

Organization and Retention of Students in Graduate Engineering Research Groups

Erin D. Crede

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Maura J. Borrego, Chair
Lisa D. McNair
Vinod K. Lohani
Theodore D. Fuller

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Abstract

The purpose of this research project was to better understand the experiences of graduate students in internationally diverse research groups, and how these research groups and international diversity contributes to a student's intent to complete his or her graduate degree. This exploratory mixed methods research was conducted in three phases: (1) an ethnographic study of selected research groups in two engineering graduate departments, (2) development of a survey for students in graduate engineering students, and (3) administering the survey to graduate engineering students in research groups to verify the findings.

In order to address the project aims, three smaller studies were initiated that address individual elements of graduate education, including: learning in research groups and international diversity, and retention in graduate engineering programs. The focus of the first study was to understand how and under what conditions research groups foster successful learning and professional development for graduate engineering students, and how these findings can be used to inform management of engineering research groups to optimize student learning, productivity, and intent to complete the degree. Key findings from the ethnographic analysis indicate that group size directly influences the mechanisms of student learning, as well as several elements common across research groups from different universities and academic departments, including: power distance and communication, access to resources, and role of the advisor.

During the (second) integration phase of this mixed methods study, the nine months of ethnographically guided observations and interviews were used to develop a survey examining graduate engineering student retention. Findings from the ethnographic fieldwork yielded several themes, including: the role of international diversity, research group organization and climate, student self efficacy, and individual and group learning experiences. Final retention

themes from the ethnographic analysis are presented along with a discussion of how these data were configured into instrument questions. A discussion of the final instrument is presented, including validity and reliability analysis, and how the final questions were integrated into themes to test hypotheses for future studies. This chapter also presents implications for mixed methods researchers interested in using qualitative methods to create new instruments.

In the third and final stage of the research study, the survey developed in the second phase of the research study was administered to four universities across the United States. Data analysis focused on better understanding the differences in retention constructs by student nationality. Results from more than 600 engineering PhD students from 6 international regions enrolled in U.S. engineering graduate programs were examined to characterize demographic differences in participant responses for intention to complete the degree. Six constructs were found to be significant in predicting students' responses regarding their intention to complete their degree, including: expectations, climate, organization, project ownership, perception of value, and individual preferences. Taken together these constructs were able to explain 28 percent of the variation in student responses. Additionally, all six constructs showed significant differences with respect to a respondent's country or region or origin. These results are discussed in light of the implications for faculty members advising similarly diverse groups of students.

In combination, these three studies represent a sequential exploratory mixed methods approach in which ethnographically guided observations and interviews were integrated into a quantitative instrument. Results of this study can be used to inform the organization and management of internationally diverse research groups to foster student development and ultimately increase retention.

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Table of Contents

Abstract.....	ii
Acknowledgments.....	iv
List of Figures.....	vii
List of Tables.....	viii
1 Introduction.....	1
2 Literature Review.....	7
2.1 Introduction.....	7
2.2 Graduate Education.....	7
2.3 The International Student Experience.....	10
2.4 Summary.....	14
3 From Ethnography to Items: A Mixed Methods Approach to Developing a Survey to Examine Graduate Engineering Student Retention.....	17
Abstract.....	17
3.1 Introduction.....	17
3.2 Existing Research Measuring Graduate Student Retention.....	20
3.3 Measuring the Engineering Graduate Student Experience.....	22
3.4 Research Setting.....	23
3.5 Research Design and Methods.....	24
3.6 Qualitative Results.....	27
3.7 Instrument Development.....	28
3.8 Discussion.....	38
3.9 Conclusions and Future Work.....	42
4 Learning in Graduate Engineering Research Groups of Various Sizes.....	43
Abstract.....	43
4.1 Introduction.....	44
4.2 Theoretical Framework.....	47
4.3 Methods.....	49
4.4 Findings and Results.....	54
4.5 Discussion and Implications for Practice.....	66

4.6	Conclusions.....	71
5	Characterizing the Influence of International Diversity on Graduate Engineering Student Retention	72
	Abstract.....	72
5.1	Introduction	72
5.2	Literature on Doctoral Student Retention.....	75
5.3	Research Methodology.....	78
5.4	Results.....	85
5.5	Discussion.....	88
5.6	Implications for Graduate Programs.....	91
5.7	Conclusions.....	92
6	Summary and Conclusions.....	94
6.1	Conclusions.....	94
6.2	Future Work.....	97
	Appendix A: Graduate Survey.....	100
	Appendix B: Question Mapping.....	108
	Complete Reference List.....	112

List of Figures

Figure 4.1. Survey Results for Aspects of Student Learning as a Function of Group Size (1 = Strongly Disagree, 5 = Strongly Agree).....	55
Figure 4.2. Survey Results Group and Advisor Meetings as a Function of Group Size. (a) Actual Frequency of Meetings. (b) Perceived Adequacy of Meetings (1 = Strongly Disagree, 5 = Strongly Agree).	59
Figure 4.3. Survey Results for Communication as a Function of Group Size (1 = Strongly Disagree, 5 = Strongly Agree).	60
Figure 4.4. Survey Results for Student Access to Resources as a Function of Group Size (1 = Strongly Disagree, 5 = Strongly Agree).	63
Figure 4.5. Organizational Space as a Function of Group Size.....	64
Figure 4.6. Survey Results for the Role of the Advisor as a Function of Group Size (1 = Strongly Disagree, 5 = Strongly Agree).	66
Figure 4.7 Structure of a Small Research Group.....	67
Figure 4.8. Structure of a Medium Sized Research Group.....	68
Figure 4.9. Structure of a Large Research Group.....	70

List of Tables

Table 1.1: Summary of Research Question, Data Collection and Analysis Information for each Chapter.....	6
Table 2.1: Component Items of Norm and Counter Norm Scales. Adapted from Anderson and Lewis (1994)	12
Table 3.1: Qualitative Themes.....	27
Table 3.2: Creating Survey Questions from Coded Data.....	29
Table 3.3: Example survey items by construct.....	30
Table 3.4: Demographic items included in the survey.....	32
Table 3.5: Pilot Test: Internal Consistency Analysis for Instrument.....	33
Table 3.6: Internal Consistency Analysis for Final Instrument.....	35
Table 3.7: Internal consistency analysis as a function of university.....	36
Table 3.8: Internal consistency analysis as a function of nationality.....	37
Table 4.1: Supervisory Roles (adapted from Lee (2008))	48
Table 4.2: Participant Demographic Information.....	50
Table 4.3: Demographic Information for Survey Respondents for each University	52
Table 4.4: Partial List of Survey Items.....	54
Table 4.5: Summary Characteristics of Graduate Research Groups.....	56
Table 5.1: Constructs used to measure intention to complete the graduate degree.....	79
Table 5.2: Internal Consistency Analysis for Final Instrument.....	80
Table 5.3 Universities selected as part of the sample (data from 2010 U.S. News and World Report)	81

Table 5.4: Demographic Information for Survey Respondents at Participating Institutions.....	82
Table 5.5: Survey Response Rates for Participating Institutions.....	83
Table 5.6: Linear Regression Results for Constructs used to Examine Intention to Complete the Degree.....	85
Table 5.7: Mean and Standard Deviation for Intention to Complete the Degree by Nationality.....	86
Table 5.8: ANOVA Results for Independent Variables by Nationality.....	87

Chapter 1

Introduction

The prevalence of international students is a defining feature of many U.S. graduate engineering programs. Non-U.S. citizens accounted for two-thirds (67%) of all engineering doctorate recipients in 2006 (NSF, 2007b). While the number of degrees awarded has risen, the proportion of domestic students attending engineering graduate school has fallen. After two years of decline, first time graduate enrollment in science and engineering increased in 2006—by 16% for foreign students but only 1% for domestic students (NSF, 2007a). To date, much of the research regarding the recruitment and retention of doctoral students has focused on examining student characteristics and factors external to the university (Abedi & Benkin, 1987; Nettles & Millett, 2006). While these quantitative studies have yielded a broad overview of possible factors that influence the decision to leave doctoral study, further work is necessary to identify the root causes of the problem. Additional studies have focused on the interaction between the student and the department or discipline, but did not incorporate engineering students (Golde, 1998, 2005). Previous studies have included a broad range of disciplines, examining the statistically significant differences in program completion rates, and identifying characteristics that distinguish one discipline from another. Paramount among these cited differences was the large proportion of international students attending U.S. graduate engineering programs (Lovitts, 2001; Nettles & Millett, 2006).

While these studies have served to situate engineering within the graduate education landscape, the high percentage of international students may have also been a reason to exclude engineering from cross-disciplinary studies. The high representation of non-U.S. students in engineering graduate education presents an opportunity to contribute both to an understanding of engineering student recruitment and retention and to the graduate education body of research regarding internationally diverse communities. Engineering retention studies at the undergraduate level, including the Academic Pathways Study, emphasize student perceptions of engineering and how these relate to individual identity development (Matusovich, Streveler, Loshbaugh, Miller, & Olds, 2008; Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008). At the same time, broader and more global perspectives among students are being called for at both the undergraduate and

graduate levels (Akay, 2008; Duderstadt, 2008; Friedman, 2007; NAE, 2005; Sigma Xi, 2007). Thus, the culture of engineering graduate education must be reframed to be more inclusive of diverse cultural perspectives so that both domestic and foreign students are attracted to and feel welcome to enroll and persist in graduate school.

The closely related theories of communities of practice and socialization provide the theoretical perspective for this study, in which students' experiences within a community of practice are viewed as a social learning process. Others have studied the role of a community of practice, mentoring, and socialization in graduate education, but there remains a need for a broader understanding that encompasses all of these contributing themes within the engineering context. This understanding must acknowledge that international students, in addition to university and faculty cultures play a significant role in the development of the culture of an engineering academic and professional community. Contributing themes may include cultural expectations regarding the hours that students work, respect and deference toward faculty, and the language spoken during informal laboratory interactions. In order to reduce doctoral student attrition for all engineering students, the engineering education community needs to understand the cultural factors and student perceptions that develop in the presence of a large international population.

Finally, graduate engineering students trained in collaborative international communities will be better prepared to succeed in an increasingly global marketplace (Downey, Lucena, Moskal, Parkhurst, & Hays, 2006). Previous studies have found that student sojourners (such as those studying abroad) who experience a greater amount of interaction with host nationals have fewer academic problems (Pruitt, 1978) and fewer social difficulties (Ward & Kennedy, 1993; Ward & Kennedy, 1999). Thus, a better understanding of students' perceived roles in an internationally diverse engineering community will contribute to their sense of belonging both to the academic community where they currently reside, and the professional community to which they aspire. Graduate engineering faculty should be aware of these relationships so that program- and research group-level changes can be initiated to create an inclusive departmental culture. Initial changes will come from faculty, but student buy-in will be critical for continuing community development. The success of engineering communities rooted in research-based understanding of

student socialization and development has wide implications for the increasing graduate engineering student enculturation, reducing attrition and increasing new student enrollment.

The purpose of this sequential exploratory mixed methods research is to develop a clearer understanding of the factors that contribute to developing the culture and community of an internationally diverse graduate engineering research group. The overarching research questions guiding this study are:

1. What are the similarities and differences among the environments for engineering research groups of varying sizes, and how can this information be used to inform development of these research groups?
2. How can ethnographic data be used to inform the development of a survey instrument for an internationally diverse population of engineering graduate students from multiple universities?
3. What elements of the graduate student experience in engineering research groups contribute to a student's intention to complete his or her degree, and how do these vary for students from a variety of national backgrounds?

This exploratory mixed methods research was conducted in two phases: (1) an ethnographic study of selected communities in two engineering graduate departments, and (2) a survey of graduate engineering students to verify the findings. Community, as defined in the existing literature, generally refers to an engineering department, but may refer to smaller communities within a department, such as research groups, or interdepartmental teams. In this study we focus on the community which develops in engineering research groups. The results of this study will contribute both to an understanding of the factors that inform recruitment and retention, and to the graduate education body of research regarding internationally diverse communities.

