. Professor Houston

The practice of receiving and responding to feedback is a challenging exercise for students. The scene described above during a group meeting presentation was not uncommon; examples of teaching moments often occurred during the group meetings. So much time is devoted to this kind of learning in group meetings that Houston team members have a running quote – that operates like a group philosophy – that "If you can make it out of here [the group meeting], then you can make it anywhere." This quote and sentiment – usually only referenced in the context of a group meeting presentation – was often invoked after a student survived an extended period of practice justifying one's work in front of the faculty advisor and student group members, like Brielle in the scene described above. In Brielle's high-stakes practice presentation, in particular, Professor Houston explained to the group that successfully passing one's dissertation proposal defense could hinge on one's ability to appropriately respond to feedback. Despite its harshness, each student in this study described the development of this skill as necessary for conducting and presenting solid research.

Another example of Professor Houston assessing a student's work and teaching audience members how to justify their work is illuminated in the excerpt below. This group meeting in the 12th month of data collection was interesting, not because there were new practices or activities occurring, but rather because after months of observing the group, it became easier to see patterns of behavior (in students' presentations and in the types of feedback Professor Houston offers):

Fielnotes Excerpt 4 (Month 12):

> This week marks one-year of my being in the field. When I started this time last year, it was also when the new people first came to the group meeting. Actually, there are new people here as well, at least three new students I haven't seen before. With the new students, remaining visiting scholars, and core group members, there are 26 people at today's meeting, good thing they moved to a classroom because they outgrew the old conference room.
>
> Something is different about the energy in the room today. When I walk in, Erik and Kelcy are laughing, and Professor Houston comes in and makes a joke that makes everyone laugh. There's also pizza and food on the tables. Apparently, they are having a farewell party for one of the visiting scholars from Germany who is presenting today and leaving Saturday…
>
> After the visiting scholar presents and answers questions, Danny starts setting up for his presentation. I'm a bit concerned about the time because my car meter is going to expire, this meeting is almost over the allotted time and he has not presented yet. But from my observations, when the first presenter goes over in time Professor Houston tends to rein in the second presenter a bit more because now he is more conscious of the time and his next appointment or commitment.
>
> For some reason, Danny appears to be a little nervous as he starts (when I arrived earlier, he did mention to me that he's tired and started preparing and practicing late last night). Not too far into Danny's presentation, Professor Houston stops him and begins asking him questions, many of which were similar to the questions he asked at Danny's previous presentations on May 24 and July 26. Professor Houston immediately asks Danny about his research design, in particular, his rationales for his methodological choices before finally stating to Danny, "…you need to work on having a clear/concise explanation. I have some ideas, but you're the presenter." Even though Danny is not done with his formal presentation, Professor Houston's questions prompt more questions from group members in the audience. One of the visiting post-docs then asks a question about Danny's methods and ended by saying his test wasn't long enough. Professor

> Houston then turns to the visiting post-doc and asks "how do you know"? Whether a doctoral student, post-doc, group member or visitor, Professor Houston wants people to justify their comments and basing them on evidence.
>
> Still not back to Danny's presentation, Professor Houston turns to the group's newest post-doc and asks her what she thinks might be happening in Danny's flawed results. Afterwards, Professor Houston continues facilitating the remainder of Danny's presentation time by telling him what is and is not presentable (i.e., what is not ready to be formally presented), "…if your electrolyte isn't sure, I wouldn't present it." "At a minimum, you need to get a diffusible set of…" "Figure out the proper protocols, first."
>
> Danny gets a final opportunity to "close out" his formal presentation. He fast forwards to his final slide labeled "Explore New Directions" and everyone in the room chuckles, while Professor Houston shakes his head and offers a resounding, "No"!

The laughter and Professor Houston's response came because in each of Danny's group meeting presentations, he received feedback to better justify his choices, to stick with the methodological protocol (i.e., the proven order of research techniques according to existing research), and to not test new ideas without a scientific rationale, especially not until he had finished addressing the issues of the current experiment.

The interchange depicted here is representative of the types of feedback students routinely received during group meeting presentations. In addition, it is illustrative of how Professor Houston used feedback portions of meetings as teachable moments for the wider audience. What is not captured in the scene described above are Danny's attempts to rebut Professor Houston's questions, nor Professor Houston's broader commentary to Danny (and the group) about how to justify one's work. Professor Houston consistently attempted to help students improve their skills in argumentation. First, he typically suggested that presenters need to allow audience members to ask their full question. This suggestion came after student presenters consistently became so defensive that they did not allow individuals to finish their question. Second, Professor Houston encouraged students to pause and think about what the audience member asked before responding. Many of the students in the group, including Danny, rushed to prove their choices, seeming to feel attacked. This sentiment is well articulated by a somber-sounding Allen:

> [It is] Terrible. Tough and terrible. Of course, you've been working on this thing for what – for how long, for so many days and times and weeks and months, and then here you are presenting the work and then somebody sits there and tells you that it's wrong, really? And you've been spending all your energy, time, everything on this thing and somebody sits there and tells you "this is wrong." That's a terrible feeling. (Allen)

Exchanging feedback and responding to disagreements helped students learn what are – and how to make – justifiable and persuasive arguments; further helping them develop expertise in their research area and the competency of presenting. After the exchange of questions and answers, senior group member, Emma, confidently asserted, "I am an expert of this research; I know the best for this work." As a result of the feedback from group meeting presentations was that students were more prepared and better able to answer even the hardest questions when they brought their research to outside audiences:

> [But] you cannot go out there (to conferences) and say anything; they will grill you, they will tear you apart, they will bring you down, they will make you feel like crap. That's the beauty of this group. It forces you to – anything you put in that PowerPoint – know the meaning. If it doesn't make sense to you, take it out; it's not going to make sense to the rest of the group either. If it doesn't they will point it out, they will grill you down. So that's one good thing about this group and that's how we are to each other. [And] that's helpful, that is very very helpful. That is the reason why we have to do feedback. Don't let me hang around with flaws in my research and then I go out there in a national conference and then I find out that there are flaws in my research and I am in front of thousands of people and I am embarrassed—who's embarrassed? I am not the only one; the whole group is, the professor is, and his whole reputation is in danger. (Allen)

Allen, who is interested in becoming an academic, saw value in practicing argumentation within group meetings because proving one is "right" and "question[ing] everything" is “how it is in academia,” and in part, what he believes will “make me a good professor.” In addition to describing the implications of developing presentation and argumentation skills during meetings, Allen argued that group members were obligated to offer strong critiques of one another’s work. Specifically, he believed that the reputation of the group and Professor Houston depended on students’ questioning and challenging each other during meetings. This sentiment was echoed by Professor Houston who often explained that the goal of the audience at group meetings is to “grill” (i.e., challenge) the presenter so that he or she does not encounter tougher questions at dissertation defenses, conferences, or interviews.

There are several notable aspects regarding this competency. First, despite the uncomfortable experience of being a presenter, all students described what they learned from the process of argumentation. In fact, students’ confidence in presenting and doing research was related to their abilities to defend their methods and ideas, and equally important, withstanding the “grilling.” Second, it appeared that students’ learning was mediated by Professor Houston’s scaffolding of the importance of feedback and disagreement in the research group – and implicitly the engineering field. Dr. Houston’s scaffolding around argumentation and presentation may not be representative of how other engineering faculty members prime students for public presentations. It suggests, however, that when this process is not well facilitated, and students do not understand the learning behind the process of argumentation, they may misconstrue “grilling” as evidence of a “chilly,” “isolating,” “competitive,” and “hostile” climate, which is well documented in the literature as to why students (especially women and students of color) leave STEM fields (Fries-Britt, Burt, and Franklin, 2012; Fries-Britt, Younger, and Hall, 2010a.; Gasman et al., 2009; Green & Glasson, 2009).

Contributing to lab operations.

Part of students' many responsibilities, included contributing to the group's overall operations to aid in the group's efficiency and success. According to Professor Houston, attending to research and other research-related tasks[24] developed students' management skills and capacities to lead:

> So, every student has some management responsibility and it might not be a big thing, it might be responsible for managing a piece of equipment, but that's something that's important to the lab…students are managing their project, their research. So, we try to give them some experience and responsibility it that regard. (Professor Houston)
>
> They have to learn how to manage – the graduate students get a little bit of management experience, and the postdocs definitely get management experience, research scientists get management experience…because when they leave here, that is what they are going to do. You will initially be a worker, but eventually you're gonna turn into – will be a manager; you're gonna manage projects and resources. So, this is a perfect time to learn or practice some of those skills. (Professor Houston)

Knowledge of lab operations was not just a skill needed to survive in the Houston Group, students needed to practice these skills in preparation for post-graduate careers in engineering. Professor Houston claimed above that in the future, his students would be expected to know how to not only independently manage themselves, but also how to manage others. Accordingly, the individual research projects in the Houston Group were where students developed this competency. Additionally, by assigning each student a "major and minor task" related to the group's daily operations, students shared

[24] "Other research-related tasks" refers to tasks that may or may not be specific to the progress of an individual group member's specific research project, but the task was important to the functioning of the Houston Group. Some examples of other research-related tasks included taking inventory of materials, creating safety procedures, maintaining the Houston Group website, organizing group celebrations.

responsibility for running the lab. Because students had ownership of its daily functions, Professor Houston was able to devote more time to guiding the overall work of the group.

Building equipment and taking inventory.

In order to run experiments, students had to have the proper tools and materials for each project. Consequently, students had to do inventory to assess their lab needs. If they needed to order materials after taking account of what was required by their experiments, they completed an order form – with budget justifications – and submitted it to Professor Houston. It was routine practice for Professor Houston to audit members' order requests; he believed that this practice gave students insight into where their research materials came from, research grants.

Beyond ordering chemicals, sometimes students needed new equipment to run more sophisticated experiments. When the equipment order arrived, some of the machinery had to be assembled by students:

> Yeah. So, almost all the reactors except for Tiffany's you'll see in this lab are all built by Model University students. This was built – this whole scaffolding, we designed it in a drawing program and then we ordered it. They shipped us all the separate parts and then Kelcy and I put this all together. We purchased this separately and put it on—we purchased all of that up there separately – all that piping and tubing that was purchased separately; we had to design it, understand what we needed, and then order the parts. And they all came in and we put it all together. (Erik)

Given that much of the equipment in the labs is customized for the Houston Group, students gain skills in designing and building equipment for their experiments. The benefit of designing one's equipment, according to Erik, is that "you can design experiments to be how you want them to be. Like, you can design a reactor such that it will do everything that you want it to do." The inverse is true, too, that if a student incorrectly designs and/or assembles equipment or forgets to order an integral piece, then they are also responsible for the flawed design and failed experiment.

Maintaining the lab.

Generally, Houston Group members monitor and maintain the equipment for which they are the primary user, the materials needed for their research (e.g., gases, powders, chemicals), and waste. As a result, they learn how to manage the resources needed to complete their research. Some group members, however, had tasks that impacted the entire group. For instance, to facilitate collegiality across research groups and to provide structure to those who utilized the lab spaces, Allen was in charge of maintaining the equipment sign-up sheet. Because the goal was to be consistently productive within the lab, this particular task was important for group members, as Erik explained:

> Here are sign-up sheets for the [equipment] and this is typically how people regulate what times people have and they'll just sign up for certain days. There are rules to go along with it such as if you're not here within an hour or two hours of your starting time someone else can use it and you can't sign up for six slots in advance or something. (Erik)

As Erik indicates, there is a process and rules for making the lab function. He also explained that group members enforced their own regulations (i.e., students could use the equipment if someone was absent from their reserved lab time). Similarly, while lab cleanliness and safety was formally Gloria's (a fourth year doctoral student and currently one of the group's senior-most students since Brielle and Emma graduated) other research- related task, Erik suggested that members ”monitor ourselves” to ensure the lab is well-maintained and "get annoyed with each other if it's not clean and what not."

Supervising members.

Some Houston student group members were charged with supervising other group members (e.g., undergraduates, master students, visiting scholars). For instance, during Summer 2013, at least six core Houston Group members had undergraduate summer researcher students. When Houston student members were tasked with supervising others, they were generally collaborating on the same project or similar projects with slight variations. As confirmed by Vince (a second year doctoral student), students were assigned undergraduate researchers when they had an unexpectedly large project or on rare occasion they had been assigned to multiple projects. Professor Houston made a determination of who needed help making sufficient progress on their research.

Vince, who supervised a student during Summer 2013, described how he had to better manage his time and the progress of his experiments while simultaneously making sure that his undergraduate researcher was having a meaningful learning experience. He explained that the strategies he used to teach and motivate his undergraduate researcher stemmed from the mentoring he received as an undergraduate researcher. He tried to shape the research experience around the learning needs of his undergraduate student, which he admitted was a challenge:

> For the summer since I don't have classes I come in around 10 in the morning – and since I work with [my undergraduate summer researcher] who [will be] a Master's student [in the Fall], I would kind of prepare – I would kind of go through what I wanted to achieve for today, and then I would separate what he would do or what he would like to do. So I would put that as a priority first. And then after he comes in – usually he comes in earlier than me – so I would talk to him about what I want to achieve today, and then have him pick out what he wants to do or would like to do. So, sometimes he picks out most of the things he wants to do and then I would take the rest of that, and work on that, and try to almost assist him as much as I can. In that way, I think he gets to learn and he gets to do a lot more hands-on experience, and I would have materials kind of prepared for him and get ready for him to do the work. Sometimes I would watch

> him assemble a couple of cells to make sure he is doing everything right. So that is normally my day, and around 3[pm] or 4[pm] I would leave and go to [my co-advisor's] lab and finish some other things. So most of the time it's just preparing materials. (Vince)

Vince, one of the newest Houston Group members, was not very removed from his own experience as an undergraduate researcher. Thus, Vince was thoughtful in trying to make the research experience of his undergraduate (soon-to-be Master's student) researcher meaningful as learning experience and helpful preparation for graduate school. Much of Vince's time as a result, was spent negotiating what he would accomplish per day based on what his undergraduate researcher "wanted" to do. Vince admitted that a challenge with his strategy was that his undergraduate student often shutdown when experiments failed. To help motivate him, Vince attempted to situate undergraduates' research contributions in Professor Houston's larger research project and to highlight the potential benefits of their work and what they were learning even when they got unfavorable results.

Chapter Summary

In this chapter my goal was to address my research questions on the nature of the research experience, and doctoral students' learning about engineering research and the engineering professoriate. Through students' interactions and participation in the group practices, students developed a variety of research competencies: solving problems; troubleshooting problems; managing projects; consulting with peers; briefing research; presenting research; receiving and responding to feedback; contributing to lab operations; building equipment and taking inventory; maintaining the lab; and, supervising members. By engaging in these practices, as well as by interacting with members in the research group, students learned about local expectations related to the conduct of strong engineering research. Some examples of students' learning to do engineering work included the ability to anticipate challenges and justify one's work, and learning how to assess one's needs and manage an array of tasks to complete one's work. Participating in these practices also provided students with glimpses of what is expected in research careers, whether in academe or industry.

Chapter 5: Perceptions of Faculty and Faculty Work

Having established the setting and contexts for learning that students in the Houston Group experience, in this chapter I address my research question on students' perceptions of faculty work and professional and personal identities.

Creation of a Faculty Prototype

Students spend a considerable amount of time in the Houston research group and interacting with its members. These interactions often take place in formal meetings, informal gatherings, and in the laboratory. The process of learning how to do research happens through participation in the group's research practices as well as through these interactions with team members. In particular, students learn to meet the standards and expectations of the group through interactions with and observations of senior students, Professor Houston, and the members of the leadership team. The data from this study suggests that students also create a faculty prototype – strongly based on their model, Professor Houston – that guides their understanding of the group's expectations of research performance.

The concept of a "faculty prototype" is borrowed from the work of Blackburn and Lawrence (1995). In their study of more than 4,000 faculty across ranks, disciplines, institution types, age, gender, and ethnicity, they argue that faculty members learn about the expectations of success in academic careers through social knowledge, which they define as a faculty members':

> …perceptions of various aspects of the work environment. Faculty form beliefs from experiences with colleagues, administrators, committee decisions, faculty meetings, institutional rules and norms, and professional association practices. These beliefs constitute their social knowledge. (Blackburn & Lawrence, 1995, p. 99).

Further the authors suggest that to gain success in the academy (e.g., receive institutional recognition for publishing, grant work, high ratings on teaching evaluations), faculty members adapt their behaviors to their perceptions of the [faculty] prototypes they cognitively construct through observing and interacting with successful colleagues.

While Blackburn and Lawrence (1995) offered the concept of a "faculty prototype" as a key variable in explaining faculty members' motivations, they concluded by suggesting the need for future longitudinal research on graduate students to learn how they are socialized to the expectations of faculty work. Such an approach, according to the authors, would account for the "ongoing cycle of interactions and altered cognitions, values, beliefs, preferences, and behaviors" (p.289). Similar to the faculty in their study, the Houston student group members also constructed a faculty prototype which they, too, used to assess themselves and adapt their behaviors.

Student learning in the Houston research group centers around two main learning goals: how to independently create and conduct strong research; and, how to present and defend one's work to wide audiences. To ensure that students are meeting these broad goals, Professor Houston has established a series of practices and activities that help to build students' competencies around these areas of conducting and presenting research. These practices and activities – for example, receiving and responding to feedback during group meeting presentations and collaborating with group members to complete one's work – are rooted in interactions with the faculty advisor, members of the leadership team, and other doctoral students in the group. Thus, students' learning towards the group's broader goals is developed through practice and interactions with the members of the team.

Professor Houston regularly evaluates students. Through his consistent feedback at weekly subgroup and group meetings, students begin to understand what he considers to be strong research and strong representations of one's work. Whether observing Professor Houston's critiques of the work and performances of other students, or experiencing them first-hand, students come to learn what is and is not acceptable to Professor Houston. Students report that presenting one's work at group meetings helps them understand what to present, how to present it, and the types of questions they should anticipate receiving from audience members. Professor Houston's expectations of solid research contribute to a faculty prototype similar to that suggested by Blackburn and Lawrence (1995).

However, the prototype is not just about how to perform in the context of the research group or in particular research practices. Students build this prototype by spending time with and observing Professor Houston in meetings and gatherings outside the lab and group meetings. His activities and attributes appear to strongly influence his students' construction of a faculty prototype.