In order to address the study research questions, three smaller studies were initiated that address individual elements of graduate education. The format for this dissertation is three manuscripts, one corresponding to each of the research questions listed above. In the following sections, the findings and results from three studies are presented which cover the following: the

characterization of graduate engineering research groups, the methodological foundation for integrating qualitative data into a quantitative instrument, and finally the results obtained from administering the instrument to several universities.

The remainder of this manuscript presents a collection of works that address the purpose of the study by telling the story of this mixed methods project. A manuscript dissertation was chosen as the format for this work in order to package the findings and results for three different scholarly audiences: engineering education, research methods, and higher education. In this way sections three through five reflect the literature, language, methods, and implications appropriate for its intended audience. Chapter 3 was written with the intention of submitting to the *Journal of Mixed Methods Research*, while Chapter 4 is written for an engineering education research audience. This manuscript will be submitted to the *Journal of Engineering Education*. Finally the final manuscript shown in Chapter 5 was written with a higher education audience in mind, and will be submitted to the *Journal of Higher Education*.

Due to the variation in expectations for these different scholarly audiences, the formatting of this manuscript style has some slight variation from a traditional dissertation. The two notable differences are detailed introductions and literature reviews contained within each of the three manuscripts and the lack of a traditional overarching methods section as a distinct chapter. Providing an introduction and literature review unique to each part of the study provides the reader with the literature most relevant to the portion of the study in question, and can be written in the style of the intended audience. This format will allow the findings and results to be disseminated more widely and expediently than would be afforded with a traditional dissertation format. The other difference is the absence of the traditional methods section that follows the literature review in the traditional dissertation format. Since this is a sequential exploratory mixed methods study, the entire purpose of Chapter 3 is to explain the methodological techniques used to integrate the qualitative and quantitative phases. This serves as not only the methodological foundation for this research project, but provides insight to readers interested in using a mixed methods approach for their research.

With these formatting differences in mind, Chapter 2 contains a general review of the literature that forms the basis for many aspects of the study, with detailed literature found in Chapters 3 through 5. In Chapter 3 the results from the qualitative phase of the study were analyzed and used to develop a multi-institutional survey. This methods-based section explains how to integrate qualitative and quantitative data, and showcases one way that mixed methods can be used in engineering education studies. Chapter 4 develops a schema for characterizing small, medium and large research groups and explains how these groups are used in graduate engineering education. Chapter 5 is the final data driven section, which presents the results from the quantitative survey administered to four universities across the country. This manuscript concludes with Chapter 6, a brief summary of the findings and results from Chapters 3-5, along with some discussion and directions for future work. A summary of the research questions, data collection and data analysis methods for the main articles are shown in Table 1.1.

Table 1.1

Summary of Research Question, Data Collection and Analysis Information for each Chapter

Article Title	Purpose or Research Questions	Data Source and Collection	Data Analysis
From Ethnography to Items: A Mixed Methods Approach to Developing a Survey to Examine Graduate Engineering Student Retention	The purpose of this article is to show how researchers can use a mixed methods approach to create a quantitative survey instrument using the results of a qualitative study	• Ethnographic Observations and Interview data • Two pilot tests at home institution	• Benchmark Coding • Validity and Reliability Analysis for Universities and Nationalities
Learning in Graduate Engineering Research Groups of Various Sizes	1. What are the similarities and differences among the environments for engineering research groups of varying sizes? 2. How can these similarities and differences inform management of engineering research groups to create an environment that optimizes the students' overall learning experience?	• Ethnographic Observations and Interviews of three graduate engineering research groups at the home institution. • Survey responses from 4 institutions	• Thematic analysis of the ethnographic data • Descriptive analysis of the survey data
Characterizing the Influence of International Diversity on Graduate Engineering Student Retention	1. What elements of the graduate experience help foster retention of students in U.S. graduate engineering programs? 2. What, if any, are the differences by student nationality in the intention to complete the degree for students in U.S. doctoral engineering programs?	• Online Survey administered to four participating institutions in the United States • Target population of approximately 5000 graduate engineering students	• Descriptive statistics • Linear Regression for Intention to Complete • ANOVA for Nationality

Chapter 2

Literature Review

2.1 Introduction

To obtain the articles reviewed as part of the larger study, an extensive search of the literature was performed during August through March of 2008. The publications cited here are not meant to be an all inclusive list of the literature on the topic, but rather serve to situate this work by highlighting several key areas relating graduate education, with specific focus on engineering disciplines and international students. The literature was collected and organized around the broad themes of graduate education and the experiences of international students. Within these themes, the focus will be more narrowly constrained to the experiences of engineering students where there is literature available, but in many cases engineering students were not the focus of the study.

2.2 Graduate Education

Guided by the study purpose, there were three areas within the body of research on the graduate student experience that were of primary relevance to the study. These include: graduate student identity development, the socialization of graduate students, and the development of communities of practice.

2.2.2 Socialization

Socialization is the process through which an individual learns to adopt the values, skills, attitudes, norms, and knowledge needed for membership in a community (Bess, 1978; Kuh & Whitt, 1988; Merton, 1957; Pruitt, 1978; Salomon & Perkins, 1998; J Van Maanen & Schein, 1979; Ward & Kennedy, 1993). In the case of engineering, this may be the graduate community, a research group, academic department, discipline or professional career. Socialization plays an important role in the graduate school experience, and when unsuccessful, may contribute to the decision to depart the degree program. Graduate student socialization differs from professional

socialization in the requirement that graduate students become socialized simultaneously into two roles: the role of graduate student and the role of professional engineer (Golde & Walker, 2006). Issues relating to graduate student socialization are discipline-specific, meaning that studies within graduate education must focus on a particular departmental and environmental context to gain an understanding of the relationships involved (Golde & Walker, 2006; Nettles & Millett, 2006).

One socialization study specifically focused on graduate education examined the experiences of doctoral students in high and low completing departments (Gardner, 2009). This study considered the disciplinary differences in doctoral education, noting that electrical and computer engineering was often considerably different than the other five non-engineering departments studied, and represented the lowest completing department. The four themes that emerged from this study included: support, self direction, ambiguity and transition. Interestingly, the author found that engineering students (unlike all of the other disciplines) depended more on faculty for support than their peers, and attributes this to the high percentage (over 50%) of international students in the engineering department. Engineering students also experienced the theme of self direction differently than students from other departments. The engineering students felt that self direction meant learning how to do research independently, something that you had to teach yourself because that information could not be obtained from a class. Students from the non-engineering departments cited their peers as a key mechanism for learning new material. This is consistent with the findings of Nettles and Millett (2006), who noted that engineering students had a high level of satisfaction in their relationship with faculty, but a low level of satisfaction in their peer interactions. Finally, relating to transition, students in engineering again offered the majority of the comments, which the author attributes to the various transition issues that international students must face in addition to the transition from undergraduate to graduate school. In addition to the above instances, the author makes multiple mentions of the high percentage of international students in engineering, arguing that considerable research needs to be done to understand how they influence the graduate student experience (Gardner, 2009).

Several other researchers have discussed the socialization of graduate students in the form of a multi-stage process, and are representative of the developmental nature of the socialization

process (Baird, 1993). Examples include the four stages presented by Weidman and coworkers (2003; 2001) and Lovitts (2001) that express socialization in regard to prior anticipatory socialization to the graduate school environment, through culmination of the degree and entrance into the profession. While these previous models have paved the way for future research, they fall short of explaining the complexity of the graduate student experience as they focus more on individual program elements, such as coursework and qualifying exams, rather than the *personal transformation* of the student during his or her educational experience. The inherent complexity of this problem requires a variety of more focused studies at the program and department level, and investigating differences across sub-disciplines and institutional types.

2.2.3 Communities of Practice

Engineering as a profession, like medicine or law, is endowed with a set of professional knowledge and associated skills that are widely accepted as a requirement of each new member. In order to obtain this required knowledge and skill base, students participate in lengthy degree programs and/or mentored work experiences. During these experiences, students observe the behaviors, norms and attitudes that are prevalent among the profession's practitioners. It is the observation of these norms and values that enable new members to begin the process of socialization to the community. A specific example of a socialization process would be a student entering a graduate research group. Similar to socialization to a community, the concept of a community of practice was proposed by Wenger as a population that defines itself along three dimensions: mutual engagement, a joint enterprise, and a shared repertoire (Wenger, 1998). There are several key components in cultivating a community of practice: a three-fold structural model for communities of practice includes domain, community, and practice (Wenger, McDermott, & Snyder, 2002). A community of practice has an identity defined by a shared domain of interest. Membership therefore implies a commitment to the domain, and therefore a shared competence that distinguishes members from other people. Community is formed when members engage in joint activities and discussions, help each other, and share information. They build relationships that enable them to learn from each other. Finally practice entails the development of a shared repertoire of resources: experiences, stories, tools, and ways of addressing recurring problems (Wenger, 1998). The defining features of a community of

practice are authentic problems and an apprenticeship-type model of learning and becoming a member, much like a graduate engineering research group or laboratory (Newstetter, Kurz-Milcke, & Nersessian, 2004).

While the concept of a community of practice has existed for some time, only recently has this been applied to engineering, specifically to faculty development, university collaboration with industry and government, and more recently engineering education (Capobianco, Diefes-Dux, & Oware, 2006; Streveler, Smith, & Miller, 2005). Capobianco *et al.* (2006) examined the development of a professional community of practice as it applies to the nation's first graduate program in engineering education. These results show how the dynamic nature of building a professional community of practice is closely related to learning, as well as how its members (faculty and students) are strongly defined and shaped by their enculturation in the engineering education program. In one of the few inclusions of engineering students, Hasrati studied the process of academic socialization of a group of Iranian Ph.D students studying in five UK universities, specifically the relationship between these students and their supervisors (2005). He argues that communities of practice are a useful tool for understanding learning at the doctoral level, but it is "realized differently for different disciplines of study" (Hasrati, 2005, p. 1).

Other works have cited the benefits of using research teams as an approach to graduate training (M. M. Turner, 2006). Turner advocates the use of research teams as a way to train graduate students to allow for a community of scholars to share knowledge and exchange ideas. Her conclusion is that this training serves as an apprentice-type program which helps prepare students to conduct their own research and will aid in the transition from a student to a young scholar. Her work emphasizes the value of studying socialization in the context of a research group, to examine how faculty members interact with students, and how student community develops.

2.3. The International Student Experience

In addition to socialization related difficulties, incoming graduate student sojourners, or students who attend an institution of higher learning in another country, face a variety of cultural and

behavioral differences as well as a different set of expectations compared to their home country. The vast majority of the literature surrounding student sojourners focuses on the problems of adaptation to the host country and discusses issues such as enculturation, acculturation, assimilation and culture shock. An article published in 2008 presents an overview of the theoretical development of culture shock in the context of student sojourners and seeks to clarify and extend these theories (Zhou, Jindal-Snape, Topping, & Todman, 2008). Early research on culture shock began in the 1950's with the examination of mental health issues related to studying abroad (Byrnes, 1966; David, 1971). (Refer to Table 1 in Zhou *et al.*, (Zhou, *et al.*, 2008) for a summary of the traditional theoretical approaches to culture shock). During the 1980's, research on culture shock shifted to view student sojourning as a learning experience and noted that steps should be taken prior to travel to prepare the student (S. Bochner, 1982) potentially alleviating some of the "shock" upon arrival to the host country. This perspective treated studying abroad as a dynamic learning experience for both the student and the host country, and served to lay the foundation for contemporary perspectives on intercultural contact (Zhou, *et al.*, 2008). The three contemporary perspectives are more comprehensive and consider the different components of how students respond to new environments: affect (stress and coping), behavior (culture learning), and cognition (social identification). These three theories are often combined into what is now called the ABC model. Theoretical details on each of these theories are well summarized (Zhou, *et al.*, 2008) and the authors conclude that "culture shock" is really "contact induced stress accompanied by skill deficits that can be managed or ameliorated" (p. 65). This suggests that there are steps which programs and universities can take to assist students, and has led to the increasing use of terms like "adaptation" and "acculturation" in the literature today.

From the closely linked theories relating to the ABC model, researchers have published literature focusing specifically on international student sojourners. One such article examines the three distinctive social networks used by students, each serving a specific function (S. Bochner, McLeod, & Lin, 1977). The primary network is communication with their home country, which provides a link to cultural behaviors and values. This is followed by interactions with host nationals, providing academic support and culturally relevant skills for relating to the host country. Finally, students develop a social network of other international students, which

provides mutual social support. These networks were classified by Furnham (2004) as mono-cultural, bi-cultural and multi-cultural friendship networks, respectively.

In addition to the theoretical models discussed previously, several researchers have noted differences between international and domestic students in certain aspects of their graduate programs, such as reliance on peer and faculty interactions. A 1994 study found the importance of technical mentoring—which may include basic information on how work is done in accordance with the norms of research—is substantial and appears to be the key to transmitting traditional values between one generation of scientists and another, particularly when the next generation comes from a culturally different background (Anderson & Lewis, 1994). Anderson *et al.* (1994) examined the views of doctoral students with respect to academic research. The focal variables for their analysis were subscription to the academic norms as described by Merton and Barber (1963), and subscription to the counter norms, based on Mitroff's work (1974). A replication of the wording used for norms and counter norms is given in Table 2.1. Their findings are based on a nationwide survey of students in chemistry, sociology, microbiology and civil engineering, with main comparisons based on gender, discipline and nationality.

Table 2.1
Component Items of Norm and Counter Norm Scales. Adapted From Anderson and Lewis (1994)

NORMS	COUNTERNORMS
<i>Universalism</i> - Scientists evaluate research only on its merit, i.e. according to accepted standards of the field.	<i>Particularism</i> - Scientists assess new knowledge and its applications based on die reputation and past productivity of the individual or research group.
<i>Communality</i> -Scientists openly share new findings with all colleagues.	<i>Solitariness</i> - Scientists protect their newest findings to ensure priority in publishing, patenting, or applications.
<i>Disinterestedness</i> - Scientists are motivated by the desire for knowledge and discovery, and not by the possibility of personal gain.	<i>Self-Interestedness</i> - Scientists compete with Others in the same field for funding and recognition of their achievements.
<i>Organized Skepticism</i> - Scientists consider all new evidence, hypotheses, theories, and innovations, even those that challenge or contradict their own work.	<i>Organized Dogmatism</i> -: Scientists invest their careers in promoting their own most important find

The largest gap between any two groups is found in the case of U.S. versus non-U.S. student support for the counter norms (Anderson & Lewis, 1994). The main effects in the analysis of disciplinary differences come from the civil engineering students, (who were chosen to be representative of other engineering disciplines). These engineering students show the weakest support for the norms and the strongest support for the counter norms, compared to the other degree programs. The authors conclude that the data suggest the need to incorporate broader cultural theories into our understanding of the value system of science. They further argue that it would be useful to determine whether or not there are sub cultural differences within the group of U.S. citizens, which might have implications for efforts to recruit and retain students from diverse backgrounds in the sciences and engineering.

Related to international student socialization, a study conducted in Russia focused on the issue of the social adaptation of undergraduate student sojourners (Dorozhkin & Mazitova, 2008). The authors assert that it is the job of the host country to “provide the optimal conditions for [student sojourners’] living and educational needs (pg 23)” and that one of the main foci for research should be the extent to which the new arrivals are prepared to adapt to a new environment (Dorozhkin & Mazitova, 2008). This echoes the argument proposed by Zhou *et al.* (2008), that students are able to overcome the stress of adapting to a new environment if properly prepared. Dorozhkin & Mazitova proceed to argue that one of the notable differences in the cultural climate may stem from the differences between a traditional and modern society. Traditional societies are characterized by a social structure with the hierarchy based on membership in a class or caste, making relationships with the family and friends the most important. Contrast this with modern societies, which value social mobility and high individual achievement or professional status. Also noted is the importance of the relationship between what is expected and the reality of the experience, indicating that how students choose an institution contributes to their expectations about studying abroad. These expectations may also influence how their identity forms in graduate school. So the question remains of what constitutes social adaptation? What factors indicate that a student sojourner has successfully adjusted to a new culture or environment? This study posits that the students’ attitude toward the host country both in an emotional and behavioral sense characterizes their adaptation to Russia. However the other indicators that the authors present, including overall satisfaction with Russian life, appropriate

functioning in the role of student, and positive perception of the new environment, could serve as indicators of adjustment to graduate school as well, a factor not considered by the present study.

Additional works have examined enculturation (Clark, Dodd, & Coll, 2008) at institutions of higher learning, but virtually no literature addresses the specific experiences of international graduate students in engineering. In their literature review, Zhou *et al.* (2008) conclude that the current theoretical models are not without their limitations and that more research needs to be accomplished to synthesize theories into a coherent framework. Assuming that adaptation, acculturation or enculturation is possible, future research should address this issue by investigating experiences or programs that assist students in managing stress and “skill deficits”, while accounting for disciplinary differences. While there are several studies which have investigated acculturation for undergraduate students, there remains a need to further explore the experiences of international graduate student sojourners who face the dual problem of adapting to both a new host culture along with the cultural differences and expectations of graduate school. There are few graduate programs where these international students are more strongly represented than in the engineering disciplines.

Finally, Zhou *et al.* (2008) note that the rapid increase in the number of international students has led to a heightened awareness of the pedagogical differences in differing cultures. Future research is needed to “clarify current teacher and student expectations in order to learn how mismatches occur, and to begin to explore how these might be resolved” (Zhou, *et al.*, 2008). Examination of the differing expectations associated with international students will yield valuable information for increasing the numbers of engineering graduate students, and reducing attrition from graduate programs.

2.4 Summary

In summary, there is a variety of research relating to graduate student identity development, socialization and communities of practice, highlighting the additional cultural difficulties faced by international students. This review offers the following summary points:

- Socialization, enculturation, and identity development are not mutually exclusive, and future research should focus on the experiences of graduate students to adequately capture these developmental traits.
- While the literature is relatively conclusive about the importance of disciplinary differences in graduate programs (Golde, 2005), few studies have focused solely on the experiences of engineering graduate students.
- One of the predominant differences between engineering and other disciplines is the high population of international students (Gardner, 2009; Lovitts, 2001; Nettles & Millett, 2006).

Each of the previously discussed research areas have themes that are common among them, not least of which is the discussion of the role international students have in the culture of engineering departments. However, many of these research areas focus on only the undergraduate experience and ignore the graduate experience as is the case with much of the cultural adaptation and engineering education literature. Much of the graduate education literature highlights the presence of international students as a defining feature, but little work has been done to understand these student experiences both from the point of view of the visiting student and the impact on the domestic students already in residence. The inherent complexity of this problem requires a variety of more experience-focused studies at the program and department level, and investigation of differences across sub-disciplines and institutional types.

The continued increase of international students attending U.S. colleges and universities presents a unique opportunity for engineering education researchers to contribute to the growing body of knowledge on graduate education. If the U.S. wishes to remain a paramount destination for international students, as well as a global power for engineering and technology, a fuller understanding of how these students impact the culture of graduate engineering departments is needed. Furthermore, a better understanding of how international diversity influences the learning environment in graduate engineering research groups may illuminate areas where changes can be made to better then experience for both U.S. students and their international peers.

When creating the final manuscripts contained in Chapters 3 – 5, these noted areas of interest provided the necessary background to focus the literature review for the specific research question(s) and intended audience. Chapters 3 through 5 contain reviews of the literature relevant to each particular study, which provide a more in depth and specific body of knowledge to understand each individual research study.

Chapter 3

From Ethnography to Items: A Mixed Methods Approach to Developing a Survey to Examine Graduate Engineering Student Retention

Abstract

As part of a sequential exploratory mixed methods study, nine months of ethnographically guided observations and interviews were used to develop a survey examining graduate engineering student retention. Findings from the ethnographic fieldwork yielded several themes, including: the role of international diversity, research group organization and climate, student self efficacy, and individual and group learning experiences. In this paper we present the final themes from the ethnographic analysis and discuss how these data were configured into instrument questions. We discuss the final instrument, including validity and reliability analysis, and how the final questions were integrated into themes to test hypotheses for future studies. We conclude with implications for mixed methods researchers interested in using qualitative methods to create new instruments.

3.1 Introduction

In the United States during the period of 1999 to 2009, 61% of doctorates earned by U.S. students were in science and engineering, compared with 85% earned by non-U.S. students (National Science Foundation, 2010). In 2009, temporary visa holders represented the majority of doctorate recipients in engineering in the U.S.; over half of these doctorates were earned by students from China, India and South Korea (National Science Foundation, 2010). Though recent findings and predictions about the future of the American economy (Committee on Science Engineering and Public Policy, 2007) and the spread of globalization (Friedman, 2007) have prompted changes in undergraduate engineering education, this urgency has not extended to students attending graduate school in engineering. However, retention of students in graduate engineering programs remains critical to sustaining U.S. economic and technological competitiveness.

In the 2006 State of the Union Address, President George W. Bush, stated, “To keep America competitive, one commitment is necessary above all: We must continue to lead the world in human talent and creativity.” A report by The Task Force on the Future of American Innovation noted that increasing the number of science and engineering doctorates earned by U.S. students was a key to maintaining a technological edge for human talent, creativity and basic research (2006). As increasing globalization threatens to move science and technology jobs to other parts of the world (Friedman, 2007), the U.S. must foster innovation and creativity in order to maintain a technological edge (Committee on Science Engineering and Public Policy, 2007; The Task Force on the Future of American Innovation, 2006). A decline in students attending graduate school in engineering translates into a loss of opportunity for personal growth, a loss of prospective workforce talent, and the potential loss of creativity in shaping future technological innovations (Cuny & Aspray, 2002). As the knowledge density of modern economies steadily increases (Committee on Science Engineering and Public Policy, 2007), the ability of the U.S. to adapt to changes in the development, production and commercialization of knowledge represents a major contribution to maintaining its technological and economic competitiveness (Carnoy, 1998). One way of generating new knowledge is through university research and the training of graduate students. This element will prove critical for expanding the knowledge base of the United States (Carnoy, 1998).

While the graduate degree is receiving increased attention by the engineering education community, there remains a daunting attrition rate from graduate engineering programs across the United States. Results from the Council of Graduate Schools indicate that over a ten year window only 58 percent of domestic engineering graduate students completed their degree, compared to 70 percent for their international counterparts (Council of Graduate Schools, 2007). To date, much of the quantitative research regarding the recruitment and retention of doctoral students has focused on examining student characteristics and factors external to the university, such as undergraduate GPA, gender and marital status (Abedi & Benkin, 1987; Nettles & Millett, 2006). Other studies have included a broad range of disciplines, examining the statistically significant differences in program completion rates, and identifying characteristics that distinguish one discipline from another. Among their conclusions, these studies cited the disciplinary differences in programs and argued that these should be accounted for when

conducting further research (Altbach, Berdahl, & Gumport, 1999; Anderson, Louis, & Jason, 1994; Anderson & Swazey, 1998; Cumming, 2010; Deem & Brehony, 2000; Gardner, 2009; Golde, 1998, 2005; Golde & Walker, 2006).

There are several disciplinary characteristics that distinguish doctoral study in engineering from other disciplines, two of which include: a highly internationally diverse student and faculty population and dissertation research conducted in groups. As noted in previous research, international students represent an average of 50% of the population in engineering departments (Bound, Turner, & Walsh, 2009; NSF, 2007b). This international diversity has been cited as a defining difference between engineering and other disciplines (Anderson, *et al.*, 1994; Gardner, 2009; Nettles & Millett, 2006). In addition to international diversity, the vast majority of engineering graduate students spend their graduate degrees organized into research groups around the specialty of their faculty advisor (Crede and Borrego, in review) especially during the dissertation phase. There remains a need for more focused studies on this phase of doctoral study in engineering, which is dominated by participation in a research group, and can be directly linked to retention of graduate students.