Student group members described myriad characteristics that lead them to respect Professor Houston. What they reportedly liked about him appeared to vary based on their individual relationships with him. Brielle admits to "idolizing" him. There were some commonly held characteristics that formed the basis for the prototype. First, Professor Houston was described as "a people person" who is well-connected across campus, across the field of engineering, and within industry circles. Brielle, for example, mentioned Professor Houston's consistent participation with the campus' undergraduate research program. She noted that, "he gives a lot of opportunities to a lot of students like high school students and undergraduates to come and work in the lab generating interest in research." In fact, during months 10 and 11 of data collection, I observed an African American high school student attending the weekly group meetings and shadowing Dr. Randall. The student I observed started attending meetings after Brielle graduated and interviewed with me, which suggests that Professor Houston has availed himself to other high school students interested in science and engineering in the past. It is not odd for Brielle to have mentioned his altruism as an aspect she admires about him because she, too, considered a career education where she could "give back the knowledge" to people in her home country who do not have access to the educational system in the United States.

Many group members agreed with Brielle's assessment that Professor Houston "commands respect automatically." Sherman noted his "no nonsense" demeanor. Both Brielle and Sherman described his seriousness and his ability to command respect. It was not clear how much students knew about Professor Houston's private company, or his role(s) within the company, but it was clear that students linked his leadership of the research group to his experience as a successful businessman. Allen linked the sentiments of Brielle and John together in his summary of Professor Houston's strengths in money and management:

> Professor Houston is a little bit different [than other faculty members]… he also is a business guy. So, he knows how to bring money, he knows how to get people's attention, he knows how to talk to people, he knows how to -- he's like a business-orientated guy. On top of that -- he's a very smart guy; he knows a little

> bit about everything. (Allen)

Similar to Allen, Vince observed that Professor Houston's knowledge in business translates to his management of the research group:

> I think he kind of micromanages everything. So he keeps track of finances and that's probably the best way to micromanage is to have monthly expense reports. He would look at how much money you are spending and the order forms, he kind of stays on it for a little bit and thinks about it for a little bit before buying it, and he wants reasons why you're buying it. (Vince)

Professor Houston admitted to grouping students into subgroups as an efficiency strategy to manage the volume of advisees and their work. Because of the subgroup design, students are expected to interact with one another and help each other through their similar – but different – projects. The design of the subgroups thus allows Professor Houston to attend to other tasks (e.g., teaching, grant-getting, traveling). Although all students would describe him as "busy," when he is present for weekly subgroup and group meetings (which is at least two hours per meeting), it is understood that "you have his undivided attention" because he wants to know what progress has been made. Students tended to describe his presence and interactions in two ways: trusting and student-focused.

Sherman juxtaposed Professor Houston's hands-off approach to other professors who micromanage students' work, "One of my biggest pet peeves is professors who try to take over a student's project. And that's something I really admire about [Dr.] Houston is that in every way he lets our projects become our own." When asked to describe the ideal professor, Erik echoed Sherman's sentiment about developing independence in one's research. He also adds that while the work is independent, the subgroup meetings provide weekly guidance to ensure they are conducting strong research:

> [The] ideal professor would be I guess in a very general thing, a professor who is very passionate about their research, cares a lot about the research, is willing to discuss research and put forth ideas, argue bad ideas, et cetera, but isn't micromanaging. I mean that's kind of actually what led me to want to work with Professor Houston because he doesn't micromanage. But he has these individual subgroups where he is able to look at your project, give you ideas, discuss it with you, but he's not in the lab every single day. (Erik)

Erik and Sherman both described Professor Houston as hands-off. Erik, a third year student at the end of data collection, has managed some of the group's lab equipment since his third month in the research group and has passed his qualifying exam; he has likely proven his ability to have more independence in the group. Sherman and Vince were both second year doctoral students at the end of data collection. Professor Houston said that as an advisor, he adjusts to meet the needs of his students. Thus, it is possible that Professor Houston adapts his approach based on his assessments of the particular needs of students.

Students, like Erik, who described Professor Houston's hands-off approach tended to link that approach to a trusting and student-focused demeanor. These students marveled at Professor Houston's ability to oversee research projects (which are tied to grants), but still allow students to learn through making mistakes. Gloria exemplified this sentiment that Professor Houston allows students to learn about research on their own:

> I have heard from others about how their group works. I really like Dr. Houston's and I can't imagine anything further from this because he guides you, and you can talk to him, and he knows "this may not work." Me not knowing why things don't work, but you can try this and this. But he knows what doesn't work. And he gives you enough room to even sometimes make your own mistakes on your own and then comeback, "ok, yeah I did wrong." I have lost motivation in my project a couple of times and then "I don't know why I am doing this." But he gives a really good broader view of why you are doing this so. He guides you but he also gives you room to do your independent thing. So I guess that's a pretty good way to lead a research lab. (Gloria)

The examples above all focus on of the positive attributes associated with

Professor Houston and the faculty prototype that students developed based on their observations and interactions with him. Other characteristics that students used to describe Professor Houston and/or discuss their perceptions of faculty roles were less positive. The first is not surprising; students consistently described Professor Houston as "busy." In fact, Sherman called Professor Houston "the busiest man around" because he is always "flying around everywhere." While some students acknowledged that they are able to make progress on their research through the support of their subgroup, other students, like Tiffany, feel that "[Professor] Houston is so busy and there's never a chance that you could ask him whatever question you have." This is likely of concern after a student has exhausted his or her options by asking subgroup members, Professor Lee, and Dr. Randall for help.

In addition to just naming Professor Houston as "busy," some students actually attempted to make sense of what makes him, and the other professors, so busy. Allen for instance noted that Professor Houston's work does not start and end on campus: "Because he came to work during day time, takes off around five or six p.m., and you think that he is off, he is off with his family and is going to come back tomorrow. But, the duties are not off he is actually still working at home." Even during group meetings, particularly when there were lull periods, or if students were in extended periods of argumentation with one another, Professor Houston would be observed reaching for his cell phone to check and respond to emails.

Even though Professor Houston was extremely busy, students appeared to understand the tasks he balances as a faculty member. Several students focused on the responsibility that professors have to find grant fund money for their work and their graduate students. Lloyd, the post-doctoral researcher who is considering a faculty career, reflected on the process of grant funding and professors responsibilities to secure funding:

> I guess on top of that [not feeling confident in one's ability to secure grants], too, is that's your funding, that's your career that's also going to be supporting your students and that sort of rests on the fact that other people are going to be relying on you, their careers, their salaries, their livelihood are going to be relying on you, and that's kind of hard to have that pressure on you. (Lloyd)

Vince's feelings around the pressure and guilt echoed Lloyd's:

> I mean it's just a lot of uncertainty. It's almost like applying to grad school or undergrad every couple of months. I remember all that anxiety, "Am I going to get in, am I not"? It's quite a bit, and it's quite stressful. So you can write grants, but that anxiety of getting it or not is what really is something that would really turn me off to the position [a faculty career]. And just getting rejected over and over again is something that is terrible on your confidence because you feel like "Am I good enough?" And you start doubting yourself. So I think that cycle of what people envision the worst case scenario being a professor and going through that in your head, kind of puts you off. You just don't want to be a faculty because you don't want to be rejected or having to worry about the ability to fund your students or research every year. (Vince)

When describing the responsibility of grant-getting, Lloyd acknowledged the tension between his dislike for asking for money (i.e., grant-getting) and the reality of an engineering faculty career that requires him to secure a lab and students to work in the lab. In addition to the pressure he describes to secure funding for his own lab operations, he also described a feeling of guilt to ensure that he can fund students and support their "livelihood." Vince, too, talked about the pressure of funding students each year, but predominantly spoke to the anxiety-inducing nature of the grant-getting experience. It appeared from Vince's statement that his perceptions of the grant-getting process, likened to a constant admissions process, are overwhelming and potentially unhealthy.

While similar to Lloyd and Vince in describing the sense of responsibility associated with funding a lab and students, Sherman discussed the burden of turning someone away from the field of engineering through another aspect of the faculty role, the classroom experience:

> I kind of enjoy teaching but at the same time I don't want to be the cause of -- I don't know -- it would be hard for me to straight up fail somebody in a class even if they deserve it. I don't want to be the reason why they dropped out of Chemical Engineering and potentially ruin their lives. (Sherman)

Students' observations of Professor Houston's personal characteristics and activities created impressions about faculty work and the attributes of those likely to be successful in academic careers. In addition, the culmination of these perceptions of the faculty prototype provides students with subjective metrics by which to self-assess their competencies and alignment with a faculty career.

Self-Assessment of Research Competencies

As described by Blackburn and Lawrence (1995), the faculty prototype is developed through any combination of social interactions, vicarious observations, and selective reinforcement of desired behaviors by those in authority or as they describe to be "social knowledge." Further, the person constructing the prototype tends to turn to certain individuals for advice – those whose opinions they have come to value. The power of the prototype is that it motivates individuals to adjust their behaviors according to those they view as the prototype (Blackburn and Lawrence, 1995). In the current study, the faculty prototype influenced students to self-assess their competencies. To self-assess their skills, they compared themselves to the faculty prototype, and in some rare cases, to other students within the group.

To help shed light onto why Houston Group student members compared themselves to others and how their comparisons shaped their self-assessments, I turn to social-psychological literature. Festinger's (1954) social comparison theory has received considerable attention and several nuanced extensions have been offered to the original theory. While there are nine hypotheses (and corollaries) to the original theory, several scholars (for example, Blanton, 2001; Goethals & Darley, 1977) note that much of the contemporary research on social comparison theory builds on Festinger's first two hypotheses: 1) "There exists, in the human organism, a drive to evaluate his opinions and his abilities" (Festinger, 1954, p. 117); and, 2) "To the extent that objective, non-social means are not available, people evaluate their opinions and abilities by comparison respectively with the opinions and abilities of others" (Festinger, 1954, p. 118). In the broadest sense, Festinger (1954) argues that in the absence of objective measures to evaluate oneself, individuals compare themselves to others. For example, because there is no rubric or checklist during one's presentation during the full group meetings, one is forced to evaluate his or her presentation in comparison to the feedback received peers.

Social comparison happens at multiple levels. Individuals compare themselves to others (the literature refers to these others as "targets"; see Blanton (2001) for a thorough explanation) at their same level (Gibbons et al., 2000), to targets which individuals deem superior (i.e., upward social comparison) (Blanton, 2001; Hackett, Esposito, & O'Halloran, 1989; Lockwood & Kunda, 1997), and to targets that individuals deem inferior (i.e., downward social comparison) (Blanton, 2001).

Scholars might suggest that Houston Group students compare themselves to the faculty prototype because comparisons often take place when the target is performing what is perceived to be an achievable task of interest or between individuals doing comparable work (Blanton, 2001; Festinger, 1954). For instance, in my interviews, Houston Group student members did not compare their research competencies to peers in non-experimental groups possibly because the research skills, experiences, and expectations are different for students engaged in that type of research. Anderson and Chen (2002) might shed additional light onto why Houston Group students choose to compare themselves to the faculty prototype. According to these authors, individuals often target "significant others," which they define as "any individual who is or has been deeply influential in one's life and in whom one is or once was emotionally invested" (p. 619). Because students worked in close proximity to and on projects that shared common linkages with Professor Houston, they tended to evaluate their progress relative to his expectations, and in some cases relative to their fellow group members. In fact, Lloyd likened the social assessments from colleagues as a form of "peer-review" whereby one's work was consistently evaluated by experts (e.g., professors) and emerging experts (i.e., peers). In this sense, participating in research provided students with social evaluations on the progress of their developing research competencies and expertise.

Explicit comparisons of other students, shared with the researcher, were rare. This might have been the case because advanced students viewed their same-class peers as being at their same skill level, thus, rendering no comparisons. This is likely the case because some of the advanced students in this study did mention those they held in high regards, but those students graduated before the start of this study. This rationale, while speculative, aligns with that forwarded by scholars who discuss how individuals decide to whom to compare themselves (Anderson and Chen, 2002; Gibbons et al., 2000). Newer students may have been so new that they were still trying to understand what the group's norms and values were before determining who their "target" would be.

While competition did not emerge as a major theme across students, nor throughout an extended observable period in this study, the social comparisons mediated by weekly group and subgroup meetings, might have influenced a culture of competition whereby students wanted to give the best presentations, show the most impressive data, and receive favorable public reviews from Professor Houston and the leadership team. This conjecture aligns with Allen's statement that "The group is very competitive." He articulated a sentiment expressed by Professor Houston that "everyone in the group wants to be a star." Allen refused to discuss this further with me, but over time I gathered from other information that the superstar(s) in the group are the students who receive the most favorable attention and feedback from Professor Houston and the members of the leadership team. If this is the case, that explicitly comparing oneself to another team member is an indication of who one's competition is, then it makes sense why more students did not explicitly self-assess their skills relative to their peers. Nonetheless, when students did self-assess their competencies, they did so against the gold standard of research and engineering work, the faculty prototype. They tended to assess their abilities in two domains: competencies practiced within the group; and, skills they have not yet learned or well developed.

Research competencies practiced and well developed.

When self-assessing their competencies, a few students selected the skills they felt best aligned with the faculty prototype, those skills that would best align to a faculty career; that is, if they chose to pursue the professoriate. Some students self-assessed the competencies they felt most confident performing. Others chose the competencies that were most practiced in their research. It is also possible that because of "interview performance" (Atkinson & Coffey, 2001; Small, 2009) some students shared what they felt they should evaluate, or those tasks they deem are their strongest to report (discussed in full at the end of this section).

Presenting and doing research.

Within the Houston Group – and in Model University – the clear focus was on developing students' research competencies through independent research and presenting and defending one's work. Dr. Randall summed up the practices and activities of the group, and shared some of the outcomes that resulted from the group's focus:

> So in a year, let's say you have nine or ten times to give a presentation. So instead of just waiting for a conference and then you do a practice, you are constantly doing practices and preparing for those meetings and you're getting constant feedback from the group and your advisor. So, you are making better slides, you're giving better presentations, you're learning how to handle all those questions. (Dr. Randall)

Professor Houston did not allow students to quit on their projects, but rather required that they built the capacity to "figure it out" until the project had been adequately completed. Brielle referenced Professor Houston's leadership style when assessing the evolution of her presentation skills. She expressed her early reluctance presenting data to Professor Houston and peers, particularly if what she presented was not groundbreaking, the experiment failed, or if she could not make sense of the data. Despite her reluctance, she believes that being forced to present on a weekly basis improved her capacity to troubleshoot, persevere through the challenges of research, and ultimately led to doing "good research":

> I think [doing good research has] more to do with a lot of resilience. I would say that—because you face so much of this not being good enough, this not working, something breaking, and it's like you have to get over it…That's the most important skill I've thought is in the research. And some sort of honesty and ethics it should be -- whatever you get, you present that. It doesn't have to be pretty all the time. Although you get into the habit -- you have to generate data and present it. I used to never be able to present horrible stuff before, but now I present it every week, and week after week I'll show bad data and say "this is bad" or I show that this is reproducible, and I show that this is good… (Brielle)

Brielle described developing resilience through having to repeat experiments, trying new strategies to receive better results, and defending her work "week after week." She became so skilled at doing (and presenting) research that she was often described as "the one" who could be successful in a faculty career if she pursued it. Brielle's reluctance to present a briefing – and that of other members who were nervous prior to meetings – was understandable, after witnessing the "grilling" that took place during the feedback portion of group meetings. Students were self-conscious about their abilities to do research, and sometimes felt ill-equipped to share the status of their work, especially if the research was a new line of work within the group. Yet they learned that the "grilling" had a purpose as they observed more senior members, learned the unstated structure of presentations, how to respond to feedback, and routinely practiced presenting over time. As a result, Houston group members seemed to agree that "good research" was about getting answers, and that any answer, even from failed experiments, still advanced one's research.

The practice of presenting one's research and offering briefings reinforced students' comparisons, which in turn shaped some students' self-assessments. For example, Vince compared his shorter presentations to Allen's lengthy talks: "He [Allen] goes through all his data when he presents in subgroup or group meeting. Other people take 15 minutes, he takes 40 minutes; he wants to point out every observation he has." Vince attributed Allen's pattern of routinely going over in his allotted time to the fact that Allen always had ample data. Yet, while Allen tended to go over in time, he often received favorable feedback on his data and presentations. Furthermore, the practices of the Houston Group (e.g., giving and receiving constant feedback) triggered students to self-assess the match between their abilities and perceived demands of faculty life. Vince noted that Allen's presentation skills are representative of one most likely to pursue a faculty career. He drew these comparisons to Allen because as a new member of the group, Vince was trying to decide whether to pursue a faculty career:

> I think one of the things that Allen does is he would always try to have a comeback to every question or every suggestion, while others might just take the suggestion and sit down, and that's why he takes so long in the group meeting because he tries to come back, sort of like the…to critique is something I think I can see a faculty doing. (Vince)

In the examples above, Vince ponders how Allen exceeds his allotted presentation time, yet still receives praise for his presentations. He assumes that Allen is acting like a faculty member, presenting all of his data, actively challenging all feedback he receives, and being "showy." Vince discussed how faculty members are "egotistical" and "like to show off how intelligent they are." He ends by aligning himself to Allen and the characteristics of faculty members by admitting that he, too, has a bit of an ego, and that "I would like to be acknowledged as a good grad student or a good researcher, that would be nice." The social psychological literature provides some possible rationales for Vince's comparison to Allen. From a social comparison perspective, Vince, a first year student at the beginning of data collection, considers Allen, a second year student, as a target for whom he aspires to emulate. Because of Vince's desire to adjust his behavior to achieve some of the acknowledgement that Allen receives, the social comparison literature would consider that "upward social comparison," whereby an individual may self-enhance his or her behavior if it will raise their self-evaluations and perceptions of others (Blanton, 2001; Hackett, Esposito, & O'Halloran, 1989; Lockwood & Kunda, 1997). From an alternative, social-cognitive perspective, we might speculate that the nature of feedback from Professor Houston and "significant others" "primes" (i.e., triggers implicit understanding) students to learn what is acceptable and unacceptable during group meeting presentations. These primes, whether intentional or not on the part of Dr. Houston, could shape students' perceptions of what faculty do, perhaps creating in their minds a faculty prototype (described more fully below).

The example offered by Vince and Allen fit with the prevailing views on social comparison and priming relationships. Specifically, Vince may have considered Allen a significant other because Vince is also considering a faculty career. Festinger (1954) noted that individuals predominantly compare themselves to targets in positions they aspire. For other students not interested in academe, comparing their performance on a group meeting presentation to that of Allen may not be as relevant.

Leading a research group.

Gloria participated in two research groups, and consequently had responsibilities to two teams. In the earlier years she also juggled coursework and research responsibilities. Whereas some students were concerned with their abilities to lead a research group, Gloria did not feel deficient in her leadership skills; she was confident that she already had the leadership skills to run a research lab:

> I hate to be all cocky and what not, but yeah, I think I do [fit the description of an ideal professor]. As you get older you get more responsibilities, you're the go to

> person on equipment, and you're doing more logistic stuff for the group. So I think just being a part of the group and progressing through it. And then like I've said, I've watched them [her co-advisors] and I've seen them for the past three years kind of day in and day out, so I know a little bit more of what that [being a professor] entails. (Gloria)

Gloria's quote highlights how students developed competencies over time. Gloria believed that she fit the mold of what it took to be an engineering faculty member because of her abilities to balance multiple responsibilities (i.e., research, teaching, and service). Within the Houston Group, she took on several important leadership roles that helped the group function and was most recently in charge of lab safety, a task that she acquired only after another senior member departed. Moreover, she was confident enough in the research competencies that she had developed and was refining that being successful in a faculty role seemed achievable.