This study aims to narrow the gap in the literature by addressing the relative lack of research focused on graduate engineering students in research groups, while accounting for disciplinary differences between engineering and other fields and exploring the influence of international diversity, which is highest in engineering compared to other disciplines. In this article we present the survey development phase of the mixed methods study, which was undertaken following nine months of ethnographically guided observations and interviews with three engineering research groups at a large public research intensive university. In this phase, a questionnaire was created using a sequential exploratory mixed methods research design (Creswell & Plano Clark, 2007). The research team selected this design to increase the utility of the instrument and maximize fidelity (Onwuegbuzie, Bustamante, & Nelson, 2010) through developing a better understanding of the cultural nature of internationally diverse graduate engineering research groups.

In the remaining sections of this article we review the existing research measuring retention and attrition from graduate engineering programs as well as studies which focus on the graduate student experience. We will then discuss the results of the current study, in which ethnographic observations and interviews were used to create and refine a quantitative instrument. We present details on the instrument design and validation, and conclude with study implications and recommendations for mixed methods researchers considering a sequential exploratory design.

3.2 Existing Research Measuring Graduate Student Retention

A seminal quantitative retention study was completed by Nettles and Millett (2006), which includes engineering students in their sample of more than 9000 Ph.D students from 21 universities. The authors conclude that engineering had the highest percentage of international students, 80 percent of which receive paid research assistantships, which would typically involve study conducted in a research group with other graduate engineering students. They also found that student social interactions with faculty were the highest in engineering, while interactions with peers are the lowest in engineering compared with other disciplines. While the authors find that both international students and engineering students were consistently the highest or lowest on many of the dimensions, they do not further explore these differences in their study. They conclude that the majority of international students are found in engineering and that across multiple dimensions international students have different experiences than their domestic counterparts. The authors comment that the high representation of international students in engineering contributes to differences in the demographic makeup of departments, which may have consequences for the overall student experience. The authors go on to suggest directions for future work including a better understanding of how the variation in the socialization of students from different cultural backgrounds impacts research productivity and other dimensions of the international graduate experience. While this study included engineering students, it omitted first year doctoral students as well as those pursuing a master's degree. Research indicates that many students who leave in their first year do so because they are unsatisfied by their experiences with their departments and faculty members (Lovitts, 2001). Experiences of doctoral students in the first year are arguably drastically different than more advanced students who have "settled" in to their programs. Variables such as mentoring, advisor selection, and

peer interactions are critical for first year doctoral students and represent areas where significant improvements can be made, informed by further research.

Another large quantitative study is the *PhD Complete Project*; a seven-year, two-phase project that addresses the issues surrounding Ph.D. completion and attrition (Council of Graduate Schools, 2009). The survey, which included engineering students, asked respondents about the main factors that contributed to their ability to complete the degree. The results indicate that financial support, mentoring/advising, and family support were highest on the list, with a majority of respondents indicating that these factors were important. Engineering graduates (70%) were much less likely to report they had access to a mentor (other than their advisor) compared with other graduates. Close to four-fifths (78%) of Engineering graduates had received a research assistantship, compared with much lower values for humanities and life sciences. Engineering students also rated family support considerably lower than students from social sciences and humanities. While this study provides aggregate data on engineering programs compared with other disciplines, and highlights the importance of mentoring and other support, it focuses on disciplinary differences rather than the influence of the research group or international diversity on engineering student retention.

Another large study, *Leaving the Ivory Tower*, takes a pointed look at the causes and consequences of graduate student attrition (Lovitts, 2001). Lovitts considers several reasons students may leave graduate programs, including: the absence of community, the advisor-advisee relationship, and disappointment with the learning experience. She concludes that access to resources is a key difference between completers and non completers, which may ultimately affect their level of participation, and consequently integration, into the community. With respect to disappointment in the learning experience, she found several levels of interaction relevant to a students' satisfaction. Among these were peer interactions, students and faculty interactions, and social interactions outside of the research environment. While this study offers several important considerations for graduate programs, it focuses on individual students in Ph.D programs (not research groups), and does not include engineering students.

In addition to large national surveys of doctoral student attrition, engineering departments collect their own “exit surveys” of students who leave without a degree. These studies provide excellent data at the level of the department or engineering discipline, but are not widely available to individuals outside of the host university. While these local studies are used for internal evaluation in individual departments, there remains a disconnect between these smaller focused quantitative studies, and those conducted at the national level. Finally, with the notable exception of Nettles and Millet (2006), these studies do not consider the how international diversity contributes to retention of graduate engineering students, or the influence of the research group on the individual student experience.

3.3 Measuring the Engineering Graduate Student Experience

Researchers in the field of graduate education have used several lenses to explore and attempt to measure the graduate student experience, including: socialization to the discipline, the role of the supervisor, the climate and organization of the department, and learning in the research group.

The concept of socialization to the discipline is not new to graduate education, and it is one of the most common theoretical lenses in qualitative studies of graduate students. Socialization is the process through which an individual learns to adopt the values, skills, attitudes, norms, and knowledge needed for membership in a community (Bess, 1978; Kuh & Whitt, 1988; Merton, 1957; Pruitt, 1978; Salomon & Perkins, 1998; J Van Maanen & Schein, 1979; Ward & Kennedy, 1993). Several researchers have discussed the socialization of graduate students as a multi-stage process including stages representative of the developmental nature of the socialization process (Baird, 1993). Examples include the four stages presented by Weidman and coworkers (anticipatory, formal, informal and personal) (2003; 2001) and Lovitts (2001) that express socialization in regard to prior anticipatory socialization to the graduate school environment, through culmination of the degree and entrance into the profession. While these previous studies have paved the way for future research, they fall short of maximizing the potential use of these models to capture the full complexity of the graduate student experience, as they focus more on individual program elements, such as coursework and qualifying exams, rather than the *personal transformation* of the student during his or her educational experience.

Two other relevant bodies of literature pertain to the relationship between the student and their faculty advisor (Deem & Brehony, 2000; Grevholm, Persson, & Wall, 2005; Lee, 2008; Malfroy, 2005; Pearson & Brew, 2002) and the climate in graduate engineering programs (Louis, *et al.*, 2007). The emphasis on the role of the advisor is often focused on individual students, and not on the supervision of research groups which are more common in the engineering disciplines and other natural sciences. Another means of measuring the graduate student experience is to examine the climate in engineering graduate programs, which may dictate student – faculty interactions and peer interactions among graduate students. Litzler *et al.* (2005) investigated the climate for graduate students in science and engineering departments and found that the degree of competition is highly and negatively correlated to degree progress.

There are two primary issues absent from the literature on graduate education that are critical to understanding the experiences of engineering graduate students: the use of research groups as methods for training graduate students and the high percentage of international students present in these research groups. A deeper understanding of the experiences of students in these internationally diverse research groups will highlight new ways to examine attrition from graduate engineering programs, and may ultimately aid in retaining new students.

3.4 Research Setting

Several studies have noted the large population of international students in engineering departments, but how this diversity influences the culture of the department has yet to be explored. Other studies including engineering students have focused on the individual student, and not accounted for the research group environment of most graduate engineering programs. In this study we sought to bridge this divide through an ethnographic exploration of the culture of internationally diverse graduate engineering research groups.

Three research groups were observed for a total of nine months of ethnographic observations and interviews from two engineering departments at a large public university (host institution). The largest research group was in the electrical engineering department and had more than 20

students from six different countries. The smallest group, with four total students, was from aerospace engineering and contained Chinese graduate students and American undergraduate students. The final group was multidisciplinary, with 12 students from both aerospace and electrical engineering. These students were primarily from India or the U.S. These three groups were selected to represent different research group environments, engineering disciplines and international diversity.

During the data collection phase, four universities were administered the instrument including the host institution. University A is a large public institution in the Midwest, and University B is a small HBCU on the east coast. University C is a large private school on the west coast. The host institution is a large public university on the east coast. All four universities have large engineering populations (relative to the size of the institution) and are research intensive.

3.5 Research Design and Methods

This study utilized a sequential exploratory mixed methods research design (Creswell & Plano Clark, 2007; Creswell, *et al.*, 2003) in which the findings from nine months of ethnographic observations and interviews were integrated into a survey instrument (Creswell & Plano Clark, 2007; Abbas Tashakkori & Teddlie, 2003). Mixed research provides an objective and holistic method for instrument development (Onwuegbuzie, *et al.*, 2010). This approach afforded the research team depth of understanding from the qualitative data while maintaining broad applicability with the quantitative results. The ethnographic observations and interviews gave voice to the students which provided rich detail on participant language, cultural considerations, and helped formulate hypotheses for the instrument. The survey enabled the research team to consider a larger and more diverse sample reflective of the graduate population in engineering as a whole. In short, we were able to capitalize on the strengths of both qualitative and quantitative approaches (Leech & Onwuegbuzie, 2010), further refine the instrument using qualitative information, and establish multiple opportunities and levels for integrating the ethnographic findings and survey results (Castro, Kellison, Boyd, & Kopak, 2010).

Prior to beginning the ethnographic fieldwork, a thorough review of the literature revealed several aspects of graduate engineering education that warranted further study: the role of the research group and the influence of international diversity on the graduate engineering student experience. We initially selected two research groups from two engineering departments for observation. Between these two research groups there were students from more than five countries. During the course of the ethnographic observations and interviews we elected to observe another “medium sized” research group to further bridge insights gained from the small and large group. This multidisciplinary group contained 12 students from both aerospace and electrical engineering.

Participants in these research groups, along with a team of experts in graduate engineering education, assisted the research team in survey development through reviewing notes, providing clarification on language, and offering clarifying information and viewpoints.

3.5.1 Qualitative Component

The qualitative phase of the study utilized ethnographically guided research methods, including formal and informal interviews, lengthy periods of observation, and participation in most research group activities. Ethnography is a strategy of inquiry in which the researcher studies an intact cultural group in a naturalistic setting over a prolonged period of time (Creswell, 2009), and is necessary when the purpose of the research is to understand how people’s beliefs and values guide their actions and understanding of those actions (Rossman & Rallis, 2003). This was deemed especially important to enable the research team to better understand the social and cultural norms of engineering research groups as well as the language of the participants (Hennink, 2008).

3.5.2 Participants

Participants in the ethnographic phase were members of three graduate engineering research groups in electrical and aerospace engineering departments at the host university. There were more than thirty students participating in these research groups, which ranged in size from less

than four students to more than twenty-five. Students were from more than six countries, and spanned a range of time in their research group, with several students in their first year and others with more than four years experience. The majority of students (75%) were completing Ph.D programs, with the remaining students working on research based MS programs.

3.5.3 Data Collection

Data collection for this study comprised ethnographic observations and interviews conducted by a single member of the research team. A total of 20 semi structured formal interviews were collected from graduate students within the three research groups (Hermanowicz, 2002; Seidman, 2005). Informal interviews were also conducted as part of the ethnographic fieldwork. Nine months of observation data was collected from the three research groups, focusing on group meetings and other key events such as social gatherings and seminars. The methods prescribed by Emerson *et al.* (1995) for taking ethnographic field notes were used along with data collection procedures discussed in Fetterman (1998). Analytic memos were used to reflect on the ethnographic data captured in field notes to both capture insights and understanding as they occur, as well as to ensure that any gaps in the data were addressed while we still had access to the participants (Charmaz, 2006).

3.5.4 Data Analysis

During qualitative data analysis, several working hypotheses suggested by the literature were explored. We considered the expectations that students develop regarding the graduate institution impact their level of participation within their research group and department (Lovitts, 1996). In addition we wanted to examine whether the presence of large numbers of international students increases the awareness of diverse perspectives among all graduate students (foreign and domestic), thus shaping the academic community. In addition to the suggestions presented in the literature, the research team allowed for additional phenomena relating to graduate student experiences to emerge.