Research competencies not yet learned or strongly developed.

As students' shared their perceptions of faculty work, they often described what was "missing" from their Houston Group research experience. These perceptions of faculty and faculty work appeared to be, in large part, framed by their observations and interactions with Professor Houston. Students respected Professor Houston, his record of grant funding, his passion for his research, and his student-centeredness. Allen and Eric, for example, selected this research group specifically to work with Professor Houston. Moreover, because of Professor Houston's traits, many of the students appeared to consider him to be a "significant other" to whom they chose to evaluate themselves (Anderson & Chen, 2002).

Students' admiration of Professor Houston, led them to value his opinion and his evaluations of them. The evaluations from the "significant other," according to Anderson and Chen (2002) and other scholars (Baldwin, 1992; Baldwin, Carrell, and Lopez, 1990), shape how individuals self-evaluate themselves. These self-evaluations involve a process of reflected appraisal whereby individuals consider how their significant others might evaluate them. According to Phillips and Russell (1994) this is not uncommon; doctoral students use their faculty models in efforts to assess their research abilities. As described by Phillips and Russell, students cumulatively learn about research from their advisors when they are progressing through their doctoral programs and are productive in research (e.g., completing [master's] thesis, working on dissertation, submitting journal articles, gaining article acceptance). This suggests faculty advisors, and the work of faculty, help to shape students' perceptions of the professoriate. It also suggests that observing, interacting with, and participating in research with one's advisor form the faculty prototype for students to emulate or reject.

Developing an innovative research agenda.

For many of the students in the Houston Group, being an engineer meant addressing a problem. Those considering a career in academic research or the professoriate, however, suggested that being successful in an academic career required one to "innovatively" (and proactively) identify solutions to problems. In order to be innovative in one's area, students asserted a need to be an expert who knows what research questions have been asked, what questions can be answered through research, and how to address these new innovative questions. Houston group students believed that once one has a "ground-breaking" and "innovative" research agenda, grant funding to support the research endeavors would follow.

Erik and Allen, both at the same stage in their doctoral program, admitted having concerns about developing new innovative studies within a research agenda. Erik stated: "I can't take some things I read in literature and completely spin it into a research project that I could write about or write grant for say as a professor." Allen, on the other hand, admitted: "I like to ask questions," but suggested that his concerns lay in the nature of the questions asked (i.e., have the questions previously been asked; can the questions be answered through research), and skills he had not yet acquired. Erik went a step further to suggest that because the field champions innovation, and because he is not confident in his ability to create new groundbreaking work, he could not see himself as a professor:

> So part of bringing in money is being able to find research that will give you success early to get [more] money to fund the more intricate projects …part of the reason I don't want to pursue the professorship, at least in my personal opinion right now, is because of my worry of that – of finding research areas that I know I can – I don't want to say succeed in, but I know can play a part. Because most of the well-known professors have a research area that at least in [Model University] that they are in the top at – like basically they control – I don't want to say control but…they play a big part in advancing the research in a certain science. (Erik)

Like other Houston group students, Erik benchmarked his current skills against those of Model University faculty whom he described as experts "control[ing]" and "advance[ing]" science. Students like Erik tended to self-assess their research abilities relative to the models they saw (e.g., Professor Houston) who routinely received recognition from Model University and secured grant and corporate funding based on research innovation.

Publishing.

Despite the significant emphasis on presenting and doing research, students did not mention publishing as a competency they learned in their research group; yet, they viewed writing and publishing as skills they would have to develop in order to secure grant funding and achieve tenure.

Students across experience levels (i.e., first years through the most senior group members) described their concerns about publishing. Vince, a first year doctoral student at the beginning of data collection, acknowledged that being able to publish would increase confidence in his abilities to do research. For him, publishing was a signal that you had adequately "convinced" the public of the importance and soundness of your work:

> I think [research] communication skills is one of the biggest things. I personally think I need to work on writing communication skills and to be able to convey what I've done and to convince people, and to convince some of the doubters, or convince the scientific community that what I've done is correct and should be applied. (Vince)

To this, he added his understanding that prospective faculty members had to be published in order to be competitive. So not only was publishing an act to build his confidence in writing communication skills, it would increase his confidence that he could be a competitive applicant in the faculty job market:

> I think that's what schools look for in faculty is to publish enough papers, to show that me and other people that what I do is actually important and can have an impact and should be looked at. So I think that would help me to gain a little more confidence of my own research work. (Vince)

Allen, a second-year student at the beginning of data collection, was confident about doing research and presenting his research, but not about publishing, and that concerned him:

> So, I still have a lot to learn. I don't really have any experience; I didn't even publish a first paper, yet, which I am working on right now. But I don't know anything about that and that's a whole experience on its own-publications, you know? So, writing papers, know[ing] what to put in the paper, know[ing] what not to put in the paper, know[ing] what kind of paper can be published or not be published, that's a whole department on its own. (Allen)

It is important to note that publishing in the Houston Group appeared to be related to a student's class standing. For instance, my observations and interviews suggested that new doctoral students created posters to share the group's findings, while more experienced students took on greater writing tasks for conference papers and manuscripts. So, while Vince and Allen explained their lack of publishing experience, as newer members of the group, it would be unlikely that in the first or second year of study they would be publishing.

As indicated by the quotes above, students like Vince and Allen commonly identified writing and publishing research as a competency that was not well developed during their graduate research experiences. Dr. Randall, the group's lab manager, agreed with students' assessments that to become a successful faculty member they must be prepared to write and publish their work: "Writing would be very important [for a faculty career] because if you're doing research you have to communicate through either oral presentation or through journal papers, and writing papers is very important."

While required by the Chemical Engineering department to publish at least one paper as a condition for the Ph.D. degree, students' concerns were not in their ability to publish a paper or two; rather, their concerns lay with the practice of consistently publishing and producing a substantial body of work that would gain them success (i.e., tenure and promotion) in a faculty position. Allen believed that assistant professors were more likely to push their students to publish, because assistant professors have to publish to gain tenure:

> [To publish as a doctoral student] you need to work with a professor that is just starting off his career—an assistant professor. An assistant professor needs to work as hard as you do, maybe three or four times harder. And assistant professor needs to publish as much as possible because he wants a tenure track. So he needs

> to make sure that his record is legit. So, therefore, he will make sure that you publish. (Allen)

Tenured professors, he believed, were more laid back: “Someone who is tenure[d], who is kind of laid back, has a lot of publications, has nothing to worry about.” Allen concluded by subtly relating his lack of publishing experience to what he perceived to be Professor Houston’s emphasis on industry preparation versus faculty preparation (i.e., publishing): “if you really are a guy or a student who likes to go into industry, doesn’t care much about publication you will work with someone like Professor Houston.” Although he described many of the skills he was developing from Professor Houston’s teaching and mentorship – as well as crediting Professor Houston for his interest in becoming a faculty member, Allen suggested that publishing was not the main focus of the Houston Group and that working with a different professor might better prepare him for a faculty career.

Grant funding.

Student participants were unsure about what tenure was and what it entailed, but they had some sense that in order to achieve it, one must get published. Grant funding was always coupled with one’s perceived abilities to generate innovative research ideas that could lead to financial support for one’s research, and/or one’s ability to secure the necessary funds to open and maintain a research lab. Further, they understood that in order to get published, one must secure grants to fund his or her research lab and hire graduate students.

Professor Houston agreed, saying “You can’t run a group and you can’t do research without funding, and you can’t publish papers without funding. So it’s a legitimate concern.” Erik said:

> Without grant money it's hard to – I mean I don't know the whole deal with getting tenure and what not, but I know that getting grant money is a huge part of the research group and in order to have a research group you have to be able to bring in money. (Erik)

Erik also described a symbiotic process between research, publications, and successful grant proposals:

> Basically finding a research area that will be productive…will give you – I don't want to say immediate success nothing is immediate success in research – but it will allow you to publish and start to get grant money soon after you start. (Erik)

Students knew that grant funding was important because they were all fully funded thanks to the grantsmanship of Professor Houston. Additionally, there were occasions where students were asked to provide written updates on their current projects so that Professor Houston could include those preliminary findings in new grant proposals. Beyond those activities, several students agreed that they had a very limited understanding of the grant funding process. Emma and Allen even admitted that learning to write grants was a competency they would like to learn, have not learned, and "if" pursuing the engineering professoriate, it was a skill they would need to demonstrate:

> One of the things that I like to have experience[d] if I want to be a professor is writing proposals. Those are the experience[s] I have not done and those require [me] to come up with new ideas and to explain how important it is and how valuable this research will be to those people who are supposed to give us money. (Emma)

She explained that grant writing included learning how to describe the value of one's research. Allen, sounding somber, similarly described the utility of learning how to secure funding beyond paying for one's research:

> Writing grants, how to get money, how to make things attractive, how to talk to people, that's a whole department on its own that I haven't mastered yet, I haven't even started learning that, yet…so I am not ready [for a faculty career]. (Allen)

While similar to the competency students developed by presenting at group meetings, Emma and Allen argued that grant writing was not the same skill; there were higher stakes and different skills needed (i.e., making your work attractive to other people, selling your research ideas to grant funders). For Emma, these were skills that she did not learn as a doctoral student in the Houston Group and had yet to learn as a postdoc in the group; and they were also skills that Allen was hoping he would learn before he graduates.

The ways in which faculty members conduct research and prepare students is often consistent with how they are prepared in graduate school (Lee, 2008; Pearson & Brew, 2010; Strauss, 1961). This suggests that graduate preparation and research experiences are mirrored and include a form of pedagogical lineage steeped in tradition (Zuckerman, 1977). According to Professor Houston, however, this was not the case for the design of the Houston Group. At the conclusion of data collection, he shared that many of his group design decisions were counter to his own doctoral research experiences. As it related to funding, Professor Houston shared that he vigorously pursues grants because his doctoral research group in graduate school was underfunded, and he and his peers were always stressed about money. As a result, he admitted to trying to shield students from the grant funding process as to not stress them out about the process, but reflected on the potential downside of this approach:

> I hope they don't see the stress of it [grant funding] because my goal is that they would never be in a situation where they are worried about funding…maybe I should be a little more deliberate in showing them the grantsmanship side. I do share proposals with them, so that's a piece of it…I guess I could do things a little bit differently to expose them to some of the stress, but I just remember when I was in grad school we didn't have a lot of money, everything was watched very carefully, and I didn't like that. (Professor Houston)

Professor Houston's reflections highlight important insights into the design of the Houston Group. What he did not consider was the potential unintended consequence; that students were stressed about – and uncertain of – their abilities to fund their future research (if they were to become a faculty member) because of the mystery of the grant writing process. For Houston Group members, grant funding was a realistic component of doing research, and as such, was a competency they felt they were missing because they had not been deeply exposed to the process.

It is important to note that in this group, according to the students and Professor Houston, grant writing is important, but is a separate activity from doing research. There appeared to be some overlap, for instance when students' research updates are solicited and used by the leadership team for grant applications. But because Professor Houston seems to distinguish between grant writing and conducting research, grant writing is not always seen as intellectual work, which may also be communicated to the doctoral students.

Mentoring and advising students.

Vince, Emma, and Erik believed that supervising students gave them insights into how faculty members were responsible for advising, mentoring, and motivating students. To assess their skills in these competencies, students benchmarked their current abilities to their perceptions of the best engineering professors. For example, during Vince's experience mentoring a summer student, he was frustrated by his perceived failure at motivating his undergraduate researcher. Thus, when self-assessing the gaps in his competencies, he described needing to be a better advisor and/or mentor who can motivate his students to participate in his research:

> If I had undergrads to mentor such as now or down the road, and [they] have learned something, or decided to go to grad school, then I would say "that's a success, I have piqued their interests, and it would be nice to publish with them together on a paper." That would show that I not only know enough to publish but I also brought someone on board in this project; and one or two of these students might be nice. I would measure my [potential for faculty] success on that. (Vince)

Vince was measuring his potential success as a faculty member based on his capacity to bring students "on board" of his projects; selling students on the research, publishing with students, and even influencing them to pursue graduate school would be by-products of his mentoring. Vince's reflection was influenced by his own research experiences (he was co-advised and both of his research groups had multiple students; the Houston Group being the larger group of the two).

Similar to Vince, other members reflected on what they learned about themselves through the experience of supervising others. Erik and Emma both realized that they distrusted working with others, which prompted them to be micromanagers. Emma was particularly concerned about the results produced by her undergraduate researchers. That is, she assumed that what her undergraduate researcher produced would be flawed. As a result, unlike Vince who let his undergraduate researcher choose what tasks he wanted to complete, Emma determined what work her undergraduate researcher could produce based on what could be quickly fixed if it were wrong.

> I usually cannot trust other people's work; I like to have control over everything. I didn't know that until I get undergraduate assistants (Laughter)… And for a professor, it's not only one assistant, it's several. So it's got to be difficult to do that I imagine. I also don't like to put a lot of pressure, I usually try to be nice and if the person don't do it, I usually think it's just easier to do it by myself…I think I tried, yeah. I guess first, you have to have good mentoring and at the beginning it is key—you build the trust between these people so that every time they have some issue they can quickly report to me and even more things will happen. I also categorize not so much important work that I can quickly fix if things go wrong or things you can screw up and try to put these tasks to undergrads. (Laughter)…To

> come up with something that's manageable. I always have in my brain "ok, this is mine, and this, others can do." (Emma)

Emma assertively described her supervisory style without regret: "this is mine, and this, others can do." She explained that the ways in which she managed students allowed her to stay productive and efficient with her projects, even if it did not offer a broad range of research experiences for her students. In contrast to Emma, who appeared to be set in her approach to supervising students, Erik acknowledged needing improvements in his supervisory skills:

> I have to admit that's one of my faults, it's the fact that I tend to – I don't want to say micromanage, but I tend to always want to do things myself. And having an undergrad student was a huge growing experience for me because of the fact that I had to literally give her things to do and just let her go and do it and not always be looking over her shoulder and see if she is doing it right. In that sense I don't do what I would want my professor to do. (Erik)

Erik recognized that he micromanaged his undergraduate researcher and he even named it a "fault." He appreciated, however, the supervision from his own research professors; he learned to do research by being hands on and having the space to make mistakes, yet he did not provide his student with the balance of independence and oversight. In reflecting on his experiences managing other students, Erik described the ideal engineering professor as one who did not micromanage students, but rather allowed students to try.

Research communication and showmanship.

Group members often described Professor Houston as charismatic and inspiring when he was describing his research and the innovative work of the Houston research group. In fact, several students recalled, as prospective doctoral students, listening to Professor Houston share the cutting-edge work being done within the group. Allen, for example, remembered being enthralled with the possibility of participating in the work of the group:

> When I talked to Professor Houston [during recruitment] he explained his research and I mean – all of a sudden I fell in love with what he was doing; the way he explained his research, the way he talked, it was so attractive and he talked about things that he did, that he was doing, that he was about to do, and it was so innovative and interesting. (Allen)

In this way, Professor Houston was an example of the ideal professor:

> [The] Ideal professor would be…a professor who is very passionate about their research, cares a lot about the research, is willing to discuss research and put forth ideas, argue bad ideas, etc...I mean that's kind of actually what lead me to want to work with Professor Houston. (Erik)

Professor Houston's sales-pitch convinced prospective students – like Allen and Erik – to join the research group. But there was another result from Professor Houston's example; students assessed their abilities to communicate his or her research based on the charismatic example set by Professor Houston.

Notwithstanding students' confidence in presenting their work at group and subgroup meetings, students described a more high-stakes competency of "selling" their research or getting "buy-in" from audience members about the importance of their research. For example, self-assessing his abilities to communicate his research to others, Danny admitted: "That [effectively communicating my research] has been a little troublesome for me and its something I could really work on to make it even better, I think." Students assumed that part of the way to become more convincing when describing their research was to – like Professor Houston – be more passionate and motivating:

> …you have to be attractive, you have to find a way to talk about your work in such a way that it motivates people. You have to motivate your student, you have to be optimistic, you have to be realistic, you have to have a vision, you have to

> have a dream; that driving force is what drives students. If your student sees you with a big dream that would motivate them to do more…that's the way I see it and that's who I want to be when I become professor, that's how I will do it. (Allen)

Like Erik, Danny, and Allen, students did not describe themselves as bad presenters or communicators, they simply acknowledged that their benchmark was Professor Houston. And to acquire this skill, they had to – in part – improve their abilities to convey their passion for research.

While students described the skill of inspiring others through research communication as "passion," Professor Houston described the skill as "showmanship." In fact, he agreed with students that new faculty members will need to "sell" their research in order to be successful in a faculty career:

> There is a bit of – I mean today – sort of showmanship – the people that are considered the most successful typically have some skills in marketing what they do and marketing could be any number of ways – the way you present, making sure that you send information to people that would ultimately – like the popular press gets wind of things if you consistently send things; we have an office here and they find ways to get it into the popular press. So that's another element that I am not really good at and I am not really a fan of, but it is what it is. (Professor Houston).

Ironically, while students described Professor Houston's "showmanship" as one factor that led them to his group, Professor Houston did not believe he demonstrated this skill himself. In fact, Professor Houston self-assessed his own competency of showmanship and suggested that because he is not particularly strong in this area: "I don't help them very much [developing the showmanship competency] because that's just not part of me." While he did use a website to market and publicize the group's work, he was aware of the increased dependence on other sources (e.g., social media, press).

Teaching.

My interview protocols focused on members' research experiences and preparation for faculty careers, which explains why the majority of my conversations with students related to their participation in and learning about research in the Houston Group. Nonetheless, some Houston Group members raised the issue of teaching. Lloyd contended that while students did not practice teaching in the group, the activities of presenting and discussing research improved their communication skills and abilities, and thus prepared them to teach. He drew linkages between his research experiences of presenting at conferences and being successful at teaching:

> I think I'd be a pretty good instructor. Honestly, I am not worried at all. I mean, I go to conferences and stuff like that, and in that case I am actually being judged by people way more experienced than me. So being in front of a classroom, they know I know more than they do, at least they should. (Lloyd)

Lloyd's view of teaching appeared to mirror conference presentations whereby information was transmitted from speaker to audience. He compared a classroom of relatively inexperienced students with the engineering experts he encounters at conferences, assuming that because the students lack expertise, he could teach them. The lack of exposure to intentional teaching seemed to limit Lloyd's view of instruction.

While some others agreed that presenting in the research group could translate to teaching a course, Allen and Vince did not feel as if they had received enough preparation to teach courses. Neither Allen nor Vince had served as a graduate teaching assistant by the time data collection ended; this might explain – in part – why Allen felt unprepared for the role of teacher, but he also suggested he simply did not yet have the requisite knowledge and practice base:

I haven't challenged myself enough, yet. So I cannot stand in front of a group of

> fresh brain[s], fresh mind[s] right now and educate them right now. I still have a lot to learn. I mean, not only the knowledge but given the wisdom, I still have a lot to learn. (Allen)

Like Allen, Vince raised issue with his content knowledge:

> The hesitancy is I don't know if I've done enough – I don't know if I've done enough to be teaching other people about engineering…I don't know if I have the experience enough. So that's the hesitancy – if I know enough to be telling other people what to think about a topic. (Vince)

Allen, Vince, and Lloyd seemed to define teaching as providing information to an audience of students. More research and presentations would, in their estimation, give them what they needed to be good teachers. In addition to Allen and Vince, several other Houston group members were uncertain about their abilities to teach. Their explanations, however, were not related to lacking content knowledge; these international students were uncomfortable teaching due to their self-assessed language skills (see more later in this chapter).

Imagining Faculty Careers

Part of students' considerations whether or not to pursue the professoriate included the negotiation of what faculty do and who becomes a professor. Professor Houston served as a prototype of an individual who did both: he successfully runs a research group in the University as well as an engineering company. The nature of the research experience with Professor Houston appeared to expand what students consider to be their professional options. With these options (i.e., faculty, industry, or a combination of the two), based off of Professor Houston's model, students contemplated whether or not they currently embody their perceptions of a professor.

Scientists and engineers.

Four Houston Group members framed their career intentions around their evolving professional identities. Their beliefs about their Houston Group research preparation shaped their perceptions of the nature of scientific and engineering work. Embedded in participants' discussions of their career intentions were ideas about what it means to "be" a scientist or engineer, and what it means to "do the work" of scientists and engineers.

A few students appeared to distinguish between (and adopt professional identities of) scientists and engineers based on where the work is done and how that shapes what is produced in those careers. Lloyd claimed that scientists working in the academy are "interested in" and create "knowledge," whereas, engineers working in industry create products that can be sold. During his second interview, Lloyd told me that he leaned more toward a faculty career: "I am more interested in knowledge for knowledge sake and I am not as interested in coming up with this great idea that I can sell." Emma's distinctions between scientists and engineers were similar to Lloyd's: "Industry – you don't necessarily get the dissertation research that you are interested in, and you may work on something profitable for the company." Emma, who worked as an automotive engineer in industry prior to enrolling in graduate school, enjoyed working in the Houston Group because it allows her to choose a dissertation topic where she was able to identify, understand, and create new scientific knowledge. Although she recognized that she might not be able to choose a scientific topic (i.e., "dissertation research") that she enjoyed if she returned industry, she was strongly inclined to return to industry.

Emma and Lloyd agreed that engineering work results in the production of something. For Emma, the opportunity to develop a concept was more appealing as an engineer because she would not have to worry about securing funding, which a scientist might have to consider. She explained: “Well for me, I'd like to put those efforts of challenge toward developing materials…at least [as engineers] you get some engineering or research work without worrying about those fundings. I guess I enjoy more that part.” Engineering work, however, provided her the chance to do what she liked, “developing” and engaging in some aspects of “research work.”

When asked, some members of the Houston Research Group described the work of scientists and engineers by explaining how both work in tandem. For instance, Kelcy, the engineer working in the group, first described scientists as doing “pure science” while engineers try to apply the knowledge created by scientists. Yet, he also acknowledged the “overlap”: “I think there's a lot of overlap. There are a lot of people who think they are scientists who get really far towards the engineering end of the spectrum, just like with engineers who are more focused on pure science, too.” Like, Kelcy, other students in the Houston Group saw the roles of scientists and engineers as related and intertwined, a few said they were different. The complexity lies in “how” students took what they perceived to be the roles of scientists and engineers (i.e., what scientists and engineers “do”) as a means of defining their professional identities of scientist, engineer, or both (e.g., because I perform and “do” this role, I “am” a scientist, engineer, or both).

During data collection, Lloyd was caught between interests in both science and engineering, highlighting the complexity of separating careers from being scientists and engineers:

> Well – it's weird being a chemical engineer because it's "engineer" in the name, and we are not chemists but we are not really engineers either. Our work is kind

> of chemistry, kind of material science, but focused more on a little bit closer to actually building stuff. (Lloyd)

Lloyd's second interview concluded with his suggestion that he identified with and participated in work perceived as "science," thus, more closely aligning him to that of a faculty member: "I guess probably as I am edging toward academia, and I think of myself more as a scientist – that seems more like my mindset." Yet, he still offered an example of how his work and interests blended into what he previously described as the work of engineers:

> It's a lot easier to explain that I am a scientist because that's what I do; I am in a lab, I do science and, I guess part of it is that's how I identify myself and maybe that's because it's a lot easier to identify myself to other people, and you say "scientist" and you know I am in a lab making stuff, testing stuff," as opposed to an engineer which could mean all sorts of different things. (Lloyd)

In Lloyd's quote above, he suggested that he was a scientist because he "does" science. Later, however, he said, "A scientist is someone who thinks he's a scientist." His statements appeared to suggest that he identifies with both which may be a result of his work in the Houston Group and previous industry experience. As a post-doctoral researcher, it is possible that he understands, in a way that other students may not (yet), that the Houston Group students are being broadly educated in research.

Lloyd was not the only one struggling with the difficulty of distinguishing the work of, and adopting the professional identity of, scientists and practicing engineers; Vince, too, wrestled with making distinctions, and decided not to distinguish between the two: "I don't have preference, so to speak. The scientist in me wants to see – or the engineer in me wants to see the thing perform, and I think both of them want to see what I came up with." Vince suggested here that the purpose of the work of scientists is to investigate problems, and that engineers use the knowledge created by scientists: "A scientist seems to look at very fundamental problems, but the solution to these problems might have far reaching impacts and an engineer might be someone that kind of makes that happen, and makes the impact happen." Vince continued on to explain that, "the lines between an engineer and a scientist is blurred." Vince continued on to describe the complexity of distinguishing between scientists and engineers:

> Now that I am in grad school I kind of feel like I am doing both at the same time and looking at fundamental problems and then, "Ok, so this is the solution." And then I will apply it immediately, I wouldn't hand it off to engineering to do it; I am the scientist and the engineer, and I would make that transition myself. (Vince)

Vince found it challenging to distinguish the work of scientists and engineers because he believed that his research experiences blended the two. Although Vince contrasted the "impact" of research and where it took place, he later explained that because his role as a graduate student included both looking and finding a solution, then applying the solution, and thus he viewed himself as both a scientist and engineer. His understanding may be more complex than that of other students due to his participation in two research groups, where the practices and activities – and the nature of the research experiences – were qualitatively different.

I offer two different interpretations that, with further study, could help explain Vince's refusal to choose just one term to describe his work and himself. First, his attempt to create a hybrid professional identity suggests that he is activating agency in managing his professional identity. While acknowledging that external forces affect individuals' constructions of themselves, scholars, Brown & Kelly (2007) also argue that individuals have agency in determining "who they understand themselves to be" (Brown & Kelly, 2007, p. 285). According to both Brown and Kelly (2007) and Shanahan (2009), one way individuals can demonstrate their agency is by choosing to participate in certain practices over others. This allows individuals to "construct identity rather than act in accordance with an imposed identity" (Shanahan, 2009, p. 45). In the case of Vince, he chooses to participate in and identify with the practices he perceives to be associated with both scientists and engineers, thus rejecting the need to choose one identity over the other. In other words, it is not as much a matter of whether to choose between scientist or engineer, but rather, what kind of professional does he want to become (that blends both the work of scientists and engineers).

While it is possible that Vince is exhibiting agency in developing his professional identity, an alternative explanation could be that Vince, a second year doctoral student at the conclusion of data collection, has not reached the point in his graduate program where he is actively thinking about and preparing for a career. And because he is still a newer graduate student, his agency might be working in tandem with naiveté. That is, if there really is a "faculty prototype" that is rewarded in the Houston Group, or on a larger scale, Model University, perhaps Vince has not learned what this prototype is or how to perform the practices associated with it. This alternative explanation is plausible, especially given existing research on students developing professional identities within the second stage of the doctoral process (after completing one's qualifying exams and dissertation proposal, but before passing the dissertation defense) (Baker, Pifer, & Flemion, 2013). Longitudinal research is needed to explore how students' identity and agency interact as they progress through their doctoral programs.

Kelcy echoed Vince's descriptions of the purpose of the work of scientists and engineers: "I guess I see scientist as a pure science kind of thing, whereas, an engineer is taking pure science and trying to apply it." This definition of the work of scientists was similar to Vince's description of scientists as looking for "fundamental problems"; for Kelcy, scientists seek to learn about the "mechanism" of how a process works. He provided an example of the continuum of science and engineering by applying his definition to his work and that of Allen:

> I see almost what Allen is doing as pure science because he is really trying to get in there and understand the mechanism of how these materials store charge. And then I see what I am doing with them as a little more engineer-y where I am not necessarily concerned of about that mechanism; I am aware of it, but I am really wanting to just utilize it and make some sort of device. (Kelcy)

It is notable that Kelcy is somewhat of an outsider in the research group. While he holds a bachelor's degree in engineering, and had the research background to run experiments and build equipment like other students in the Houston Group, he was not a doctoral student in the group. As such, he was not bound to all of the departmental requirements and practices and activities of the group. Kelcy's time was actually split between the Houston Research Group and Professor Houston's private company. Ultimately, despite his attempts to clearly distinguish the work of scientists and engineers, he ended by articulating a continuum of scientific and engineering work.

Alignment with faculty careers.

What students came to learn and perceive about faculty careers, as a result of participating in the practices of the research group and through interactions with group members, sometimes aligned with their personal values and desires. The alignment of their perceptions and knowledge about what it means to be and do the work of faculty influenced students' intentions to pursue the professoriate.

Allen's identification with being a Black male plays a role in how he experiences graduate school, perceives who comprises the faculty role, and his intentions to pursue the professoriate. He admitted that having an advisor of the same race helped mitigate some of the challenges and pressures of being underrepresented in engineering:

> It feels good [to have a faculty advisor of color] in the sense that at least that part of racism is out of your mind. I don't think about racism when I work with people with different race…But at least having the same kind of advisor who's the same race, you don't have to deal with that and that takes off a lot of pressure. (Allen)

Allen's interpretations of how race operated in his experiences are complicated. On one hand he acknowledged that he did see race, and on the other hand he tried to suggest that race did not matter. While we see Allen grappling with the complexities of race, he explicitly acknowledged the benefit of having Professor Houston as his advisor.

During the third month of data collection, I attended the group's annual holiday party at Professor Houston's house. While sitting next to Allen at the kitchen's bistro table he passionately described how being in Professor Houston's "beautiful house" and meeting his "beautiful family," all while bringing the group together in the informal setting, was inspiration and motivation for him to pursue the professoriate. Because of his interactions with and observations of Professor Houston, Allen, too, communicated his passion for conducting research, gaining recognition for discoveries, and mentoring students.

Even though the group was racially and ethnically diverse, rarely did Houston Group students explicitly describe what it felt like to be an underrepresented student of color in engineering, let alone within the context of their research group. While it is not evident how many Houston group members "see themselves" when they see Professor

Houston, it was evident that Allen views Professor Houston as more than an advisor, but as a vision of his future self as an engineering professor.

Allen was not the only student whose image of the professoriate aligned with his own values and desires, Ralph also holds an image of a professor that aligns with his own, that of his father. Both of Ralph's parents have Ph.D.'s. In fact, because his parents are professors, Ralph feels more knowledgeable about the expectations of a faculty career: "Actually, my father is a professor at a college, my mother is an assistant professor, they are both teachers in a college. I think that's the reason [why I want to be a professor]. So I know what this job looks like." As it related to his interest in pursuing the professoriate, Ralph viewed his father as a model of what the professoriate entails. Compared to many other Houston Group members, he was less concerned with aspects of the faculty career, such as grant funding; from his observation, his father is a successful professor and grant funding "is not a problem for him."

Ralph's model of an engineering professor, who looked like him, also helped him negotiate some of the barriers that might prevent others from pursuing a faculty career. Ralph pointed out that while his English skills were not strong for an American audience, if he were to return to his country of origin as a professor, his communication skills would not be problematic. He reported: "My English skills ability is important for me, but also really challenging for me…if I am going to be a professor in [my country of origin or a nearby country], this language is not even a problem for me." In addition to language barriers, when asked to describe what a professor looks like, he first described what he perceived to be the typical American professor: tall, White, male, with a deep voice, and white beard. Then, in contrast, while sitting at a secluded dining table looking out the window and pointing at other Asian students, he described what a faculty member in his home country looks like: “[Someone with] Glasses – um, I think just like the students we see on the street here; It’s not really uncommon. It’s just like every people we see.” His statement about what a faculty member in his country looked like is significant; where he is from, all faculty members look like him. Thus, it is not challenging for Ralph to envision himself as a faculty member when he sees himself reflected in his parents and other faculty in his home country.

Misalignment with faculty careers.

Participating in research practices, while also interacting with and observing faculty, also helps students learn which of their personal values, skills, and desires do not align with faculty careers.

For example, gender underrepresentation in engineering had an effect on at least one member’s pursuit of the professoriate. Tiffany linked her underrepresentation to what she perceived as the challenges of women professors: “I heard that lad[y] professors in engineering is in general a minority group. One of my friends who just started in a faculty position, she feels very lonely being a lady in the department and I have some concern about that.” Similar to female participants interviewed by Gardner (2008a), Tiffany’s uncertain intentions to pursue the professoriate were in part shaped by what she saw and heard about the experiences of women in faculty roles.

In another example, many Houston Group students praised Dr. Houston for his ability to passionately speak about the group’s research. It was his communication skills that several students described as their motivation to want to work in the Houston Group. Their recognition of the importance of communication in a faculty career prompted several students, all international students, to consider how much improvement would be needed to become a successful professor. While Ralph was not deterred from pursuing a faculty career, he was cognizant that it would be more challenging if he were a professor in the United States. Two other international students were not as confident in their abilities of being successful in faculty roles given heir language skills, which in part shaped their intentions in pursuing a faculty role. Tiffany described her communication skills as a barrier reducing her competitiveness on the faculty job market: “I would have some disadvantage compared to my other competitors, and all of this will make me feel hesitant about it [pursuing a faculty career].” Emma shared how teaching undergraduate students shaped her professorial intentions: “[I had] bad experience when I did the [graduate teaching assistantship]…It was very difficult to teach – English is not my first language…I felt [a faculty career] wasn't for me.” Despite the practice students receive by regularly presenting their work to the group, Tiffany and Emma’s language skills influence their assessment and intentions to pursue faculty careers because they perceive successful faculty as having communication competencies that exceed their current skill level.

Another clear perception about faculty careers that misaligned with students’ values and desires related to how busy professors are. For some students, the nature of faculty work, including all of their responsibilities, appears to conflict with students’ values and desires for work-life balance. When discussing that group members have conversations about careers, Allen recalls talking to Brielle about her interests in the professoriate versus industry:

> Even Brielle, when she first got here she told me she wanted to go to academia. But the way she saw [Dr.] Houston working hard, not sleeping, sending emails

> [at] 2-4am in the morning, that scared the hell out of her. So because of that and because of the stress, there was no way she will consider academy. She just could go take a job in industry; take a job from 8a-5p or 9a-6p and that's it, she doesn't have to worry about anything. When she's off and just enjoy the rest of the day and come back in the morning, But academia is not like [those] careers. (Allen)

Other students shared their concerns about the demands on their personal time, if they were to choose a faculty career. The concern about how much time a faculty career takes is especially salient for those group members whom have families or want to have families in the future; they were not interested in sacrificing their personal interests for a faculty career. Emma mentioned pursuing a faculty career as her least likely career option. In between the industry and faculty ends of the career spectrum, however, she said she would consider the option of "raising a child or [becoming a] full-time mother." Likewise, Brielle mentioned that she had "responsibilities" that she needed to take care of that a faculty career would get in the way:

> I am happy teaching people or doing stuff for people, but right now I also know that I have some other responsibilities and personal responsibilities that I need to take care of and I can't devote as much time [to teaching]. (Brielle)

When Brielle noted her "responsibilities," she was referring to eventually marrying and raising children, and the cultural pressures to do so. Further, she described the time constraints that accompany a tenure-track faculty position like Professor Houston's.

Gloria is also married, and expressed the conflict between balancing a faculty career and motherhood:

> Also, seeing the time that's involved in it. I want to start a family someday; I don't want to be the mom that's working odd hours, all hours, and everything like that. So, I want something that has better predictability. (Gloria)

Gloria recounted an instance in her department at Model University where a female assistant professor worked all the way up until giving birth and returned to campus a few days later. Gloria described this as “ridiculous” even as she explained that while the professor had since earned tenure and “has a good position and everyone respects her.” She proclaimed: “I just don’t want to have to work that hard. Obviously, I am going to work hard, but I don’t want to have to make sacrifices like that just to get to that position.” For Gloria, the expectations of professors who are also mothers conflicted with her own views of motherhood. Because of what she witnessed within her own department, she believed that an industry career (or a non-tenure-track teaching position) might be better suited to her needs and her interests.

The desire to raise a family was not exclusively expressed by women students; two male doctoral students also mentioned wanting to maintain balance in their marriages and eventually raise children. Sherman, for example, described how the faculty career would impede on his ability to balance family life with work:

> The few professors that I've gotten to know really well are some of the busiest people I've ever met. And I am married, I want to start having kids relatively soon and I don't want work to be my life and I feel like if you're a professor that's exactly what's going to happen. (Sherman)

Sherman was one of three married doctoral students in the Houston Group. Sherman took into strong consideration how other faculty members balance – or do not – work and life as he explained his intention not to pursue the professoriate. This finding relates to the work of Levin, Jaeger, and Haley (2013) and Quinn and Litzler (2009). In particular, Quinn and Litzler (2009), find that work-life balance is not only of concern for women; they assert that work-life balance may be a generational priority rather than a “gender-specific phenomenon” (p. 86). The example of the women doctoral students in this study, however, appeared to be different, reflecting the cultural pressure for women that did not appear conducive to a faculty career. The career intentions of the two White men from the U.S. were conscious decisions, rather than ascribed by their nationality and gender.