3.6 Qualitative Results

A number of factors emerged from the ethnographic observations and interviews relevant to the graduate student experience in engineering research groups, which are summarized in Table 3.1.

Table 3.1

Qualitative Themes

Theme	Description
International Diversity	International diversity reflected the presence of students from multiple countries, the value students placed on this diversity, and how this diversity has impacted their preparation for future work in internationally diverse teams.
Expectations	Expectations refers to whether students felt they were prepared for graduate school, whether their expectations were met, and whether their advisor was clear in his or her expectations for participation in the research group.
Climate	Climate focuses on the “feel” of the research group. This could include the presence of cliques of students, the level of competitiveness, and whether students feel like they fit in or not.
Organization	Organization covers items like the presence of more experienced students, availability of resources, research group meetings, advisor meetings, and clear expectations for participation in the group.
Individual Preferences	Individual Preferences refer to students’ personal beliefs about the importance of various activities. These include: valuing international diversity, working in a team environment, speaking up in group meetings, and taking initiative to accomplish a task.
Feeling Valued	Feeling Valued refers to students’ sense of their value to the group, project value, and value to other group members and faculty advisor.

These themes were determined through a combination of deductive and inductive methods. Several of these aspects of graduate education have been studied before, notably climate and organization (Litzler, *et al.*, 2005; Louis, *et al.*, 2007; Lovitts, 1996; Nettles & Millett, 2006) although not always in the context of graduate engineering research groups or with an internationally diverse population. Considering these themes in light of both the literature and

our ethnographic observations and interviews we were able to combine a deductive review of the literature with an inductive approach to coding that allowed an engineering specific context to emerge. The other themes emerged from a purely inductive coding strategy, and enabled the research team to capture information pertaining to the research group as a whole and the individuals that make up the group. For a detailed analysis of the role of the research group see Chapter 4.

3.7 Instrument Development

The themes developed in the qualitative data analysis phase were used to develop constructs for the survey instrument. These constructs then formed the basis for creating individual Likert scale questions which made up the first half of the instrument. Using the six themes as a guide, the field notes, interview transcripts and analytic memos were reviewed and coded to reflect specific examples within each theme. If a code appeared several times it was used to create a survey question that would address that item or construct. Additional Likert style questions were added to each construct based on a review of the literature, while still others were included based on their absence in the qualitative data. Table 3.2 presents three examples of data coded and transformed into survey items.

Table 3.2

Creating Survey Questions from Coded Data

Qualitative Data	Theme	Survey Item
“[working in my group I’ve] gained an international perspective, I’ve learned a few words in other languages”	International Diversity	My experiences in my research group have prepared me to work in international teams
“[5 th Year Student] organized everything, he was the lab manager. His leaving was a big change. He was the first person we went to with questions. He was patient, and a great support for us....Now they come to me for help”	Organization	There are more experienced members in my research group to whom I can ask questions
“[students in the group] can be kind of clique like”	Climate	My research group has cliques (subgroups) of students that primarily interact with each other

Then the survey items were grouped into their respective constructs with accompanying working hypotheses for future analysis. Due to the commonalities among many of the themes, several questions were deemed relevant for more than one theme or hypothesis. Several examples of Likert scale questions within each construct are shown in Table 3.3. These questions use a scale from 1 – 5, where 1 is strongly disagree and 5 is strongly agree.

Table 3.3

Example survey items by construct

Theme	Survey Item
International Diversity	• My experiences in my research group have prepared me to work in international teams • The ability to work effectively in internationally diverse groups after graduation is important to me • I value international diversity in my research group
Expectations	• My undergraduate education prepared me for graduate school • If I had to do it over again, I would make the same decisions about graduate school • My advisor has clearly stated his or her expectations for satisfactory participation in the research group
Climate	• My research group has cliques (subgroups) of students that primarily interact with each other • My research group environment is overly competitive • I am in the minority in my research group
Organization	• There are more experienced members in my research group to whom I can ask questions • I get to meet with my faculty advisor often enough to be successful • My research group meets often enough for me to be successful
Individual Preferences	• It is important to me to be able to work in a research team • I am comfortable speaking up during research group meetings • I am comfortable taking the initiative to accomplish a task
Perception of Value	• I feel like I am a valuable member of my research group • My work is valued by my faculty advisor • My research is valued by members of my research group

Two Likert scale dependent variables were included in this survey: students' intention to complete their graduate degree and satisfaction with their experience in their research group. Intention to complete the degree was chosen to reflect student self-reported measures of attrition, and to identify where improvements to graduate programs might be made immediately. Satisfaction was chosen both as a measure to correlate with intent to complete and as a means of comparing the results to other previously conducted studies in the literature (Elliott & Shin, 2002; Girves & Wemmerus, 1988; Gregg, 1972; Lovitts, 2001).

While the Likert scale items attempted to understand students' perception of their experience in their graduate engineering research groups, several other types of questions were used to gather descriptive information about the individual students and their research groups. The highly diverse nature of the population, in terms of university culture, research group organization, and international diversity, necessitated a thorough exploration of demographic variables in order to characterize the sample.

Table 3.4 presents many of the demographic items included in the instrument. The items listed in Table 3.4 were either multiple choice or check all that apply, with a variety of possible selections determined through the qualitative data analysis or by consulting the participating universities. Several items had an "other" option where students could fill in a response if the appropriate one was not listed. This was especially useful for the questions about nationality, type of funding, and timeline for establishing a research project.

Table 3.4

Demographic items included in the survey

Survey Item	
Individual Demographics	• How does your level of participation in your research group compare to other members? • How long after joining your research group did you establish your research project? • At what point are you in your graduate program? • How is your research primarily conducted? • What type of funding do you have? • Where did you complete your undergraduate degree? • What degree do you expect to receive? • In which discipline do you expect to earn your graduate degree? • Did you participate in undergraduate research? • What is your age? • What is your gender? • What is your nationality? • If you are a U.S. student, what is your race/ethnicity?
Research Group Demographics	• Including yourself, approximately how many members are in your group? • In your research group, are there students or faculty from different departments? • On average, how often do you meet individually with your advisor? • On average, how often does your research group meet (the majority of the group is present)? • Which organizational unit is your research group primarily associated with? • How is the space for your research group organized?

Several of these questions were included with the Likert scale items when developing the final analysis plan to consider student perception of their research group along with the actual composition of the group. These items include how the group is organized, the international diversity of the sample, students' level of participation, and when they established their research project.

3.7.1 Initial Instrument Development and Pilot Testing

Prior to administering the instrument to a sample of students from the host institution, we sent the survey for review to several of the students who were participants in the ethnographic field work. Interviews were conducted with five students from these three groups to solicit feedback

on the question type, language used, and completeness of the instrument. Findings from these interviews were used to modify the survey instrument. Participant reviews were followed with a survey review by a panel of experts from each of the participating universities. These faculty members reviewed the items for clarity, completeness, and language appropriate to their institution. Experts provided additional insight into practices that were not evident at the host institution but would likely occur at the participating institutions. Several additional questions were added to the instrument using this feedback. This also helped to better focus the multiple choice options (especially for nationality) for each institution, which would later reduce the amount of time needed to analyze the data.

After the final edits were completed from the expert review, the research team pilot tested the instrument with a sample of 50 graduate engineering students from the host institution. Forty-four students completed the pilot instrument, and the results of the internal consistency analysis are shown in Table 3.5.

Table 3.5

Pilot Test: Internal Consistency Analysis for Instrument

Theme	Number of Items	Cronbach Alpha
Perception of Value	4	0.91
Individual Preferences	7	0.67
Expectations	5	0.65
Organization	5	0.65
Climate	4	0.63
International Diversity	4	0.50

While there is no fixed criterion for minimum internal consistency required, generally a Cronbach alpha greater than 0.7 is desirable (Allen, Reed-Rhoads, Terry, Murphy, & Stone, 2008). In order to address internal consistency concerns, the pilot tested instrument was sent to an expert in the field of graduate education from a fifth university not participating in the data collection. This expert was able to provide a broader perspective on graduate education and ask questions which resulted in further insights into the instrument themes and wording. Findings from the interview with this expert resulted in the creation of a new construct for the instrument:

student development. This construct served as both a dependent variable for student learning as well as another construct to understand students' intention to complete their degree and satisfaction with their program.

Following the review with the graduate education specialist and the results of the pilot test, 12 items were reworded for clarity and 10 items were added to the instrument. Most of the questions that were added related to student development (seven), and the reworded items ranged from clarifying the definitions of terms to changing the connotation from positive to negative (or vice versa).

3.7.2 Final Instrument

The completed survey instrument contained a total of 63 questions. There are 42 Likert-style questions that use a scale from 1 – 5 where 1 is strongly disagree and 5 is strongly agree. Nineteen items were used to gather individual demographic information as well as data on the research group. We concluded the survey with two open ended items which would be used to further revise the instrument and create additional opportunities for data integration during analysis. A replication of the survey instrument from one institution is listed in Appendix A.

The survey was broken down into five sections. The first section was used to display the privacy information, document informed consent to participate in the survey. We also included two filter questions to ensure participants were reflective of the desired population. Section two contained the 42 Likert type questions, which addressed the 7 qualitative themes and 2 dependent variables. The number of items included for each construct ranged from four to eight, with several questions used to address more than one construct. Sections three and four contained the group and individual demographic questions respectively. Section five contained the two open ended survey questions. At the beginning of each section instructions were provided for the participant. The questionnaire was administered via an online interface and took between 10 and 20 minutes to complete.

3.7.3 Rigor

In addition to the traditional frameworks for rigor associated with qualitative research (Patton, 2002), we also employed iterative validity and reliability measures during the creation and revision of the instrument (Onwuegbuzie, *et al.*, 2010). Reviews completed by the participants and experts in the field of engineering and education were initially used as a validity measure, while a pilot test at the host institution provided initial reliability analysis. During the first large scale administration of the instrument to the wider population, additional qualitative data was gathered through the use of open ended questions to further revise and validate the quantitative tool (Dellinger & Leech, 2007; Mertens, 2010).

In addition to the validity measures, detailed reliability analysis was completed following the first large scale administration of the instrument. During the fall of 2010 the newly revised instrument was administered to four universities across the United States using a web interface. The response rate was 18.5% for a total of 837 completed responses. Internal consistency for this data set is shown in Table 3.6. This data set shows considerably higher values for internal consistency compared with the initial pilot test, with only three themes falling below the desired limit ($\alpha = 0.7$).

Table 3.6
Internal Consistency Analysis for Final Instrument

Theme	Number of Items	Cronbachs Alpha
Feeling Valued	5	0.86
Development	7	0.83
Organization	7	0.73
International Diversity	5	0.72
Climate	7	0.66
Individual Preferences	6	0.64
Expectations	6	0.63

One of the goals of this study was to design an instrument that was usable by multiple universities as well as a highly internationally diverse population. As an additional measure of

reliability we compared the internal consistency values for each university in the sample against the complete data set. Not surprisingly these results indicate that there are differences in reliability based on the university. However if we consider the spread of values we see that most themes contain a range of acceptable reliability levels. Those that are more variable include climate, organization and expectations, which reflect the cultural differences at these institutions. Items which relate to individual student perceptions have relatively little variation in the range of Cronbach alpha. These are themes such as feeling valued, individual preferences, and personal development.