When students see examples of their advisor and their other faculty members who work long hours, send emails late at night, for example, shapes their views of what it means to be a professor, at least a professor at Model University, which appears to be the frames of reference students use when describing their concerns about balancing their career and personal lives. This finding illuminates that the academy may be losing talented prospective faculty because of an antiquated faculty prototype who does not represent the balance students demand today, echoing that stated by Levin, Jaeger, and Haley (2013).

Commentary: Students' Interview "Performance" and Confidence

From my fieldwork, students' self-assessments did not always align with the evaluations others might make of them. After interviewing with students and considering the feedback on their presentations from the leadership team and other students, it appeared that some self-assessments were overly optimistic.

As a researcher I am aware that part of participants' interview is "performance." That is, participants negotiate issues of trust and presenting their authentic selves when determining what information to share with the interviewer (Small, 2009). Furthermore, participating in this study may have been the first time these students had engaged in substantive and specific self-assessment and thinking deeply about their own competencies with regard to what they were "learning" about themselves rather than their research topic. As such, participants "constructed themselves" as they wanted to be viewed by the interviewer (Atkinson & Coffey, 2001).

In addition, because students are more focused on their day-to-day research activities, their responses to questions related to their research were much more fluid and easy for them to describe. Whereas, when students were asked questions about their career intentions, the group itself (i.e., organizational structure, dynamics between members in the group) and other aspects of their identities and experiences (i.e., race, gender, career intentions), students were less articulate when responding. Throughout interviews, several of the students let it be known that they had not been asked social scientific questions related to their learning or the other types of questions described above. This suggests that the process of reflection may have been difficult for some participants. This observation is not uncommon. In Burt et al.'s (2013) multi-site study with engineering undergraduates, the undergraduate students were capable of describing their involvement in out-of-classroom experiences, but the authors note students' challenges reflecting on what they learn about ethics from their out-of-classroom experiences. Like the students in the current study, in Burt et al.'s (2013) study, the undergraduate students stated that being interviewed was among their first time reflecting on their learning. Duke and Appleton (2000) also find that the process of reflection is developmental. They note that students are often able to describe practices, but experience difficulty analyzing knowledge (or in the current study, "learning"). If undergraduate students' are not taught to development their reflective skills, it should not be assumed that they will know how to reflect in graduate school. In any event, in the present study, I did not just accept students' assessment as "true," rather I attempted to understand how they made their self-assessments.

It is important to note that on the whole, students tended to be confident about their research competencies. One possibility could be that students are confident to prevent feeling inadequate (Blanton et al., 2001; Taylor & Brown, 1988), and/or as motivation to progress in one's task (Gibbons et al., 2000; Taylor & Brown, 1988). For examples, those who are interested in the professoriate, undecided, or even uninterested in academe may feel obligated to confidently speak to their developing competencies that closely relate to the work of faculty, so as to prevent feeling inadequate. In Gibbons et al.'s (2000) follow-up study of the academic performance of first-year college undergraduates, the authors find that optimism (rather than pessimism) moderates the psychological impacts of poor academic performance. Supporting their hypothesis, their findings suggest that, "a positive outlook (even if it involves some self-deception) is associated with more effective performance" (p. 646), and relates to other scholars (Taylor & Brown, 1988). In fact, Taylor and Brown (1988) assert that individuals "distort reality" in effort to enhance his or her self-esteem, personal efficacy, and positive view of the future. In light of these perspectives on overconfidence, doctoral students, especially those in the prestigious chemical engineering program at Model University, may be used to being the star academic in their classes, undergraduate research lab, etc.; that is likely how they earned graduate admissions to Model University. So even if students are not yet reached full competence in their research skills, being optimistic (or overconfident in this case) may be their coping strategy for not performing up to par, and perhaps motivates students to better perform (Gibbons et al., 2000; Taylor & Brown, 1988).

Chapter Summary

In this chapter, my goals were to address my research questions on understanding students' perceptions of faculty work and how research experiences influence students' professional and personal identities. Students' perceptions of faculty work were largely shaped by their interactions with and observations of Professor Houston (as well as by other professors). Their interactions and observations of Professor Houston appeared to facilitate students' construction of a faculty prototype which students used to compare what they were learning to what they viewed as the roles and responsibilities of an engineering faculty career. The faculty prototype also influenced students' self-assessments of their research competencies and helped them identify the skills they have yet to learn or better develop, if they choose a faculty career. Similarly, the faculty prototype appeared to shape some students' professional identities. Specifically, how some students view the work of scientists and engineers, and identify with those roles, related to Professor Houston's model of performing both the roles of scientist and engineer. Finally, some students' personal identities shape how they perceive faculty and faculty roles. One student, who shares Professor Houston's same race, claims to see himself reflected in Professor Houston. For one woman in this study, the challenge of underrepresentation of women engineering faculty poses a challenge for seeing herself in a future faculty role.

Chapter 6: Engineering Professorial Intent

In this chapter I draw upon the setting, research practices, and competencies described in Chapter 4, and students' perceptions of faculty roles, and self-assessments of competence described in Chapter 5, to examine how these influence students' intentions and willingness to pursue the professoriate. This chapter focuses on students' perceptions of the variety of practices that comprise the faculty role, their interests in participating in these practices, and how these interests influence their intentions to pursue faculty careers. Figure 4 identifies the career intentions of students at the time of this study. Thus, this chapter addresses my research questions about doctoral students' sense of personal and professional identity and its relationship to their career intentions.

The doctoral students in the Houston Research Group had two main career options: positions in faculty or industry. Students' career intentions appeared to be formed based on perceptions of faculty practices, which were influenced by social comparisons to the faculty prototype and the assessment of their competencies in relation to this prototype. It is important to establish that Professor Houston intends to broadly educate his graduate students in the conduct of research, regardless of their desired career (i.e., faculty, industry). He believes that the practices and activities of the group (e.g., giving feedback to the presenter) are inherent to engineering research, and thus, essential to building students' engineering competencies.

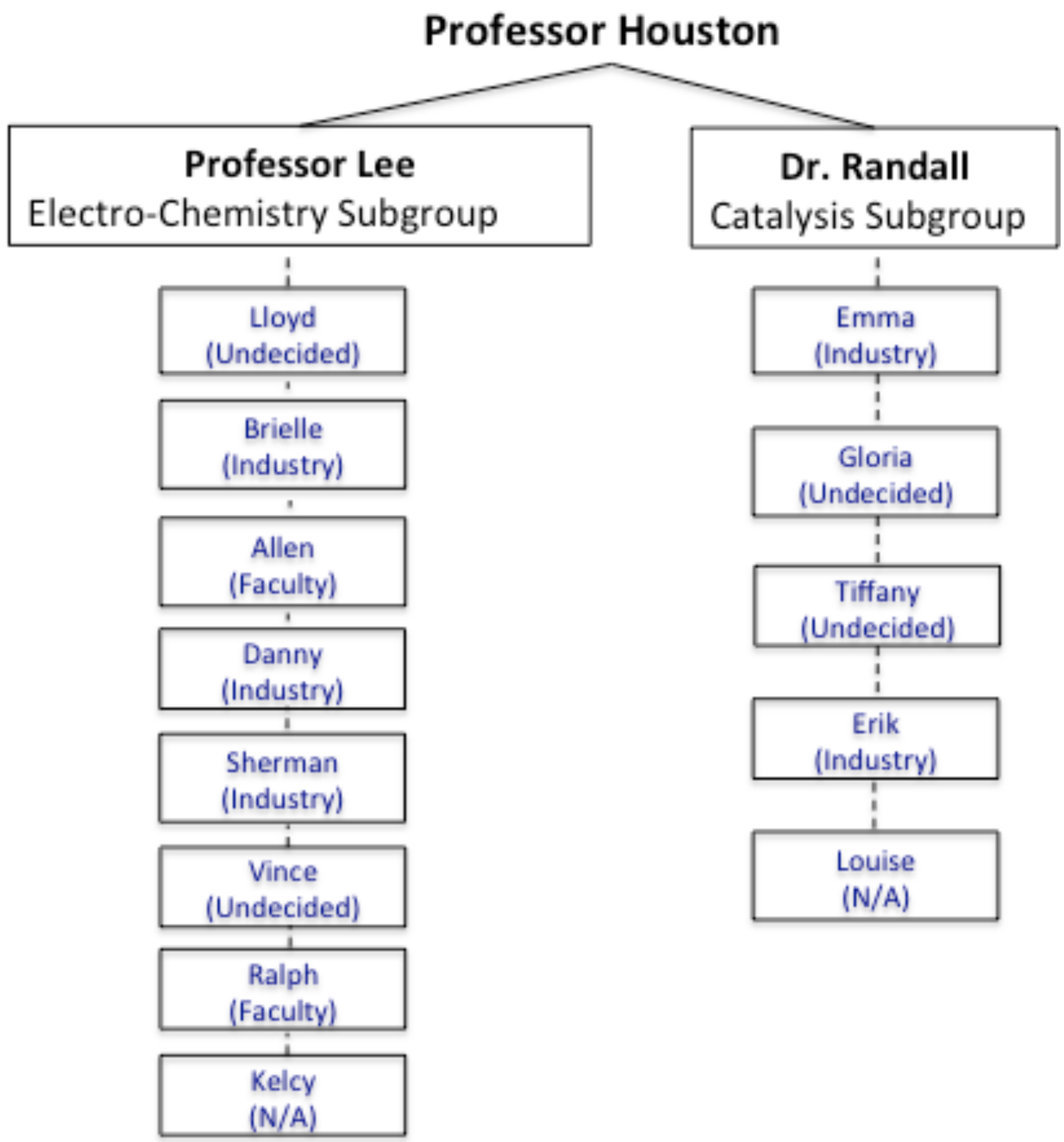

Figure 4: Houston Group Students Career Intentions

Professor Houston did not have explicit conversations with students about the design of the research group, nor his intentions regarding their training as researchers who might work in a variety of settings. Many students within the research group believed that they were being prepared for industry careers. According to several students, this widely accepted assumption was based on students' interpretations of their research experience, which stressed team meetings, Professor Houston's leadership style (i.e., as an overseer of the group's research production), and the fact that most Houston Group alumni enter industry careers upon graduating. Sherman commented: "[The group is] just kind of more oriented regarding where most students go afterwards." Like most of the graduate students in the Houston group, Sherman told me that he intended to return to an industry career after graduate study. With that goal in mind, he explained that practices and activities of the Houston Group were meeting his expectations: "I like it because Professor Houston is much less geared, at least his lab, towards the academic…I knew his lab was going to be more of an industry-type setting and it will feel more like you were working for a company." Even Allen, who is interested in becoming an academic, shared Sherman's perception that the Houston Group is geared towards industry, asserting that, "If you really are a guy or a student who likes to go into industry…you will work with someone like Professor Houston."

Professor Lee acknowledged that "[students] may have their own view" of why the group is designed as it is, and the careers they are being prepared to take upon graduation. In response to my question about why students believe they are being prepared for industry careers, he stated, "That might reflect either what they thought they wanted out of it or [they] just don't necessarily see the bigger picture." The "bigger picture" echoes Professor Houston's assumption that the group provides students with broader skills that can be applied in multiple contexts.

Faculty Practices and Faculty Intentions

By the end of data collection, two students confidently proclaimed their intentions to pursue engineering faculty careers: Allen, a third year doctoral student, and Ralph, a second year doctoral student who is co-advised. These two group members discussed their strengths and also identified the gaps in their learning. Despite acknowledged shortcomings, they saw their weaknesses as temporary challenges they would overcome with time and more training.

Both Allen and Ralph were interested in faculty careers for similar reasons. They both viewed the faculty career as an honorable profession where they could make a social impact through research and discovery. Ralph declared: “I want to be a professor…that’s kind of my dream.” He continues by describing the vision of himself in a faculty role:

> If it is possible, I want to go back to [country of origin] and teach and be a professor…Because I grew up in [country of origin], I want to do something like work or give feedback to make and teach [my] people and to make [country of origin] stronger. (Ralph)

Allen and Ralph are both international students with dreams of providing encouragement to future generations of students in their countries of origin. In addition, both were inspired to join the professoriate by a professor. For Allen, it was the example of Professor Houston that ignited his passion to do research, gain recognition for discoveries, and mentor students. Ralph on the other hand was most inspired by his father, a college professor in his home country. Both students agreed that while industry positions would pay significantly more, the professoriate would still provide a comfortable lifestyle.

Allen and Ralph were aware of some of the challenges of faculty roles. These challenges were often expressed in terms of particular practices that they witnessed as members of the Houston group. For instance, Ralph perceived that being a faculty member "takes a lot of time," providing the example that "professors like to send emails back during the midnight…the working hours for a professor would be much longer than the other people working the company." Allen, in contrast, shared a concern about obtaining grant funding and developing an innovative research agenda that would best position him to receive grants.

Yet, Allen and Ralph resoundingly proclaimed their interest in the professoriate. On several occasions, Allen expressed his confidence in overcoming the potential challenges and barriers of faculty practices:

> I like challenge – I love challenge [and] competition. So if I see it [a faculty career] as a challenge, I'd be up to it. So, the work that I am doing makes me confident, the challenge that I overcome every day makes me confident…So the more I learn about my work, the more confident I am. The more I talk about my work the more confident I am. The more people challenge me the more confident I am. (Allen)

Allen's confidence in his abilities to do the work of faculty, and overcome the challenges of faculty work, comes with increased participation in the practices of faculty work. Talking on the phone near me while in the hotel at an academic conference (Month 6), he enthusiastically said "I told you, I was born for this life!" referring to his conference attendance, the practice of disseminating his research, and his excitement for pursuing a faculty career. And in answer to my question about the challenge of acquiring grants, he appeared undeterred:

> No, that doesn't make me don't want to become a professor. Like I said, that's a challenge for me and I like challenge. So that's something that I think about and it makes me work harder it makes me want to publish more papers, it makes me want to make or have a good network. So it makes me want to do more because I know it's not going to be easy. (Allen)

These two Houston Group members were enthusiastic in their desires of becoming faculty members. Their comments about the desirability of academic positions often reflected what they perceived to be positive aspects of faculty work. Ralph, for example, is interested in the autonomy that faculty have to do their own work and “not having a boss” because “I don’t really like to have a boss…If you are a faculty then you are the boss of yourself.” Research experiences within the Houston Group appeared to solidify Ralph’s existing interest in faculty work. For Allen, research experiences under the tutelage of Professor Houston appeared transformative. Allen recalled his disinterest in a faculty career prior to joining the Houston Research Group. Now, as he engaged in independent research, was practicing and honing his presentation skills, and presenting his work at national conferences, he felt assured that he, too, could be successful in a faculty role.

Faculty Practices and Industry Intentions.

Students who expressed disinterest or uncertainty about a faculty career often could – and sometimes did – envision themselves as professors. But these students tended to discuss the faculty role (and its practices) as if it was an a la carte meal; if they could, they would want to pick and choose some aspects of a faculty career and leave out others. To some extent, they may be able to do that by choosing an institutional type or academic position that is conducive to their wants and needs. Students’ reflections on particular practices sometimes revealed disinterest in particular aspects of faculty work, but in other instances revealed questions about their own abilities to master a particular practice, such as grant writing.

Sherman, Emma, Brielle, and Danny emphatically proclaimed, “no” when asked whether they want to be faculty members. For instance, Sherman unequivocally stated: “I have no desire, none whatsoever.” “I don't want to be a professor.” For the students like

Sherman, it was not a lack of competence that dissuaded them from a faculty career; rather, their disinterest stemmed from a lack of desire to perform the roles of professors.[25] Sherman reflected on Professor Houston's late working hours and made it clear that he did not want a career where he would be expected to work similar hours:

> I can't tell you how many emails I have gotten from Professor Houston at two or three o'clock in the morning. And I love engineering and I love research science. I just got married and we want to have a family eventually. I have no desire to answer emails at four o'clock in the morning. (Sherman)

Emma, too, observed that Professor Houston was always working. She perceived that he was always working on getting grants *instead of* conducting research in the lab: "I have been looking at Professor Houston, he's always writing proposals and he's not doing research. We are. But, I guess I...based on that part, I don't think I would be likely to be a faculty [member]." Brielle, too, had a similar view of what constituted "research," but she also explained that many of the responsibilities of a university faculty member did not interest her:

> It's so much [grant] writing and management of people and resources and identifying what the market is…at some point in my life, I definitely want to teach high school students or maybe at a university…but it doesn't have to be a research faculty position for me, I am not interested in that. (Brielle)

Brielle makes clear her desire to teach, but not in a research-oriented position like Professor Houston's. Her comment indicated that she was aware of teaching-focused positions that might better suit her.

Because Professor Houston was "always" working on grant-getting, according to Emma, students were aware of the importance of the grantsmanship competency in an

[25] It is important to note that because my research questions focused on students' intentions to pursue the professoriate, my interview protocols aligned with this study's focus. As such, members offered more information on why they were not interested in a faculty career rather than explaining why they were interested in an industry career.

engineering faculty position. Vince described his concerns about grant funding in an early interview:

> I have some reservations towards writing grants. I haven't done one so I might like it who knows, but I've heard you have to do a lot of them from the labs I've observed, and I don't know how Professor Houston does it because I never hear him mention any grants or anything, (Vince)
>
> However, the funding and stuff, I think because I don't have the experience dealing with the grant writing, I don't know if could do that, but I would like to try. (Vince)

In a conversation two months later, he suggested that grant funding was no longer a great concern:

> Grant funding…I wouldn't rate it as big of a concern because like I said, getting people to see eye to eye and seeing your vision – I think if I can get a student to get on board on a project and to motivate or be motivated to work on a project, I can probably do the same thing with grants and funding; I think it's based on how you sell your project. (Vince)

These quotes are presented to illuminate Vince's thought process, and to highlight how his self-assessments changed over time. In the first two quotes, he shared his nervousness about grant funding, largely because it was a faculty practice that he had not learned in the Houston Group, nor had he seen or heard Professor Houston talk much about the process. Because he had not done it, and because he knew little about the process, he was not sure that he could obtain grants. A couple of months later he suggested that grant funding really was not germane to his career choice. While he was no longer concerned about grant funding, his lack of experience was apparent as he correlated the activities of recruiting a student to his project to selling a funding agency on a grant proposal.

While Emma said she enjoyed doing the research (versus focusing on grant writing), Gloria, who had been doing research since elementary school (i.e., science fairs, undergraduate research), appeared to be "burnt out." At the time of data collection, she was working in two research groups at Model University. She confidently stated that she has the leadership skills to complete the tasks associated with faculty work, but was not certain she wanted to:

> I am just not sure that I think I want to do this [research] every day for the rest of my life every day...I think I could do it and I have the leadership traits and whatnot, but I don't think I want to. I think that comes from seeing it for the past three years. (Gloria)

She also pointed to the tasks other than research that faculty must do to be successful but that she viewed as undesirable:

> One thing like I said, just, the amount of writing involved. You sometimes go through so many other logistics just to do a project or the requirements of a project like, you have to a hire a postdoc – stuff like that, there's just a lot of hoops and whatnot. (Gloria)

Danny, a fourth year doctoral candidate at the beginning of data collection, commented on the nature of research itself. He viewed the work of faculty research as "endless":

> You have to know at some point just to relax and enjoy some other aspects of life, rather than searching for this one thing because this one thing always keeps evolving and turning itself into another thing and you basically keep searching for it. And I don't know if I want to make that my life goal really. (Danny)

Danny expressed a further concern about the process whereby faculty members start with a narrow research focus that generates new questions that further narrows their work.

> [As a faculty member] you keep on tracking new research and you find a new aspect of research that you want, and it evolves into another. That's how it happens actually for most of the professors; they search for one thing, and they delve into another thing, and they narrow down, and it keeps changing like that…I don't want to search for that one thing because there is not that one thing, really. (Danny)

In contrasting the work of faculty with that of practicing engineers, Danny implied that industry work was defined by bounded projects with definitive end dates.

Lloyd, one of the married members of the Houston Group, identified personal boundaries around balance that may conflict with a faculty career. In his first interview, his thoughts about returning to industry dominated his career plans, in large part because of his desires for work-life balance. In his second interview, however, he shared that he recently began receiving more acceptances for conference presentations and publications. Thus, his career plans began shifting more towards the professoriate as he received more indications that he could be successful in a faculty role. Lloyd identified what engineers do and what he enjoys about it, as well as what he would find hard to give up if he pursued a faculty position:

> I like building stuff, I like wiring equipment together, and obviously a lab is like putting Legos together. It's the fun part, you just construct and build and design...[Hypothetically, as a faculty member] I think what I would be like is someone who delegates grudgingly and probably be as much interested in methods, materials, and design of the equipment and how you are going to do things as much as the results because that's the thing that fascinates me. And I think that's how I probably translate my fascination with the methods and tools into the professor role where I can't be there in the trenches but I want to know how things are being done because that's what interests me. (Lloyd)

Lloyd revealed another reason why students preferred industry careers: they preferred to build and create things (i.e., doing research) in the lab. Similarly, Emma said she enjoys making "stuff." She described her desire to design and see a physical product or something of her creation in the real-world:

> Yes, because I have industry experience and I really enjoyed making stuff, there are things we worked on that are on the street. So I thought that was very exciting and I'd like to do that again if I can and hopefully relate it to my research. (Emma)

Her comments implied a contrast between industry work that results in immediate and tangible products and the less visible and, for her, less rewarding work of academic research. Her comment also implied that it is in industry careers where one can participate in the practice of doing research, versus academia where the focus is more administrative (e.g., the grant funding that she mentions seeing Professor Houston doing instead of conducting research in the lab).

For some students, the time it takes to write and publish contributes to their current disinterest in pursuing a faculty career. Sherman, who returned to graduate school after working in industry, repeatedly mentioned his certainty about an industry career when sharing his disinterest in publishing. He noted: “So you're required in order to get tenure you have a number of publications that you have to get out, not only a number of publications but also with a certain impact factor…That coupled with the amount of time required -- I have no desire, at all.” Students like Sherman who came from and plan to return to industry, may have a harder time considering a faculty role in the future. It is also worth noting that comments like Sherman’s reveal how students’ faculty prototype influences career choices.

In addition to students’ disinterest in participating in faculty practices, it was evident that some students were concerned that they did not have the personality traits or knowledge and skill set that they deemed necessary for success in academic careers. Tiffany suggested it is harder to enter – and be successful in – the professoriate than it is in industry. Sighing, she explicitly compared herself to her faculty prototype, suggesting she did not have the skills, abilities, and personality traits to make her a competitive faculty applicant:

> (Sigh) I think the bar [to be] faculty is higher than [for] industry, I think so. For faculty, it requires more quality of people. You basically need to have everything; you need to have a decent technical background, you need to have a good personality, you need to know how to manage people and how to work with people, you need to know what are the trends and how to organize grant

> proposals. And to me right now I don’t have the confidence to say “I have all the qualities [to] get [a] faculty position. (Tiffany)

Although confident of her research competencies, she was still cognizant of other skills that she had not mastered (e.g., management of people, writing grant proposals). Describing Professor Houston as “my role model in terms of being a professor,” Tiffany believed that personal qualities were also important (i.e., “you need to have a good personality”) for success in a faculty career.

Finally, at the time of this study, Erik, a member of Allen’s cohort, mentioned his concern about what he perceived as the self-reliance required to be successful as a professor:

> You are your own professor in terms of – you are learning as a professor, you are also teaching yourself. And it's kind of – not a lot of stuff is going to prepare you for that in terms of – I don't want to call it loneliness – you are on your own as a professor. (Erik)

Erik suggested he had not been well-prepared for a faculty career, which seemed to require a lot of solo, on-the-job learning. Erik mentioned “you are your own professor,” suggesting that he would have to teach himself the skills he has not yet learned. Furthermore, what some might praise as “autonomy,” Erik described as “loneliness,” exacerbating his concern that not only was he unprepared, but that he would have to address gaps in his learning by himself.

“Maybe one day.”

Despite their indecisiveness and/or clear disinterest in particular faculty practices and norms, some students still viewed a faculty career positively. Erik described it as “one of the best jobs”:

> I can guarantee you one of the best jobs is being a tenured professor at a very good research institution because it's fun. Like, at that point you are doing

> research on what's interesting…so when you get to do that, it allows you to do things that are fun for you. (Erik)

It is ironic that Erik held this view while emphatically stating his disinterest in pursuing the professoriate upon graduating. His rationale aligned with those of who were considering careers in industry but viewed the professoriate as something they might do "later." Like his peers currently uninterested in pursuing the professoriate, Erik said he might consider a faculty career after gaining more research experience:

> My opinion has already started to change during my grad school. When I came, I thought I was going to go into industry and now I am thinking I might want to go to a national lab where they do write grants to get money to do their own research that they're interested in the national lab. So it's quite possible that I will [pursue a faculty career] as I grow. But right now I still get slightly stressed out about that whole thing [developing a research agenda and writing grants], but it's not out of the question. I can imagine perhaps working for a little while maybe in the national labor in industry, and then coming back to be a professor. (Erik)

Erik thought that working at a national lab would provide him with opportunities to develop those research competencies he felt he is lacking (e.g., grant writing, developing his own research agenda), which he assumed he will not get in an industry position. By the end, Erik showed a glimmer of interest in pursuing a faculty career, but qualified that interest by saying he needed to build skills that he had not developed as a member of the Houston Group.

Lloyd started off by describing exactly what he enjoyed doing, "building stuff, wiring equipment together," working in the lab to "construct and build and design." Unfortunately, he suggested faculty do not have time for the 'interesting' stuff that happens "in the trenches" and that he valued in engineering. More interested in the professoriate at the end of data collection, Lloyd shared what he liked about the professoriate and what he might lose if he chose an industry career over the professoriate, highlighting a personal value system that aligned with the faculty career:

> So the idea of not doing that [publishing and disseminating research] anymore by going into industry bothers me because this is a skill that I have put a lot of work into and I don't want to give this up when I am very good at it and I am getting better. So it would be a totally different thing to work in industry where all my writing is going to be internal reports where I mean – in [an automotive company] no one reads any of these things. So it's basically like, now, if I come up with a great idea I can write up and send it to a publication and then it's published for the entire world to see that I did this great work. Whereas, if I wanted to earn the money of working industry I could do the same thing except I write up everything and someone puts it into a file and no one ever looks at it. And that's – it's kind of hard. (Lloyd)

Earlier I noted Lloyd's confidence in his ability to publish: "I am already good enough." In the quote immediately above, he explains what he likes about the practice of publishing. In particular, he places value on the rewards of publishing, describing his interest in contributing to science and publicly sharing his "great work." He concluded by weighing the costs and benefits of his career choices; an industry position would afford him a greater salary, but a faculty career would provide him with opportunities for his work to be public and recognized.

Brielle took a different approach to the question of faculty practices and the question of when she might pursue it. She stressed that what she likes is teaching, because it offers the ability to "give back." Like Allen and Ralph, some of Brielle's altruism appears related to her status as an international student who wants to share her learning with students in her home country. Her commitment to giving back and teaching prompted her to consider opportunities beyond the professoriate, "At some point in my life I definitely want to teach high school students, or maybe at a university." She further explained, however, that teaching in a university does not require a tenure-eligible position on the faculty:

> Do you know [Mechanical Engineering adjunct professor]? He used to work in [automotive manufacturing company] as a researcher and he worked there for a good number of years, and then he's here now as an adjunct faculty. That's sort of a role I would want. Because at some point you want to give back. The knowledge that you've gained and everything that you've learned you want to give it to people back. It may not be totally faculty; I may teach in a high school or something. But I really want people to be interested in science and interested in problem solving in general. (Brielle)

When considering what her future career in academe will look like, she drew upon what she saw from an adjunct on campus. To offer more career flexibility, however, she also mentioned the possibility of teaching "high school or something," to further illustrate that her passion is for teaching – wherever she might find the opportunity. Upon graduating from Model University, Brielle started a research engineer position at a global electronics company.

Perhaps because graduation is not in the immediate future, or because of Professor Houston's example of one who balances both faculty and industry careers, some students felt as if they had more time to decide on their career plan. For instance, both Vince and Tiffany described times when they feel they want and do not want to do the work of faculty. Vince could not choose between his interests in both faculty and industry positions; at times he talked about starting in industry to gain experience and then returning to academe, while at other times he talked about targeting faculty positions upon graduation. Vince, for example, acknowledged his indecisiveness:

> I would say I don't know for sure, I am open to the opportunities whether it's more applicable to a faculty position or an industry position and I am thinking about faculty position…But I would be open to both and I would like the opportunity to have both. I don't mind working harder if that's what it takes to have both experiences. (Vince)

Like Vince, Tiffany, too, is not sure if she can successfully do the work of engineering professors. The “pressure”, she suggested, is the critical concern:

> I will say that I like a lot of aspects about being a faculty but I don’t quite like the pressure that I will face as well. So I am still in the middle and it’s like I don’t want to close the door…but I understand the challenges there as well. (Tiffany)

Tiffany nonchalantly laughed when she referred to her vacillating career intentions. Although she acknowledges thinking about her career options for years, her laughter suggests that she did not feel a sense of urgency in choosing a career or a track.

> One thing that I want to say is if you asked me this three months ago or three months later maybe it would be very different (Laughter). It’s flipping all the time, I’ve been thinking about this for many years. (Tiffany)

As she continued explaining why she was leaning more towards the industry career, she discussed how she believes the practices and activities of the Houston Group lend themselves to industry careers:

> Back one year ago, I didn’t have the confidence to say “I could do this,” but now after one year of training, I feel I have the confidence to say that. And another [reason] I am more into industry is possibly the environment of the Houston Group because we work, I think, sort of like industry – project based, meeting every week, talking to each other a lot, think of the real problem solving. Although it’s research-based, I think we are solving the real problem that maybe potentially, could be useful in industry later. (Tiffany)

Here, again, students’ perceptions of the practices of the Houston group were relevant in their considerations of their career options. Tiffany’s intentions fluctuated for a number of reasons. During my study, I heard her making self-assessments of her research competencies, sharing ideas about what she wanted from her career (e.g., work-life-balance), and considering the realities of having a boyfriend on the faculty job market in engineering. Through his experiences, she was learning more about the hiring process and the faculty career itself.

Tiffany also noted that because a majority of students from the Houston Group go on to work in industry careers upon graduating, students more regularly talk and think about industry careers; group member alumni stay connected and if they remain local, they return to the group's out-of-lab gatherings at Professor Houston's house. Tiffany said interactions with group members – and alumni – influenced her career intentions:

> You are always affected by the people around [you]. So if all of your group members want to all go to academia, then maybe you would think that "maybe I should go in academia because everybody else do the same thing." But in our group I would say most people go to industry, and if I see them go to industry I see them leave very happily, and I would opt to go out and see what happens at least. That's another factor; we don't have so many group members in our group that do faculty positions. (Tiffany)

Tiffany suggested that it was easier for students to make linkages between the work they do in the Houston Group and a potential career in industry. Interactions with group alumni and current students interested in industry careers appears to dominate the narrative about what their research experiences in the Houston Group are preparing them for post-graduation. Hence, the Houston Group may be serving as a conduit for industry careers.

By the end of the data collection period, Tiffany expressed greater interest in a faculty position, saying, "I think it's more work to be a faculty, but it's also more reward[ing] to be a faculty." Yet, she remained concerned about her competitiveness as an applicant, and her ability to be as successful in a faculty role as her "role model," Professor Houston.

Commentary: "The reality is…they don't come back"

Several students who were not interested in pursuing a faculty career upon graduating thought it was possible to blend faculty and industry careers over their lifetime by starting in industry and then transitioning into a faculty position. In fact, students interested in pursuing industry careers upon graduation, with the intentions of pursuing the professoriate later in their careers, seemed relatively confident of their employability after working in industry. They believed that they would have amassed transferable research skills, experience, and a better understanding of the engineering field that would make them better equipped and stronger candidates for positions. It was also possible, however, that based on the nature of my questions these students felt the need to suggest an interest in pursuing the professoriate later in their career. Additionally, one might argue that a research university like Model University emphasizes preparation for the professoriate. Several participants, however, indicated that there was no pressure – at least within the Houston Group – to pursue faculty careers.

Despite students' confidence that they could later return to academe after working in industry, the members of the leadership team viewed this line of thinking as naïve. Professor Lee observed that students should not assume that what they would gain from industry experience would easily translate into a faculty position:

> I am not sure what's motivating it [returning to academe later in one's career] – that track in chemistry doesn't work real well. In engineering I think it's more – there are in fact people who get hired in at a certain mid-career time from industry. But it's not so common in chemistry. One of the difficulties with that track is that many of the things that people do in industry is either proprietary or not published. Sometimes it is with patents, but even with the patents, you have a team and it's not always clear who's really the creative force. So it's difficult in industry to establish a profile that a university like Model University would say "Oh, this person should be on our faculty. (Professor Lee)

Beyond whether or not someone in industry was competitive to secure a faculty post, Professor Lee said that in his experience on the faculty, those whom entered the professoriate from industry careers did not do well in their positions.

> Now, it does happen, but that tends to happen (like I said) much more in engineering. In chemistry over the 40 years – I was in chemistry – we hired out of industry a couple of times. And in hindsight, they weren't necessarily the most successful hires. (Professor Lee)

Professor Houston believed that, for personal reasons, some students might consider entering the professoriate after working in industry, but in reality, he said, they were making a choice that was hard to change:

> If you're, for example, considering starting a family, it's more difficult starting a family as a junior professor than it is maybe working in industry. So there are a lot of reasons why you would consider putting it off. But the reality is that most people go to work in industry and they don't come back. (Professor Houston)

He believed that if students were not on the research and faculty track relatively early upon graduating, it was highly unlikely that they would later seek a faculty post. Despite their understanding of students' rationale, Professors Houston and Lee alluded to students' uninformed and perhaps unrealistic job-related career paths.

During my final interview with Professor Houston, I shared with him what I was learning and provided him with an opportunity to comment on my understanding of students' professorial intentions. When I asked him why several students were considering starting in industry and then pursuing a faculty career, he paused to think and eventually processed the unintended consequences of the group's research practices (e.g., implementing the subgroup meeting structure instead of one-on-one meetings). He concluded by considering his role in students' lack of knowledge around faculty roles – or at least what his faculty career looked like. Then – thinking aloud – he contemplated how to adapt the group meeting as a way to explain to students what his role as a professor entailed, grant funding, and other aspects of the faculty role he had not previously shared with his students:

> **Professor Houston:** So, what I might do is take a day in one of our group meetings and describe what I do, where the money comes through, why I do things the way we do it…
>
> **Me:** [nervous and stuttering] I am not trying to change the whole [research group operation]…
>
> **Professor Houston:** …No, no – in sort of a generic way, I can use this as an opportunity to catch up on those issues that I probably haven't spent enough time with. And this is not because you may have revealed this. As I am sitting here thinking about it, I don't talk to them about it [the professoriate]. If we had more individual meetings I probably would. But this might be an opportunity to get the information to all of them so they understand how this team is working. I think they appreciate the fact that when they ask for things [e.g., equipment] there's a reasonable expectation that they'll get it. I also believe that they appreciate sort of the openness. But if there are legitimate questions about teaching versus industry, we don't have a forum or a convenient forum. You [can] come in and say "I'm interested," but we don't have a convenient forum for discussions about that and the group meeting would be a perfect place.

My exchange with Professor Houston was prompted by his reflections about how he leads the Houston Group, and its impact on student learning and career intentions. He realized during the conversation that students were getting information about post-graduate careers, but not from him. Additionally, he realized that students were relying on incomplete information about the professoriate to determine their career intentions.

This interview – and the group meeting observation that followed – marked the end of data collection. I do not know if there were discussions about the faculty career at later group meetings. But I do know that by the end of data collection, Professor Houston was more aware of how students' research experiences in the Houston Group – including his supervision of the group – influenced their professorial intentions.

Chapter Summary

In summation, the majority of Houston group student members do not intend to pursue the professoriate after graduating. Their intentions largely hinged on negative perceptions of a small number of faculty practices that dissuaded them from seriously considering a traditional tenure-eligible faculty position. The two students who planned to apply for faculty positions appeared to be steadfast in this career choice, despite acknowledging the potential challenges they faced. Their positive perceptions of faculty practices and the alignment of faculty work with personal values appeared to influence their desires to become faculty. Equally important, both had ready models of professors who, for them, exemplified the faculty careers they envisioned for themselves. Professors Houston and Lee realized that the graduate students in their research group might not have had adequate information on post-graduate career planning, which prompted Professor Houston to consider strategies to better inform students about the work of university faculty.

Chapter 7: Discussion and Conclusions

Summary of Study

Much of the existing research on doctoral education suggests that learning takes place during interactions among students and advisors (Austin, 2002 & 2009; Barnes, 2009-2010; Barnes & Austin, 2009), and learning is greatly influenced by the culture of the academic department and institution. A growing body of research, however, illustrates that doctoral students gain important knowledge of careers, and in some cases the work of faculty, especially through their participation in research experiences (Crede & Borrego, 2012; Pearson, Cowan, & Liston, 2009; Stubb, Pyhalto, & Lonka, 2012). Because science and engineering students spend substantial amounts of time doing research in the laboratory, these experiences are likely the predominant mechanisms through which science and engineering students are socialized to the behaviors, norms and values of a faculty career. Scholars logically argue that engaging in research experiences influences graduate students' perceptions of faculty work and their aspirations to and preparation for the professoriate (Brazziel & Brazziel, 2001; Fries-Britt, Johnson, & Burt, 2013; Crede & Borrego, 2012; Pearson, Cowan, & Liston, 2009).