Table 3.7

Internal consistency analysis as a function of university

	University A (263)	University B (60)	University C (188)	Host University (326)	Range for Cronbach Alpha	Magnitude of Range
Feeling Valued	0.878	0.847	0.851	0.844	0.844 – 0.873	0.029
Development	0.849	0.835	0.821	0.803	0.803 – 0.849	0.046
Organization	0.714	0.792	0.685	0.731	0.685 – 0.792	0.107
International Diversity	0.692	0.779	0.639	0.729	0.639 – 0.729	0.09
Climate	0.623	0.691	0.690	0.570	0.570 – 0.691	0.121
Individual Preferences	0.676	0.655	0.624	0.623	0.623 – 0.676	0.053
Expectations	0.681	0.618	0.660	0.552	0.552 – 0.681	0.129

Another goal for the validity of the instrument was to ensure that it was understood by an internationally diverse audience. We have computed the internal consistency for the variety of nationalities represented in the survey population (Table 3.8). In order to have enough respondents for each nationality, several countries are grouped together into regions. For example, Asia (which excludes China and India) includes students from countries such as South Korea, Indonesia, and Taiwan. The Middle East includes students from countries including Saudi Arabia, Iran, Jordan, and Palestine. The Other category was used to account for a variety

of other students, including but not limited to students from South Africa, Mexico, Brazil, Iceland, Peru, and Canada.

Table 3.8

Internal Consistency Analysis as a function of nationality

	U.S. (427)	Asia (53)	China (109)	India (103)	Middle East (52)	Other (39)	Range for Cronbach Alpha	Magnitude of Range
Feeling Valued	0.850	0.872	0.834	0.772	0.704	0.900	0.704 – 0.900	0.196
Development	0.805	0.762	0.859	0.807	0.773	0.867	0.762 – 0.867	0.105
Organization	0.719	0.41*	0.786	0.751	0.589	0.829	0.589 – 0.829	0.240
International Diversity	0.688	0.587	0.777	0.657	0.506	0.654	0.506 – 0.777	0.271
Climate	0.642	0.725	0.640	0.700	0.586	0.517	0.517 – 0.725	0.208
Individual Preferences	0.584	0.716	0.729	0.670	0.516	0.772	0.516 – 0.772	0.256
Expectations	0.639	0.608	0.691	0.604	0.505	0.46*	0.505 – 0.691	0.186

*These items were highly unlike others in the data set.

These results show that there are differences in internal consistency values depending on which country or region of the world respondents are from. Two items are starred indicating they are very different from all others in the data set. For students in Asian countries (excluding China), Organization had an extremely low internal consistency. Also in the Other region, there were extremely low values for Expectations. Students from the Middle East were the only respondents to report lower internal consistency compared to the complete data set (Table 3.5) across all seven constructs. These results indicate that while there is some variability in the responses of students from different regions, the design of the questions is such that it is understood by an internationally diverse population. The notable difference in respondents from the Middle East is likely due to the absence of these students during the ethnographic fieldwork and will be considered for the next iteration of revisions.

3.8 Discussion

Two issues were immediately evident at the onset of this study. The first was the limited information regarding the retention of students in graduate engineering research groups. The second was the international diversity of the sample which necessitated a more in depth approach to understanding the student experience. Through the use of sequential exploratory mixed methods we were able to explore the student experience in internationally diverse research groups, and use these findings to inform the development of a survey which could be used to examine cultural differences both within universities and with students from a range of countries outside the United States.

Study data were integrated at several levels. First we integrated the qualitative findings at the design level to create individual questions for the instrument. Second, qualitative data collected from the two open ended survey items will be used to further revise the instrument prior to continued use. Finally we were able to triangulate the qualitative data from the ethnography and the final survey results to draw additional conclusions about how international diversity contributes to the graduate student experience in engineering research groups. By integrating the data at several levels we were able to fully realize the value of such an in-depth qualitative component to this research, and offer recommendations to mixed methods researchers considering this approach.

3.8.1 Advantages of a Qualitative Component

The purpose of using ethnographically guided methods was to enable the research team to better conceptualize the graduate student experience. This technique has been used by researchers in the past, specifically in cases where there are cultural factors that the researchers may not comprehend at the outset of the study (Fuller, *et al.*, 1993). Through interviews and observations we were able to strengthen our understanding of the phenomenon, increase our awareness of different cultural considerations, and generate new hypotheses to test. Summary results are presented here, and a detailed discussion is covered in Crede and Borrego (2010b).

3.8.1.1 Modeling the Phenomenon

Did we learn anything from the interviews and observations that we could not have learned from the instrument alone? A thorough review of the existing theoretical literature (Crede & Borrego, 2010a) included many of the main constructs we were interested in measuring, however, there was little guidance about how these concepts should be measured. Through observations and interviews with research groups and individual students we were able to identify several characteristics of research groups, both present and absent from the literature, and explore how students interact in social and academic settings. While participating in many of the research group activities we were able to observe interactions between students and faculty members, along with the general group dynamics. Additionally, exposure to graduate students in a research group setting shed light on other factors that contribute to the graduate student experience we had not previously considered, such as how motivation and informal learning practices contribute to socialization and individual development. Finally we were able to observe the language of the participants, and consequently could use this wording in the questionnaire design. This was beneficial not only for the terms used by domestic students and faculty members, but especially so for the international students.

3.8.1.2 Hypothesis Formulation

We began the ethnographic data collection with a few working hypotheses suggested by the literature. First, we hypothesized that prior expectations regarding the graduate institution held by graduate students impact socialization within their research group and department (Lovitts, 1996). Second, that the climate within the research group, especially competition, impacts student satisfaction and ultimately retention. Initial data collection employed a highly inductive approach, allowing themes and additional constructs to emerge. After a few months we began to simultaneously collect and analyze data, which is common practice with ethnographically guided observations and interviews (Charmaz, 2006; Emerson, *et al.*, 1995). From this analysis we developed some additional research interests, including: the impact of group size on student learning, the importance and influence of international diversity on student development, and students' efficacy and perceived value to the group as it relates to their degree intentions. The

collection and analysis of the interview and observation data allowed the research team to design the survey with an analysis plan already in place, which greatly facilitated expedient design and pilot testing.

3.8.1.3 Cultural Considerations

Lastly our qualitative data provided needed information regarding cultural considerations for this study: the cultural differences from the large percentage of international students in the participant population, and differences in engineering culture from the culture of other disciplines. Observations of research groups enabled the authors to develop an understanding of the research lab “culture”, while interviews with several students provided an avenue to explore variations in cultural understanding. Observations of students confirmed findings from the literature, as well as revealed other examples of differences in communication patterns of students from various nationalities. Perhaps most importantly we were able to confirm that the variables we were interested in were salient to students from countries other than the United States. The large research group had students from nine different countries, allowing the research team to ensure that the instrument was understood by individuals from a wide range of backgrounds.

3.8.2 Implications for Survey Researchers

Using a mixed methods study design opens the researcher to using a variety of data analysis techniques at the conclusion of the study. Depending on the depth of qualitative data acquired a research team could use these data to triangulate results, or further integrate the qualitative findings with the quantitative results. The use of qualitative research methods prior to designing and administering a survey will help ensure a more valid instrument, open the researcher up to new hypotheses to test, and provide a means of exploring mixed analysis techniques, and further review and revise the instrument.

Perhaps the most important implication this study provides is the importance of understanding the social, cultural and personal factors about a population prior to conducting quantitative

research. Without a thorough investigation of the important themes that comprised our constructs, we would not have known how to develop questions for the initial iteration of the questionnaire, how to word them, and what would be of interest to our participants. While pilot testing alone would have enabled us to fix many of the pitfalls encountered by survey researchers, the deep understanding of our participants through several months of observations and countless hours of interviews was invaluable to instrument construction.

The ethnographic methods employed by the authors represent only one type of qualitative inquiry that may guide instrument development. There are many other qualitative methods that may serve interested survey researchers, including focus groups, interviews, case studies, document analysis and diary methods (Bolger, Davis, & Rafaeli, 2003; Creswell, 2009; Patton, 2002; Seidman, 2005; Yin, 2003). Researchers interested in using qualitative methods to design better survey instruments should consider several questions when choosing a method:

1. What is your overall research question and how does it relate to what you are trying to measure?
2. What type and level of background information is available on the topic?
3. How easy will it be to gain access to participants, and for how long can you gain access to them?
4. What don't you know about the population of interest that may influence your choice of questions?
5. How large and diverse is the population you are trying to generalize to?

The availability of background information can be a driving factor in the length of your qualitative investigation. For example, focus groups and interviews can provide an excellent medium for gathering information on the basic terminology used and the level of understanding held by the participants in a shorter timeframe than ethnographic methods.

3.9 Conclusions and Future Work

Through the use of ethnographically guided interviews and observations we were able to obtain insight into the way that graduate students think and behave in internationally diverse research groups. Collection and analysis of qualitative data contributed to the design of the questionnaire in several ways. The first was the actual development of specific questions. We were able to uncover several measureable variables through the prolonged ethnographic investigation of the constructs of interest. We were also able to investigate firsthand how and where interactions might occur in the data and generate new hypotheses that data from the survey would be able to test. Second, interviews with various participants showcased how the research was viewed by the different types of participants. The diversity of the target population for this questionnaire required careful attention to the values, norms and cultural expectations of vastly different groups. Had we not experienced lengthy periods of contact with several different cultures we might not have obtained the full benefits of the instrument. Additionally the exposure to such a diverse sample of our target population helped to reduce potential measurement error, increasing the overall validity of the instrument.

Chapter 4

Learning in Graduate Engineering Research Groups of Various Sizes

Abstract

Background

Engineering graduate education, particularly at the doctoral level, relies heavily on mentored research experiences often conducted in a research group. In this study we explore the nature of graduate student research participation and how the group size influences student learning.

Purpose

To understand how and under what conditions research groups foster successful learning and professional development for graduate engineering students, and how these findings can be used to inform management of engineering research groups to optimize student learning, productivity, and intent to complete the degree.

Scope/Method

This study utilizes a sequential exploratory mixed methods design, with nine months of ethnographically guided observations and interviews used to develop an online survey instrument. Data reported in this paper feature summary results from the ethnographic analysis as well as survey responses from over 800 students at four institutions.

Results

Key findings from the ethnographic analysis indicate that group size directly influences the mechanisms of student learning. Survey results confirm the prevalence of engineering graduate research groups, as well as several elements common across research groups from different universities and academic departments, including: power distance and communication, access to resources, and role of the advisor.

Conclusions

An understanding of the mechanisms for learning in research groups can be used by engineering administrators, faculty members, and graduate students to create an environment that fosters

successful learning and professional development among graduate engineering students. We also recommend practices for ensuring positive experiences for all graduate students, which may ultimately reduce attrition from graduate engineering programs.

4.1 Introduction

While the landscape for graduate education in the U.S. has changed in the past several decades, the basic model of doctoral education remains unchanged (Editorial, 2011). A few years of prescribed courses are typically followed by examinations for advancement to degree candidacy and culminate in a dissertation that reflects original research conducted by the student and supervised by a faculty advisor (Altbach, Berdahl, & Gumport, 1999). How this research training is conducted however, reflects distinct disciplinary patterns (Cross, 2001). In the sciences and engineering, research is often laboratory intensive, in which the student works under faculty supervision, and the dissertation is often a piece of a faculty member's research project. This research training is central to transforming the student into a producer of knowledge, so much so that departments design specialized training programs to meet the needs of individual disciplines (Gumport, 1999).

Unlike their counterparts in many of the social science fields, the majority of engineering students spend their graduate school years as part of a research group (Deem & Brehony, 2000). These groups are generally organized around the research specialty of a primary advisor, or a collaboration between faculty advisors, depending on the size of the research group (Adams, Black, Clemmons, & Stephan, 2005). Doctoral students, master's students and post doctoral researchers work together under the guidance of these faculty advisors, often in shared laboratory and office spaces (Louis, Holdsworth, Anderson, & Campbell, 2007). The vast majority of students entering science and engineering graduate programs will participate in a research group during the course of their program (Alberts, 2009; Altbach, *et al.*, 1999; Deem & Brehony, 2000; Louis, *et al.*, 2007); therefore, attention to this learning environment is critical for understanding student development and ultimately persistence (Cross, 2001).