Despite the acknowledged importance of doctoral research experiences in preparing graduate students for faculty roles, literature on what and how students learn from participating in research, and how this affects their potential identification with the professoriate, and its norms and values, is limited. This study aimed to build our understanding and develop mid-range theory about how doctoral research experiences might provide formative experiences that prepare engineering doctoral students for – and shape their perceptions of – the professoriate.

Theoretical framework.

Sociocultural learning perspectives provided initial theoretical grounding for this study of what engineering doctoral students learn by participating in an experimental engineering research group. Specifically, the interrelated key concepts of context, mediation, participation, and to a lesser extent, identity, guided data collection and analysis. Sociocultural theories stress the critical role of contexts in individuals' learning. From a sociocultural perspective, the goal of research on human learning is to understand how individuals' learning and identity development are influenced by the environments in which they learn, their interactions with others in these settings, and their participation in the activities and practices common to those who live and work in these sociocultural contexts. Specific contexts play a major role in shaping how individuals learn and view themselves, as well as setting the tone for how individuals within a community of practice interact. Because of the impossibility of separating the experiences of individuals from the contexts in which those experiences occur, some sociocultural theorists define the unit of analysis as "person-in-context" to capture this inescapable interaction. In the foreground of this study were doctoral students' experiences and understandings of the practices conducted within their research group.

The focal context for this study was the Houston research group. Group members interacted with – and learned from – their research supervisors (two faculty members and a lab manager), postdoctoral researchers, an engineer, and other student members of a research group. These interactions mediated their learning in the group. Further, doctoral students participated in a number of critical independent and group research-related activities that shaped their learning about faculty work and the professoriate. They ran experiments, presented their work in regular research full- and subgroup meetings, presented at conferences, and wrote journal articles. Through participation in research-related practices with members in the community of practice, student group members acquired many of the same values and norms as the more experienced members of the Houston Group. While all identified with the work of engineers, only two appeared interested in pursuing a faculty career at the time of this study.

Research questions.

Although there is a growing body of scholarship on doctoral students' research experiences, less is known about nature of these experiences, what students' learn within these experiences, and how their learning shapes their interests in post-graduate careers (namely the professoriate), especially in the field of engineering. The goal of this study was thus to learn more about the nature of doctoral research experiences, and begin to theorize how research experiences influence engineering doctoral students' intentions to pursue a faculty career. The following research question and sub questions guided this study:

> *How do doctoral students' research experiences in an engineering research group influence their perceptions of, and interest in pursuing, academic careers? Specifically, how do research experiences influence:*
>
> a. *Doctoral students' learning about engineering and the professoriate?*
> b. *Their perceptions of faculty work?*
> c. *Their personal and professional identities?*
> d. *Their intentions to pursue a faculty position?*

Methods.

My research design drew heavily on ethnographic methodology (Emerson, Fretz, & Shaw, 1995; Fetterman, 2010; Van Maanen, 1988; Wolcott, 1994). I conducted 13 months of fieldwork (September 2012 to October 2013) during which I observed the interactions and activities of a 20-member research group in chemical engineering at one institution. Fieldwork involved observations of group meetings, subgroup meetings, laboratory work, dissertation defenses, group celebrations, and conference attendance; formal interviews (16 first-round and 15 second-round interviews); and informal interviews (i.e., conversations in the field that allowed me to check interpretations). Observations of the research group provided me with a holistic understanding of the research itself, and group members' roles, practices, interactions, and relationships. As a consequence of conducting extensive fieldwork, I developed rapport with group members which afforded me the opportunity to ask specific questions about research group members' interpretations of activities and interactions, and the nature of students' research skills, aspirations, and scholarly and professional identities. All observations and informal interviews in the research setting were documented through field notes; all formal interviews were audio recorded and transcribed verbatim. Additionally, after each interview, I wrote a reflective memo detailing key aspects of the interview, considering the appropriateness of interview questions, how to best adapt questions for future interviews, and speculating on my emerging understandings about participants' experiences.

The Houston Group at Model University was selected as the site for this research for several reasons. First, Model University is a large, public university where engaging in research at the faculty and student levels is a top institutional priority. I chose to study doctoral students' experiences in engineering because we know from existing research that engineers spend a considerable amount of time in the research lab (Brazziel & Brazziel, 2001; Crede & Borrego, 2012; Saddler, 2009; Saddler & Creamer, 2009), making the lab – and the experiences within the lab – a critical site for learning. The chemical engineering research group, the "Houston Group," was selected for several reasons as well. It is a large, diverse, group where members participate in experimental research and engage in collaborative interactions. The faculty advisor for this research group is also recognized on campus as an exemplary researcher, teacher, and mentor, who would be receptive to allowing a social scientist to observe his research group for an extended period of time. Judgment sampling was used to determine individual group members to interview; this technique required me observe the research group until I had a sense of how the group members worked together and who might be key informants likely to provide the richest data to address my research questions (Fetterman, 2010).

Consistent with other ethnographies, grounded theory tools provided the foundation of my analysis (Corbin & Strauss, 2008; Merriam, 2009; Strauss & Corbin, 1990). I analyzed data relative to the three waves of data collection (i.e., after the Fall 2013 and Winter semesters 2013 (pilot); Spring/Summer 2014; and Fall 2014). This analytic strategy helped me manage the volume of data. As a result, my understanding of the competencies that group members were developing through engaging in engineering research and what they were learning about the engineering professoriate evolved as data collection and analysis progressed. In each wave, analysis began with open coding where I determined initial chunks of data – within individual student transcripts and fieldnotes – that captured important information about students' experiences with research and career intentions. I used the constant comparative technique to continue searching for data and to ensure the coding categories were logically coherent. Axial coding allowed me to create new categories by identifying relationships among codes. I also wrote analytic and theoretical memos throughout data collection and analysis. In these memos I explored my preliminary and evolving hypotheses about the research competencies that students were learning, how they perceived the professoriate, and the other factors contributing to their intentions to pursue faculty careers. In time I generated theoretical propositions for future testing.

Limitations.

There were several limitations of this study that warrant note. First, this study examined the dominant research practices of only one research group. As such, I cannot make recommendations on whether or not this group's research practices are best practices for preparing students for faculty careers. The goal of the study, however, was to generate propositions for future research, rather than generalize about research groups. Second, I focused on the practices and activities of this group. There may have been additional contexts where learning about research and the professoriate took place that were not explored in this study. Third, while I was able to interview, observe, and exchange emails with the research supervisor, more formal and informal interview time with the research supervisor would have provided greater understandings of his intentions in promoting particular research group practices. Finally, although I was able to show how some students' intentions changed through the duration of this study, by the end of data collection, I cannot confirm whether students will act on their stated intentions.

Summary of Key Findings

This study provided an in-depth understanding of what and how students in a chemical engineering research group at one institution learned about faculty careers from their participation in their research group, and how this learning influenced their intentions to pursue the professoriate. Students participated in research in a number of contexts that provided many opportunities to learn about research, engineering, and the professoriate, including group meetings, subgroup meetings, laboratory, out-of-lab gatherings, and conferences. The practices that appeared to be most dominant in the group, however, were: 1) working on individual research projects; and, 2) engaging in weekly full group and subgroup meetings. Through these activities students came to understand what to expect in engineering careers involving research, whether in academe or industry. These activities also provided doctoral students with the opportunity to develop a variety of research competencies: solving problems; troubleshooting problems; managing projects; consulting with peers; briefing research; presenting research; receiving and responding to feedback; contributing to lab operations; building equipment and taking inventory; maintaining the lab; and, supervising members. These competencies are critical for research in general, not only for faculty careers. Furthermore, students' observations of their research group leader revealed the skills students had yet to develop.

The key findings in this study contribute to the growing body of research and theory on engineering doctoral education in a variety of ways. I first present a set of testable propositions to guide future theory development and research. I then proceed to a set of recommendations for research design that address the limitations of my research.

Propositions for Future Research

Proposition 1: Engaging in team-based research promotes both independence and interdependence in research practice.

Existing research on doctoral education identifies the development of independent thinking and research in students' academic success (Baker & Pifer, 2011; Gardner 2008b). In fact, becoming an independent researcher is assumed to mark that a student has learned the necessary skills of being a scholar, and serves as an indication that a student could be successful in a faculty role (Baker, Pifer, & Fleminon, 2013; Lovitts, 2005).

The findings from this study of an experimental research group in engineering speak to and expand the conceptualization of research skills and scholarship. The Houston research group, like many research groups in engineering and the sciences, relies on a team-based approach to research. In the case of the Houston Group, doctoral students pursue individual research projects in a fairly independent manner, but these projects are linked to a larger research agenda that the group jointly pursues. Students in the Houston Group are able to assist one another on different projects because the subgroups share a set of research methods and equipment. Moreover, the leaders of the Houston Group expect that before students bring questions to him or other members of the leadership team, they first ask their fellow subgroup members for help.

This finding highlights the dimensions of collaboration in engineering research practice. While the projects are independent, to accomplish the group's larger research goal, students must help one another; the group does not succeed (i.e., acceptance of conference presentations; publications; grant-getting) if individual projects do not succeed. In this sense, students are interdependently collaborative – while they independently work on their projects, they still rely on one another to accomplish their work on a day-to-day basis, and importantly, to accomplish the research team's overall goals.

Research on doctoral education has yet to fully explore the role of the academic discipline in shaping the research experiences and learning of doctoral students. My findings suggest that further investigations of the team-based research practices common in science and engineering fields are needed to bring nuance to scholarly discussions of the doctoral experience. The science of team science literature is beginning to investigate the elements of successful teamwork, but a special emphasis on the role of teamwork and collaborations of different kinds in STEM doctoral programs is also needed.

Proposition 2: As doctoral students participate in practices of their research group, and observe their research supervisors in action, they form a prototype of a faculty member that represents their understandings of faculty work, and that they use to self-assess their suitability for faculty work.

In this study, learning was observed in three main contexts: individual research completed in the laboratory; full group meetings; and, subgroup meetings. The meetings in particular appeared to be the social forums where the advisor could not only monitor the progress of students' research work, but also shape the expectations of students in the group. In particular, during full group meetings, the advisor often provided constructive criticism on students' presentations. Over time, patterns of feedback were observed. Feedback ranged from light-hearted and affirming to stern and critical, based on the level of development needed in a student's work.

According to Blackburn and Lawrence (1995), faculty members are socialized to a "faculty prototype" that is the result of their perceptions of the expectations and values of their environments, and others in these environments. This social knowledge, according to the authors, influences their behaviors as they strive to be successful in their workplace. Similarly, students participating in the Houston Group appeared to form a faculty prototype that was at least in part based on the perceptions of their advisor and his work practices. Although this prototype would appear to be consistent with the characteristics of faculty and faculty work prevalent in Model University, it also appeared to be heavily influenced by students' personal experiences in their particular research group. This faculty prototype shaped students' understandings of research expectations, their perceptions of faculty and faculty roles generally, and affected their self-assessments of their alignment to these roles. The faculty prototype thus does not appear to be a generalized model of the Model University faculty member, but rather a more specific example grounded in students' particular research experiences.

Proposition 3: The faculty prototype prevalent in a student's research team creates and promotes particular kinds of social comparisons with peers.

Learning to do research in a team-based research group is a social process whereby students learn from and with peers as they participate in the practices of the group and interact with its members. In this process, some students make social comparisons between themselves and peers they believe to be relevant given their personal goals (Anderson & Chen, 2002). In the current study, the subgroup and full group meetings served as social forums in which the leadership team reinforced some behaviors and discouraged others, and where students could observe the actions of others. For example, one younger student mentioned that he actively observed a more senior student because the senior student received more recognition from his presentations and thus impressed the research advisor and members of the leadership team. Such social comparisons, like the faculty prototype, provide students with a way of benchmarking their performance on their research team and a learning tool to improve their research skills. Importantly, social comparisons also provided students' with opportunities to assess their ability to be successful in faculty careers.

Proposition 4: Students' perceptions of alignment or misalignment between faculty work and personal values shape their (dis)identification with the academic profession.

Perceived competency, however, does not necessarily lead to a students' identification with faculty work. While some students in this study chose not to pursue the professoriate because they did not believe they had the needed knowledge and skills to succeed as a faculty member, other students were confident they were developing the skills of their faculty prototype, but did not desire a faculty appointment. In these cases, students' values and desires seemed in conflict with those of their prototypes and thus produced disidentification with faculty work.

During the course of interviews, each student participant mentioned some of the positive aspects of faculty work. Some examples included the internal reward of publishing groundbreaking work, the external recognition of receiving accolades, the flexibility to set one's working hours, autonomy to work on one's own research agenda (which actually prompted mixed feelings for a few students), and the opportunity to impart knowledge into young minds. Each student also shared several negative perceptions and/or examples of faculty life. A common negative perception of the faculty career included lack of work-life balance. For example, one student recalled receiving emails from his advisor late at night, which suggested that faculty work at all hours of the day. Another student recalled a woman professor in the department working throughout her pregnancy and then returning to work shortly after giving birth. Students understood that running a research lab requires securing grants and supervising and advising graduate students. In addition, however, several students in this study argued that because faculty focus primarily on grant-getting, faculty do not actually *do* research; rather it is the graduate students who conduct the research. The perception for these students was that the need to obtain funding meant forfeiting the enjoyment of actually conducting research.

When the faculty prototype created a value conflict, it was hard for students to see themselves in a faculty role. Additionally, because students did not talk to their advisor (or other faculty members) about how they might differently navigate negative faculty experiences, the negative impressions appeared to outweigh the positive perceptions of faculty life.

Proposition 5: Concerns about gaps in engineering knowledge and skills negatively affect students who are undecided about faculty career directions.

Two male students in this study who intended to pursue a faculty career believed they had not yet learned all the necessary research competencies required of faculty, but did not seem to be dissuaded from aspiring to faculty positions. Concerns about what one had *not* (yet) learned appeared to mainly affect those doctoral students who were undecided about their career intentions. For these students, identifying gaps in their learning (e.g., developing an innovative research agenda, publishing, grant-getting, mentoring and advising students, teaching) amplified concerns about the difficulty of achieving success in a faculty position and the need to learn on the job.

The propositions described above could be explored in future studies of graduate education in engineering, as well as in team-based sciences and technical fields. Such studies would further develop our understanding of learning in doctoral education in engineering and the sciences. Eventually, these propositions might also lead to a mid-range theory that helps explain how doctoral students' research experiences shape their career intentions.

Implications for Future Research

Longitudinal research design.

While I was able to capture much data on the research experiences of Houston group members throughout this 13-month longitudinal study, much more learning continues to take place after the data collection period ended. What is being learned, and how this learning is different than the data I have already collected is unclear. What is likely, however, is that students are having critical experiences and/or are continuously evolving over time, which is undoubtedly shaping their understanding of and intentions to pursue the professoriate. Future researchers should consider following doctoral students throughout the doctoral experience as Baker and Pifer (2011) and Baker Sweitzer (2007 & 2009) have done. A longitudinal approach that follows students' learning in the context of a research group would allow researchers to explore students' many steps and how these influence professorial intentions (e.g., assumption that choosing a research post-doctoral position could be the first step in pursuing a faculty career).

Role of the post-doc in preparation for the engineering professoriate.

Post-doctoral students continue to learn about faculty work. But potentially, capable future faculty may opt out of pursuing the professoriate before securing a post-doc. These potential future faculty members may not know that a post-doc is where they might develop the skills they are currently lacking. In this study, there were two post-doctoral students in the Houston Group. Although the primary focus in this study was the doctoral students, the experiences and insights from both of the group's post-docs provided important information to juxtapose with the doctoral students' perceptions and intentions. Evidence from this study suggests that while students learn much about research and the professoriate in their doctoral research experiences, the learning between post-doctoral researchers and doctoral students is qualitative different.

It is possible that the confidence needed to pursue the professoriate is not solely gained during the doctoral research experience, but is rather acquired during the post-doctoral experience; if a post-doctoral research experience includes practices such as writing, publishing, regularly presenting, and working on grants, students' competencies and confidence in performing those competencies may be improved, which may shape professorial intentions. Thus, future research should examine the experiences of post-docs to better understand what they learn in their research experiences, and how their experiences influence intentions to pursue the professoriate. Further, because research experiences are important pathways to the professoriate in engineering, studying students from their graduate research experiences and post-doctoral research experiences could provide a more nuanced understanding of the pathway to an engineering faculty career.

Multi-group investigations to explore contexts.

This study focused on the research experiences of engineering students in one group at one institution. While it provides depth to the experiences of students in the Houston Group, it limits my ability to understand the effect of the departmental and school contexts on student learning and professorial pursuit. Thus, future studies should examine the departmental and/or institutional contexts as other mediating factors that shape students' learning and professorial pursuit. As a final consideration, if scholars explored the research experiences across institutions, more insight could be gained into the field of engineering as a particular context, which could shed light onto larger field-specific norms and values influencing students' interest in doing the work of faculty members

Examining engineering post-graduate career choice.

Evidence from my dissertation research highlights the various career options students consider. For instance, in this study I focus on the professoriate career choice. Hence, less was examined about why students choose industry careers, and/or how research experiences prepare members for industry careers. Future research should explore the relationships between engineering students' research experiences and post-graduate career plans (i.e., industry, research, faculty, non-engineering careers, other). Such a study could utilize a multiple-method, multiple-institution approach, with students from a diverse group of institutions to inform the development of a survey. A study of this nature could provide a wider interpretation of engineering post-graduate career choice. The knowledge from such a study could lead to implications for practice and policy that addresses the current demands of more highly skilled labor with advanced training in science, technology, engineering, and mathematics. Additionally, new knowledge on students' career plans may shed light onto larger issues of recruitment, retention, and completion, and lead to improvements in preparation for the engineering workforce.

Exploring additional contexts for learning.

In this study I was able to investigate students' learning in a number of research-related contexts. More observations and targeted questioning related to one context (e.g., lab, out-of-lab gatherings) could have provided more in-depth knowledge of the learning that takes place within that specific context. It is possible that students learn about research and the professoriate in contexts that were not explored in this study. For instance, several students mentioned that they learn about research from networks of peers and colleagues outside of the Houston research group. Because social interaction is a component of sociocultural learning perspectives, it comes as no surprise that student-learning takes place outside of the Houston Group. For the purposes of this study, however, examinations of social interactions were confined to those occurring between members of the Houston group. Future research may want to consider an analysis of one's network, and how the interactions with those in one's network influence his or her understanding and perceptions of the faculty role as Sweitzer (2007 & 2009) did for doctoral students in business.

Exploring the role of identity characteristics in faculty pursuit.