The experiences of graduate students reflect a complex series of interactions between various cultures, networks and structures (Cumming, 2010). The conditions under which students work, study, and develop their research capability can either encourage their interest or discourage them from program completion (Cross, 2001). Disciplinary and departmental conventions may significantly influence student experiences, including access to resources such as personnel, equipment and materials. In engineering, academic departments consist of a series of research groups, which could look like “quasi-firms” (Etzkowitz, 2003, p. 110; Gumpert, 1999), just a step away from becoming full-fledged companies, differing only by their orientation to profit. In the sciences and engineering, professors are expected to be group leaders, and graduate student group members are simply scientists or engineers in training (Alberts, 2009). Other research groups may be much smaller, consisting of perhaps one or two students who develop a strong mentoring relationship with their supervisor, but have few interactions with peers (Louis, *et al.*, 2007). While the experiences of individual students within these groups no doubt differ a great deal, each of these groups forms a community of practice, the purpose of which is to train the next generation of engineers and scientists.

Turner (2006) described the benefits of using research teams as an approach to graduate training to build a community of scholars to share knowledge and exchange ideas. Nersessian (in press) argues for the importance of studying the process of knowledge development in science and engineering, specifically in the environment where this knowledge is developed; the graduate research group. One study aimed to develop an understanding of the reasoning and representations used in problem solving in biomedical engineering laboratories (Nersessian, Kurz-Milcke, Newstetter, & Davies, 2003), which they found serves as a “*problem space*” (Nersessian, 2006, p. 130) that is continuously changing as the lab and community within it develops. The graduate student experience has been explored more often in the laboratory sciences (Cross, 2001), while other studies have noted disciplinary differences (between science and engineering) and argue that future studies should focus on understanding the role of the individual discipline (Golde, 2005).

Beyond science and engineering, a large cross-section of the research on graduate education employs a socialization lens to study graduate student assimilation to a community of practice

(Anderson & Lewis, 1994; Anderson, Louis, & Jason, 1994; Gardner, 2009; Hasrati, 2005; Lovitts, 2001; Nettles & Millett, 2006; Pearson, 1996; Sweitzer, 2009; J. L. Turner, Miller, & Mitchell-Kernan, 2002; Weidman & Stein, 2003; Weidman, *et al.*, 2001). However, little if any of this research characterizes the nature of this community in engineering. There are a few studies, such as Crede and Borrego (2011) which include engineering students in their study of graduate student socialization to the discipline. Other studies that discuss graduate student training exclude engineering altogether (e.g. Reason & Marshall, 2001). If the majority of the socialization of graduate engineering students occurs in the research group environment, then to truly understand student learning and socialization we must first understand how graduate research groups function as communities of learners. Variations among research groups, including their size, organization, attitudes, norms, power relationships and student diversity will greatly influence the graduate student experience. Understanding these groups – how they are created, transformed, utilized, and developed over time – is required to fully understand the context for engineering graduate student learning.

The purpose of this study is to understand how and under what circumstances research groups foster successful learning and development for graduate engineering students. Specifically, we addressed the following research questions:

1. What are the similarities and differences among the environments for engineering research groups of varying sizes?
2. How can these similarities and differences inform management of engineering research groups to create an environment that optimizes the students' overall learning experience?

The remaining sections of this paper present the theoretical framework and the qualitative and quantitative methods used. We then describe differences in research groups of varying sizes, providing specific examples from the qualitative observations and interviews. These qualitative findings are compared with the results of a multi-institution survey, which highlights the prevalence of similarities and differences between and among research groups, and further explores variations based on student learning. Finally, we consider how an understanding of this

system can be used by university administrators, faculty members, and graduate students to create an environment that fosters successful learning and development for graduate engineering students.

4.2 Theoretical Framework

To understand learning in graduate engineering research groups, we begin with a situated learning perspective, considering graduate research groups as communities of practice (Lave & Wenger, 1991; Wenger, *et al.*, 2002). The defining features of a community of practice are authentic problems and an apprenticeship-type model of learning and becoming a member, much like a graduate engineering research laboratory (Newstetter, *et al.*, 2004).

Community is formed when group members engage in joint activities and discussions, and share information; participants establish relationships that enable them to learn from each other. Research group communities develop a shared body of resources: experiences, stories, tools, and ways of addressing recurring problems (Wenger, 1998). Resources may include specific tools, advice passed to new students, and shared experiences such as presenting to the large group or at conferences. The research group as an organization acts as the community that entering graduate students seek to join. This community is formed through members engaging in joint activities and discussions, such as attending large research group meetings, working with peers on course assignments, and learning to use equipment and conduct research with other members of the group. A workshop sponsored by the U.S. National Science Foundation concluded that *community* is of overarching importance for the future of graduate education (Lorden & Slimowitz, 2003); however, there are several characteristics of community in graduate research groups that we do not fully understand.

Both the supervisory relationship an advisor develops with individual students and the peer learning and development that occurs without the advisor are critical elements of the graduate research group. Several studies have explored the relationship between graduate students and their advisors (Belcher, 1994; Frehill, Lain, Jacquez, Luces, & Ketcham, 2007; Ku, Lahman, Yeh, & Cheng, 2008; Rose, 2005), citing the importance of this relationship for satisfaction and

success in graduate school (Deem & Brehony, 2000; Malfroy, 2005; Pearson & Brew, 2002). In a recent study of doctoral student supervision, Lee (2008) considered the concept of supervision from the viewpoint of the research advisor, and discussed several approaches to supervising graduate students. She proposed a framework of five concepts of research supervision, and for each concept outlined the supervisor's activity, knowledge and skills, and the possible student reaction to this style of supervision. Although her framework did not consider the research group explicitly, nor the number of students being supervised as a factor, we find these concepts useful for exploring the advising practices of engineering faculty members as one element of the graduate research group community. These concepts are summarized in Table 4.1.

Table 4.1

Supervisory Roles (adapted from Lee (2008))

	Functional	Enculturation	Critical Thinking	Emancipation	Relationship Development
Supervisor's Activity	Rational progression through tasks	Gatekeeping	Evaluation, challenge	Mentoring, supporting, constructivism	Supervising by experience, developing a relationship
Supervisor's Knowledge and Skills	Directing, project management	Diagnosis of deficiencies, coaching	Argument analysis	Facilitation and reflection	Emotional intelligence
Student Reaction	Obedience, organized	Role modeling	Constant inquiry, fight or flight	Personal growth, reframing	Emotional intelligence

For the current study, the first three concepts of research supervision are of primary interest. The first supervisory style is functional. Functional supervisors follow a rational progression through tasks and take a more directive, project management approach to training. The second approach is enculturation, where the supervisor's activity is that of a gatekeeper who diagnoses student deficiencies and acts as a coach. The final supervisory concept used in this study was a critical thinking perspective, where faculty advisors evaluate and challenge the student through argument and analysis of the students' work. Lee (2008) also discusses two other styles: emancipation and relationship development activities. While elements of both styles were used

by advisors in one-on-one meetings with students, they were not directed at the research group as a whole. As our primary unit of analysis is the research group, we have included these other two styles where appropriate, but focus primarily on the first three activities observed in our three research groups.

While the advisor is clearly an important factor in student success in graduate school, few studies have investigated the supervisory practices within research groups where faculty members are advising several students at a time. In addition, so much emphasis has been placed on the role of the advisor in graduate school that the influence of peers is often overlooked, or studied separately (e.g. Sweitzer, 2009). Both the supervisory practices of the faculty advisor and the role of peers have been considered separately in previous work; however, student learning and success in a research setting often hinges on the interaction between these two influencing factors, which has seen less treatment in the literature.

In this study we employ a community of practice framework to explore the experiences of students in graduate engineering research groups. Student experiences are the result of several group characteristics; however, one of the biggest factors in how these group characteristics develop is the size of the research group. We present our results comparing and contrasting groups of various sizes, considering how the myriad characteristics of small, medium and large research groups manifest, and furthermore how group size contributes to student learning.

4.3 Methods

This study employed a mixed methods approach to data collection and analysis (Creswell & Plano Clark, 2007). The qualitative and quantitative data were collected and analyzed sequentially, with priority given to the qualitative findings. Three research groups from two engineering departments at the same university were the primary units of analysis, and they served as the focal point for ethnographic observations and supplemental interviews (Fetterman, 1998; Tedlock, 2000; John Van Maanen, 1988). Based on the findings of these observations and interviews, a survey was developed (Dillman, Smith, & Christian, 2009; Fowler Jr, 1995; Fuller, Edwards, Vorakitphokatorn, & Sermsri, 1993; Rea & Parker, 2005) and administered to

students at four universities across the United States. Collection of data from several sources, both qualitative and quantitative, allowed for triangulation (Creswell, Plano Clark, Gutmann, & Hanson, 2003; A Tashakkori & Teddlie, 1998) of the similarities and differences between various research groups and departments, as well as examination of the transferability of the findings to a larger population (Guba, 1981).

4.3.1 Participants and Setting

The setting for this study was three graduate research groups at a large public research university on the east coast of the United States. The two departments identified for the observations and interviews are (1) Electrical and Computer Engineering and (2) Aerospace Engineering. These were purposefully selected to represent different types of research groups, overall size, and demographic representation. Summary demographic information for participants who were interviewed or participated in observations is listed in Table 4.2.

Table 4.2

Participant Demographic Information

Research Group	Total Graduate Students	Gender of Graduate Students	Degree Programs	Total Group Size⁺
Electrical Engineering	23	20 Male 3 Female	18 Ph.D students, average of 3-5 MS students*	30
Dual Aerospace/ Electrical	12	12 Male 0 Female	8 Ph.D, 4 MS students	15
Aerospace Engineering	2	1 Male 1 Female	Ph.D	5

*In the electrical engineering group there were a few students that graduated or changed universities during the nine month observation period

+The Total Group Size includes faculty advisors, post doctoral researchers and undergraduate researchers in addition to graduate students

Initially, two research groups were chosen for observation from within these two departments. The first research group was a large group from electrical and computer engineering, and the second was a small, newly formed research group from the aerospace engineering department. As the data collection and analysis progressed, it became clear that these groups represented extremes that did not capture the full spectrum of variation (specifically medium-sized groups).

We then selected a third research group that was in between the small and large group, with students advised by faculty members from both departments. Overall, the groups chosen range from 4 – 23 students and contained both MS and Ph.D students.

Upon completion of the ethnographic observations and interviews, we created a survey (Chapter 3) and administered it at four different universities across the United States, including the site of the ethnographic data collection. All four institutions (three public, one private) have large engineering programs with between 8 and 14 engineering departments. Demographic data for the entire survey sample is shown in Table 4.3.

Table 4.3

Demographic Information for Survey Respondents for each University.

Age							
	24 or Younger	25 to 30	31 to 35	36 and Older	Total		
EPUB 1	131	143	23	21	318		
EPUB 2	8	35	7	9	59		
MPUB	112	133	10	5	260		
WPRI	57	107	16	6	186		
Total	308	418	56	41	823		
Year in Program							
	First	Second	Third	Fourth	Fifth or More	Total	
EPUB 1	89	104	54	37	30	314	
EPUB 2	4	20	12	6	17	59	
MPUB	58	67	42	49	43	259	
WPRI	56	37	31	29	32	185	
Total	207	228	139	121	122	817	
Nationality							
	U.S	Asia	China	India	Middle East	Other	Total
EPUB 1	179	16	35	45	18	22	315
EPUB 2	31	3	6	11	4	4	59
MPUB	164	12	32	27	10	15	260
WPRI	64	18	40	21	21	20	184
Total	438	49	113	104	53	61	818
Gender							
	Male	Female				Total	
EPUB 1	228	89				317	
EPUB 2	33	26				59	
MPUB	179	82				261	
WPRI	136	49				185	
Total	576	246				822	

4.3.2 Qualitative Data Collection and Analysis

A total of 20 interviews were collected from graduate students and faculty advisors, along with three or four months of observations in each of the three research groups. Observation data was collected via shadowing the research groups for up to 20 hours per week, paying special attention to be present at lab group meetings and other key events such as group lunches and social events. During the months spent observing the research groups, detailed field notes were made following the recommendations of Emerson *et al.* (1995) which included sketches of the lab space,

observation notes from the research groups meetings, and notes from informal interviews. As patterns began to emerge, follow-up formal and informal interviews were used to confirm or clarify the interpretations, to tie the evidence to the findings and to determine relationships which address the research questions (Miles & Huberman, 1984). Demographic information was collected from the participants using a short questionnaire which was administered following a research group meeting or via email.