Based on assumptions of the sociocultural learning theories framework, I aimed to take social identity characteristics into consideration, and not treat them as background characteristics. Future scholars attempting to investigate the underrepresentation of students of color and women in engineering should be mindful that many of these students may be marginalized in the field of engineering. Encouraging these students to think about and discuss their underrepresentation provides a challenge because some of these students have never been given the space to articulate or make meaning of their underrepresentation in science and engineering. Future researchers will need to be cautious not to “lead” participants’ responses while exploring the meaning they have made and are making of their doctoral experiences.

Concluding Thoughts

Although this dissertation was not designed to produce implications for practice, one clear finding from this research group that could be helpful to doctoral advisors is that research advisors shape student learning about both research and the professoriate. Like crafting a syllabus, research experiences should be designed with learning outcomes in mind. In this study, Professor Houston and the leadership team were thoughtful about developing students’ research competence when considering the group's organizational structure, composition, and practices and activities. In designing the group, however, the leadership team gave less consideration to how the group’s organization, and all of the group’s practices and activities, might influence students’ career outcomes.

The findings from this study suggest that intentions to seek faculty appointments are influenced not only by participation in research and the knowledge and skills that it imparts, but by students’ perceptions of academic cultures, norms, and values. Discussing students’ perceptions on value conflicts may enable students to see how they might be successful in faculty roles while maintaining their personal commitments. As Anthony & Taylor (2004) and Nyquist et al., (1999) found that some students remain interested in faculty careers even when their advisors are candid about the challenges of a faculty career, and when the advisor shares personal experiences of negotiating and navigating the academy.

Also before creating subgroups, members of Professor Houston's group would have one-on-one meetings with him. While Professor Houston described this adaptation as a management strategy to create greater efficiency, he also recognized that changing the structure of the Houston Group practices (i.e., transitioning to the efficient weekly subgroup meetings versus one-on-one meetings) meant that he was no longer providing career counseling to his students, and perhaps more importantly, that he was actually unaware of most students' post-graduate career intentions. At the conclusion of data collection, Professor Houston shared that he might consider using a portion of group meetings to discuss what he does as a faculty member. Because everyone is gathered at group meetings, this change in how he structures the group meeting practices could influence how members perceive the professoriate as a potential career option. Hollingsworth and Fossinger (2002), offer similar recommendations. They suggest that faculty members should change the research training environment in efforts to better promote an interest in research careers, namely the professoriate. They argue that the nature of the research experience bears on what students learn about and how they perceive the professoriate.

Further research is needed to improve our understanding of the practices that influence doctoral students' learning about, perceptions of, and interest in faculty work. This study provides useful information about the nature of research experiences, and provides recommendations whereby researchers can engage in future research. There should be urgency to learn more about how graduate education – namely, participation in research experiences as a context for learning – prepares students for the professoriate. This is particularly true at this time when the economy is rebuilding, and current faculty members begin to retire; graduates will be expected to replenish the academic workforce. New knowledge that links students' learning and identity and career intentions could provide keys to creating practices and activities that acknowledge and affirm students. Furthermore, such research will be helpful for faculty and administrators aiming to improve, replenish, and diversify the professoriate.

APPENDICES

APPENDIX A: Number and Distribution of Doctoral Awards, by Decade

1900–99

Decade	Number	% distribution
All decades	1,364,069	100.0
1900–09	3,654	0.3
1910–19	5,542	0.4
1920–29	11,935	0.9
1930–39	25,674	1.9
1940–49	30,629	2.2
1950–59	82,689	6.1
1960–69	162,071	11.9
1970–79	320,936	23.5
1980–89	319,501	23.4
1990–99	403,861	29.6

Source: National Center for Science and Engineering Statistics (2012)

APPENDIX B: Dissertation Timeline

2012	
June-August	Pilot study: obtain IRB approval; contact research site
	Draft dissertation proposal and constitute committee
September-April	Revise dissertation proposal
	Pilot study: conduct data collection; ongoing analyses to develop research design and procedures, get familiar with qualitative management software
2013	
April	Send proposal to committee
	Defend dissertation proposal
April-September	Analyze pilot data
	Continue interviews and observations
October-November	Conclude data collection
November-December	Analyze dissertation data
2014	
January-May	Continue analyzing data
	Draft findings chapters
	Draft and revise concluding chapters
May	Full dissertation revisions
	Give full draft to committee
June	Complete necessary dissertation and graduation paperwork
	Pre-Oral dissertation defense (with committee members only)
July	Defend Dissertation (public defense)

APPENDIX C: Faculty Supervisor Recruitment Email

Hello (insert Prof. name),

I am Brian Burt, a doctoral candidate in the Center for the Study of Higher and Postsecondary Education, in the School of Education here at the University of Michigan. I am emailing you today to ask for your help with my dissertation study.

My study will examine the role in which the research experience plays in the preparation for engineering faculty careers. To inform my dissertation work, I would like to gain a better understanding of your research group and how the research experience influences your students' career aspirations and perceptions of faculty work.

I am asking, specifically, to

- observe your research group in your lab and in group meetings
- interview you two times this summer, and
- to interview some members of your research group twice this summer

With your permission (and that of the members in your group), I would digitally record interviews so that I can reflect on our conversations. All materials will be de-identified and remain confidential.

May I set up a time to talk with you by phone or in person to provide more information about my pilot study?

Thanks for your time and consideration,

Brian Burt

APPENDIX D: Student Recruitment Email

Hello (insert group member name),

I am Brian Burt, a doctoral candidate in the Center for the Study of Higher and Postsecondary Education, in the School of Education here at the University of Michigan. I am emailing you today to ask for your help with my dissertation study.

My study will examine the role in which the research experience plays in the preparation for engineering faculty careers. To inform my dissertation work, I would like to gain a better understanding of your engineering research experiences and how they influence your career aspirations and perceptions of faculty work.

Professor X has already agreed to participate in this study. I am asking you if I may include you in the study. In addition to observing your work on the project and in group meetings, I may ask you to participate in two interviews. The interviews will focus on your research experiences and your career aspirations and preparation. With your permission, I would digitally record interviews so that I can reflect on our conversations. All materials will be de-identified and remain confidential.

I will begin interviewing & observing in May. I would be honored if you could participate in this study. Would you agree to participate? May I set up a time to talk with you by phone or in person to tell you more about the study?

Thanks for your time and consideration. I hope you'll join the study.

Brian Burt

APPENDIX E: Fieldwork Schedule

Event	Date	# of Participants	Method
Email Introduction	July 10, 2012	n/a	Email
Group Meeting	September 27	13	Observation
Thesis Defense+	October 4	n/a	Observation
Group Meeting	October 4	20	Observation
Group Meeting	October 11	18	Observation
Group Meeting	October 25	19	Observation
Group Meeting	November 1	17	Observation
Interview++	November 6	n/a	Interview
Celebration	November 8	15	Observation
Dr. Randall 1	November 27	n/a	Interview
Professor Lee 1	November 29	n/a	Interview
Group Meeting	November 29	20	Observation
Professor Houston1	December 5	n/a	Interview
Group Meeting	December 6	20	Observation
Group Meeting	December 13	16	Observation
Subgroup A Meeting	December 18	15	Observation
Sherman 1	December 18	n/a	Interview
Subgroup B Meeting	December 19	6	Observation
Holiday Party	December 20	n/a	Observation
Ralph 1	January 5	n/a	Interview
Allen 1	January 7	n/a	Interview
Subgroup B Meeting	January 8, 2013	7	Observation
Group Meeting	January 11	20	Observation
Thesis Defense	January 14	n/a	Observation
Group Meeting	January 18	17	Observation
Subgroup A Meeting	February 6	11	Observation
Subgroup B Meeting	February 19	7	Observation
Subgroup B Meeting	February 26	8	Observation
Subgroup A Meeting	March 20	14	Observation
Group Meeting	March 22	19	Observation
Group Meeting	March 29	18	Observation
Conference	April 8-12	2	Observation
Group Meeting	May 24	22	Observation
Group Meeting	May 31	22	Observation

Group Meeting	June 7	20	Observation
Brielle 1	June 13	n/a	Interview
Danny 1	June 13	n/a	Interview
Group Meeting	June 14	25	Observation
Gloria 1	June 19	n/a	Interview
Group Meeting	June 21	25	Observation
Celebration	June 26	n/a	Observation
Lab Tour	June 28	n/a	Informal Int.
Erik 1	June 28	n/a	Interview
Group Meeting	June 29	22	Observation
Group Meeting	July 12	27	Observation
Safety Certification A	July 14	n/a	Internet
Safety Certification B	July 14	n/a	Internet
Group Meeting	July 19	24	Observation
Vince 1	July 24	n/a	Interview
Emma 1	July 25	n/a	Interview
Emergency Building Tour	July 26	n/a	Tour
Group Meeting	July 26	26	Observation
Lloyd 1	July 26	n/a	Interview
Group Meeting	August 2	26	Observation
Tiffany 1	August 8	n/a	Interview
Louise 1	August 8	n/a	Interview
Group Meeting	August 9	22	Observation
Kelcy 1	August 21	n/a	Interview
Group Meeting	August 23	24	Observation
Group Meeting	September 6	23	Observation
Ralph 2	September 12	n/a	Interview
Erik 2	September 12	n/a	Interview
Group Meeting	September 12	24	Observation
Vince 2	September 12	n/a	Interview
Allen 2	September 12	n/a	Interview
Sherman 2	September 13	n/a	Interview
Tiffany 2	September 13	n/a	Interview
Emma 2	September 13	n/a	Interview
Gloria 2	September 16	n/a	Interview
Lloyd 2	September 16	n/a	Interview
Louise 2	September 17	n/a	Interview
Danny 2	September 25	n/a	Interview
Kelcy 2	September 25	n/a	Interview
Professor Lee 2	September 26	n/a	Interview
Group Meeting	September 26	26	Observation
Group Meeting	October 3	20	Observation
Dr. Randall 2	October 3	n/a	Interview
Professor Houston 2	October 10	n/a	Interview
Group Meeting	October 10	26	Observation
Group Meeting	October 24	22	Observation

Notes
+ denotes observation with a non-Houston member to get a cultural perspective of Model's University's School of Engineering
++ denotes interview with a non-Houston group member to get a cultural perspective of Model's University's School of Engineering
* On average, Group Meetings lasted approximately one and a half hours, and Subgroup Meetings lasted approximately one hour. Interviews ranged from one hour to nearly two hours
* "Informal Int." (June 28) stands for "Informal Interview"
* Interviews ending with "1" represent the first interview, and interviews ending with "2" represent a follow-up second interview

APPENDIX F: Student Interview Protocol (Interview 1)

Interview 1

Description of the Project

1. When did you come to UM?
2. When did you start working with Dr. X?
3. Can you tell me about your research project?

Research Experience

4. I'm interested in learning more about who is in your research group. Can you describe your research group?
    a. How did you come to be apart of the group?
5. Tell me what an average day of working on this research looks like.
    a. Do members of the group have specific roles, do they know their roles?
    b. Do you interact with the other members of the group (relates to collaboration, situated learning, community of practice)?
        i. If so, how?
    c. How are tasks delegated (by skill level, career interests, stage in grad. school)?
        i. Observation: Is there a hierarchy in the research team? (power structures between students and faculty member, or amongst students)
6. What is "good research?"
    a. What kinds of research skills are needed?
    b. How are/were you prepared to do good research?
    c. Have you written any papers in this research group?
    d. How do you and your colleagues learn to write conference papers? Publications? Grant proposals?
    e. How do students identify their dissertation research topics?
7. How are your progress and contributions evaluated (don't lead, just for my reference: take the lead on a project, mentor or manage colleagues/or undergrads, take the lead on a paper, present at a conference)?
    a. Do you receive written assessments or one-on-one meetings?
    b. Are you expected to do different kinds of tasks/things over time? (Do students take on increasing responsibilities over time?)
    c. Are there other ways in which you and your colleagues can demonstrate progress?
8. What happens when a group member is not pulling his or her weight on the team?

Careers

9. Now tell me about yourself. What experiences/factors led to your intention to pursue a faculty career?
10. When did you start to think of yourself as a future faculty member?
11. Have you expressed your career interest to Professor X?
    a. If so, how did he/she respond?
    b. If not, why not?
12. Do you think students are encouraged to pursue a particular type of career (at Michigan, your department, your research group)?

The Professoriate

13. What qualities/characteristics/abilities do you think future faculty have to possess to be successful?
    a. Do you think certain students are more likely to become professors over others?
14. I'm curious about your perceptions of faculty careers. What do you think a faculty career entails?
    a. Where did these perceptions arise?
    b. Have your perceptions of the professoriate changed over time?
    c. Are there aspects of the faculty career that are appealing to you?
    d. Are there aspects that are not appealing?
15. Do you think you are being prepared to pursue a faculty career?
    a. If so, what experiences are preparing you? If not, why not?
    b. Are there experiences you wish you had/will have?

Socialization

16. Describe the role of a faculty-advisor
    a. What would be the ideal faculty-advisor
17. What makes a good student and faculty-advisor relationship?
18. Is your faculty-advisor also your research supervisor?
    a. If they are the same person, are they able to separate the research experience from advising?
19. What is the primary method of communication between you and your advisor?
    a. How often do you see or talk to your advisor?
20. If you were designing a study on how the research experience influenced doctoral students perceptions of and aspirations for academic careers, what would you study?
    a. What else should I be observing/asking?

APPENDIX G: Houston Leadership Team Interview Protocol (Interview 1)

<u>Interview 1</u>
Description of the Project

1. Can you tell me about your research projects?
    a. Can you explain where you are in the projects (the stage…beginning, middle, end)?
2. What is your role as the supervisor of these projects?
3. Just curious, have any of your doctoral students expressed an interest in pursuing the professoriate?
    a. Which ones?
    b. Are you encouraging them to pursue the professoriate? How?

Research Experience

4. I'm interested in learning more about who is in your research group. Can you describe your research group?
    a. How did you select the members of your group?
        i. Does the way you run your group mirror the group you were in as a doctoral student?
5. Tell me what an average day in the lab looks like.
    a. Do members of the group have specific roles, do they know their roles?
    b. How are tasks delegated (by skill level, career interests, stage in grad. school)?
        i. Observation: Is there a hierarchy in the research team? (power structures between students and faculty member, or amongst students)
6. What is "good research?"
    a. What kinds of research skills are needed?
    b. How do you prepare students to do good research?
    c. How do students learn to write conference papers? Publications? Grant proposals?
    d. How do students identify their dissertation research topics?
7. How do you evaluate students' progress and contributions (don't lead, just for my reference: take the lead on a project, mentor or manage colleagues/or undergrads, take the lead on a paper, present at a conference)?
    a. Do students take on increasing responsibilities over time? (Do you expect them to do different kinds of things over time?)
    b. How do you know if they are ready?
    c. How do students demonstrate their progress?
8. What happens when a student is not pulling his or her weight in the group?

Identity

9. What qualities/characteristics/abilities do you think future faculty have to possess to be successful?
    a. Do you think certain students are more likely to become professors over others?
10. Now tell me about yourself. Why did you become a faculty member?
    a. What experiences/factors led to your intention (the answers to this question may shed light unto what questions to ask students)
11. What were your perceptions of a faculty career when you were a graduate student?
    a. Where did these perceptions arise? Have they changed over time?
    b. Which aspects of the faculty career were appealing to you then?
    c. Were there aspects that were not appealing?
12. When did you start to think of yourself as a future faculty member?
    a. What experiences led to this realization?
13. Were you prepared to become a faculty member when you took your first faculty position?
    a. If so, what experiences prepared you?
    b. Are there experiences you wish you had?

Socialization

14. What makes a good advisor/student relationship?
15. Do you encourage students who do not express interest to consider an academic career?
16. Earlier you mentioned qualities, characteristics, and abilities that are needed to be successful for a faculty career. How do you figure out if your doctoral students have these?
17. Do you think students are encouraged to pursue a particular type of career (at Michigan, your department, your research group)?
18. If you were designing a study on how the research experience influenced doctoral students perceptions of and aspirations for academic careers, what would you study?
    a. What else should I be observing?
    b. Asking?

<u>Extra questions</u>

1. Can you describe some positive experiences you have had as a faculty member?
2. Can you describe some challenging experiences you have had as a faculty member? (the answers to this question may be things that students observe, and encourage/dissuade them to pursue faculty careers

APPENDIX H: Student Interview Protocol (Interview 2)

Interview 2

In the following questions, I'm going to pose some hypothetical questions:

1. If you were building the ideal engineering professor, what would that person be like?
    a. Do you fit that description, why or why not?
    b. Ok, so now that that's the ideal, what's a more realistic description of an engineering professor?
2. If you "had" to start a faculty career next semester, would you be ready?
    a. What aspects of your doctoral education (or research experiences) make you confident in your future role as a professor?
    b. What worries you about your future role as a professor?
    c. What kinds of skills do you feel like you would still need to learn/develop in order to be successful in your new faculty role?
3. My final hypothetical question, [even though you may not want to be a professor] can you "see" or "imagine" yourself as being a faculty member?

Ok, now, I want to ask you questions based on what I'm hearing in my interviews:

4. One thing that seems to be emerging from my interviews is that people who rule out a faculty career do so because they are worried about grant funding, not because they don't like teaching or something else associated with faculty work.
    a. Is that true for you?
    b. What are your concerns with grant funding? *(Why are you worried about grant funding?)* OR
    c. Why do you think some others are worried about grant funding?

APPENDIX I: Houston Leadership Team Interview Protocol (Interview 2)

Interview 2

5. What do you think students learn from group meetings, subgroup meetings, and working in the lab?
    a. Differences between the learning contexts?
6. Students feel as if faculty members need to be skilled at: having a research expertise, persevering through failures (experiments, publishing, grant funding), interacting with others (people person), managing people
    a. What do you feel about those competencies?
    b. Are there other characteristics and skills needed to be a successful professor?
7. How do research experiences help develop these skills/characteristics/confidence for students?
8. When you started off teaching, were you doing a lot of experiments in the lab or did you have to manage your graduate students in the lab?
9. From my conversations with students, most students are interested in pursuing industry jobs, or say that they'll consider a faculty job later in their career after first gaining industry experience.
    a. Why do you think most students in your group are more interested in pursuing industry jobs rather than aspiring to pursue faculty careers?
10. One thing that seems to be emerging from my interviews is that people who rule out a faculty career do so because they are worried about grant funding, not because they don't like teaching or something else associated with faculty work.
    a. Why do you think some students are worried about grant funding?
11. It appears as if students' interest in faculty careers are related to their **confidence** in their abilities to: **articulate the novelty** of his or her dissertation research; **translate his or her research into a competitive faculty research agenda** that can secure grant funding; and, **"being" the expert** in his or her area of research.
    a. Why do you think this might be?
12. What experiences could a faculty member provide for students to prepare them for a successful faculty career?

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