In order to address the research questions, observations and interviews were analyzed using accepted methods for ethnographic analysis (Fetterman, 1998; Tedlock, 2000). These methods included the review of field notes and subsequent creation of analytic memos to capture insights (Charmaz, 2006) as well as a review of the written documentation (Seidman, 2005; Strauss & Corbin, 1998). Narrative accounts and detailed reports were prepared on each research group, categorizing interview questions and answers and examining the data for similarities and differences (Creswell, 2007).

4.3.3 Quantitative Data Collection and Analysis

Based on the results of the ethnographic observations and interviews, a survey was developed to explore the potential transferability of the findings to a larger population. Detailed information on the creation and validation of the instrument was discussed in Chapter 3. In summary, the survey gathered data on six key retention constructs, with several items specifically concerning differences based on the size of the research group. Data were collected via an online survey tool administered through a commercial web interface. An administrator from each of the participating institutions sent survey invitations through graduate student listservs. Following the recommendations of Laguilles *et al.*, incentives were to increase the response rate (2010). Online surveys have an extremely low volunteer response rate (Dillman, Smyth, & Christian, 2008), but through the use of incentives we were able to obtain response rates between 6 and 29 percent at the survey sites, with an overall response rate of 16 percent, or 836 responses.

The survey remained active at each participating institution for a period of three weeks, with two reminder emails sent during that timeframe. There were a total of 836 usable participant

responses, which are reflected in Table 4.3. Several items from the instrument that were analyzed for this study are shown in Table 4.4.

Table 4.4

Partial List of Survey Items

Multiple Choice or Check All That Apply Items
How many students are in your research group?
How often does your research group meet (the majority of members are present)?
How often do you meet with your advisor?
How is the space for your research group organized?
What type of funding or assistantship do you have?
Likert Scale Items (1 = Strongly Disagree, 5 = Strongly Agree)
I get to meet with my advisor often enough to be successful
My research group meets often enough for me to be successful
There are more experienced members in my research group to whom I can ask questions
I have secure funding for the duration of my graduate degree
Members of my research group compete against each other for resources
My advisor has clearly stated his or her expectations for satisfactory participation
I am comfortable speaking up during research group meetings

Once the survey was closed, the responses were cleaned, configured and compiled into a single integrated data set. A variety of summary statistics were computed to test the transferability of the qualitative findings. Analysis of the survey data included descriptive statistics and the use of ANOVA tests (Kaufhold, 2007; Keith, 2006; Pedhazur & Schmelkin, 1991) to compare the mean responses for students participating in groups of various sizes.

4.4 Findings and Results

Readers may be curious to know which engineering research group size is “best.” To address this, we analyzed a number of learning and organization survey items for differences by research group size. The learning items are plotted in Figure 3.1. Overall, there are no statistically significant differences as a function of group size, and most questions resulted in few positive or

negative trends. The one exception was students' responses to whether participating in their research group increased their self confidence. Our results indicate that as the group size moves beyond 10 students, participants responded less positively about their level of self confidence. Thus, rather than advocating for a specific size or configuration, our descriptions of various-sized research groups are offered in the spirit of understanding how best to facilitate learning within each, as well as considerations for group growth over time.

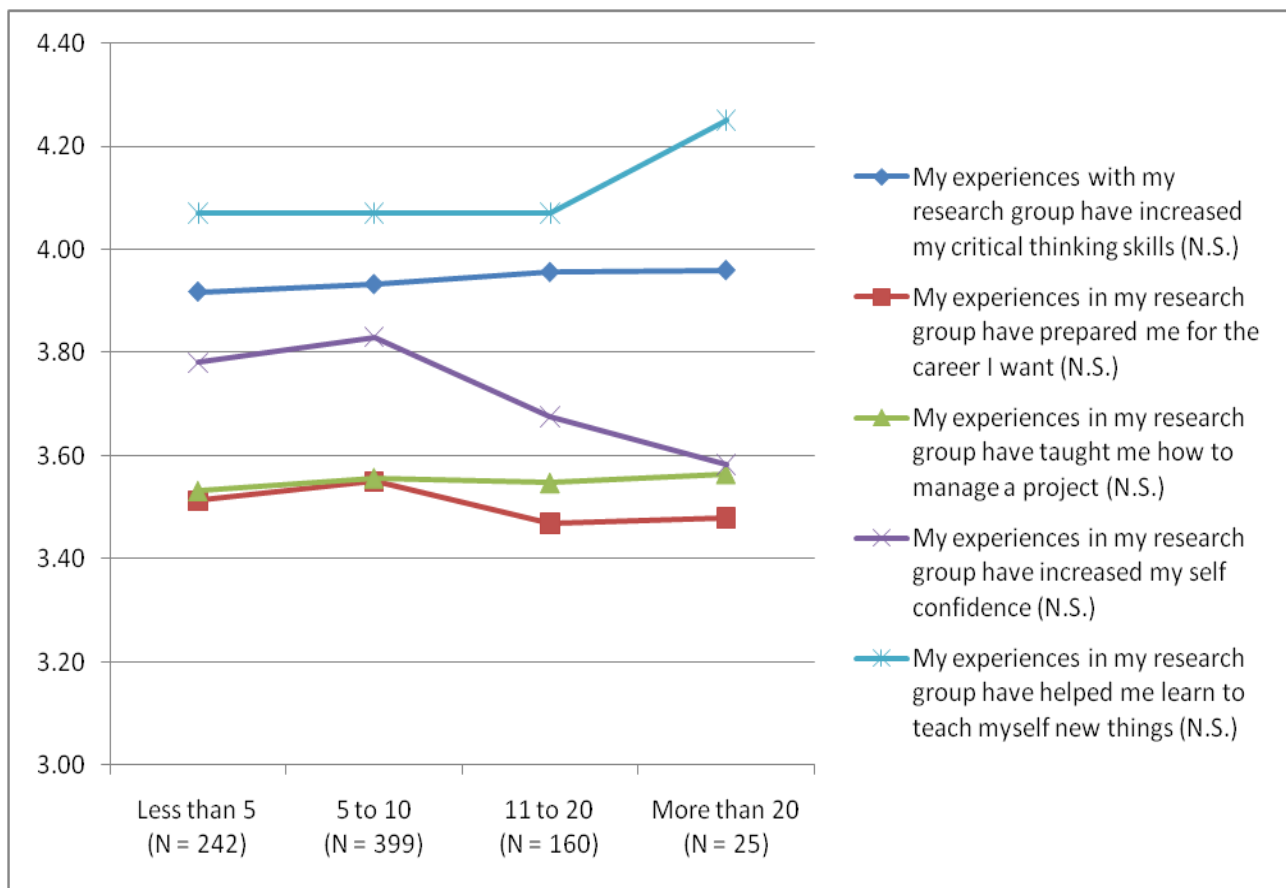


Figure 4.1. Survey Results for Aspects of Student Learning as a Function of Group Size (1 = Strongly Disagree, 5 = Strongly Agree).

Table 4.5 summarizes the findings of the qualitative phase, which are supported by the quantitative results. The following sections are organized by qualitative themes; each presenting the relevant qualitative and quantitative data.

Table 4.5

Summary Characteristics of Graduate Research Groups

	Small (less than 5 students)	Medium (5-20 students)	Large (More than 20 students)
Power-Distance and Communication	Low Advisor Dominated	Moderate Mixed	High Student/Group Dominated
Resources	Peer-Low Faculty-High Funding-Moderate	Peer-Moderate Faculty-Moderate Funding-High	Peer-High Faculty-Low Funding -High
Supervisor Role	Enculturation, Critical Thinking	Enculturation, Gatekeeper	Functional

4.4.1 Power Distance and Communication

We define the power distance (Stephen Bochner & Hesketh, 1994; Hofstede & Bond, 1984) of a research group as the distance between those in power (faculty advisors) and those who need access to individuals in power (newer graduate students). Originally used to describe cultural practices in different countries, power distance was defined by Hofstede as the degree of inequality existing between a less powerful person and a more powerful person, “which in industry would be represented by the supervisor-subordinate relationship” (Stephen Bochner & Hesketh, 1994, p. 235).

A research group with high power distance may have several gatekeepers who must be consulted before a new student can reach the faculty advisor. These gatekeepers include postdoctoral researchers or more experienced graduate students, from whom new graduate students may get the majority of their information. As a result, communication in the group is most often between students. High power distance groups are often quite large, which creates multiple within-group networks, or cohorts, and a perceived hierarchy within the group.

The largest research group observed for this study was an example of a high power distance group. Although the faculty members stated and were observed to have an open door policy, the number of students (over 20) and the associated time constraints made gaining access to faculty time challenging for many students. Within three weeks of joining the research group, a first-year student commented that he noticed “how busy the faculty are” and that the “simplest way to a solution was to go to another student.” Eventually if none of the students could solve the problem, then one of the more experienced students would take the problem to a faculty member for assistance. However, “most of the learning is from the students, not the professor.” This group was observed to have high levels of information communication between students, especially in the informal setting. During the formal group meetings the amount of communication declined; students who were not directly presenting their research tended to observe only. The more senior students and those offering research to the faculty advisors dominated the conversation, which has been noted in other studies of engineering graduate group meetings. Students who were not presenting waited until the faculty advisors left the meeting before asking clarifying questions of the more experienced students. Regarding hierarchy, a first-year student commented on the wide range of students in the group, including “those that were just beginning and those that were close to finishing.” He went on to explain that there was a “natural order to the group; someone [more experienced] took responsibility to keep the group together.” This “natural order” was created and maintained by current students. Faculty advisors may introduce new students to the group during a large group meeting, but it was the more experienced students who “take on the responsibility of mentoring the new students in the group.” For example, when one of the more senior students graduated, a first-year student noted that another experienced student in the middle of his program had “nonchalantly taken over the previous student’s responsibilities...you know, manage the lab, maintain the network.”

At the other end of the spectrum are research groups with low power distance. These groups are often small (less than 5 students), and the majority of the communication and mentoring occurs between the faculty member and each student directly. A student’s relationship with his or her advisor is critical in low power distance groups, as students often have few other sources for mentoring and learning within the research group. Unlike high power distance groups, where the

majority of the learning occurs between students, there is little to no peer learning in low power distance groups.

We observed an example of low power distance group (the smallest), in which a newly hired faculty member was just beginning his research program. With only two graduate students in the group who both began their studies at the same time, there was little collective experience to draw upon. These students met at least bi-weekly with their advisor, and exchanged several emails a week with him. Communication between the students and the faculty advisor did not differ between formal group and individual meetings. The two students were observed to interact little with each other during the group meetings and even less outside of the group setting.

Observations of power distance and communication within the research group with 12 students fell in between the experiences of the small and large research group. These students had more collective experience to draw upon, and often consulted each other before approaching the faculty advisor. In addition, this group was multidisciplinary, with two faculty advisors (one from each department) who were both associate professors with established research programs. Students were able to talk to either faculty member about the project; consequently, students from this group had more access to faculty time and resources than they would have in a smaller group. All students participated in group meetings, but the nature of the communication varied based on student experience: more experienced students tended to present their work and wait for faculty questions, while the less experienced students spent more time asking questions of the faculty advisors. There was little communication between students during the formal group meetings, which may have been due largely to the faculty members controlling the meetings. However, we observed some informal communication between students working in the lab area.

Power distance and communication were also examined through the survey instrument. Figure 4.2a shows the results of the frequency of student meetings with their research group and advisor, while Figure 4.2b examines whether student feel they get to meet with their advisor and research group often enough to be successful.

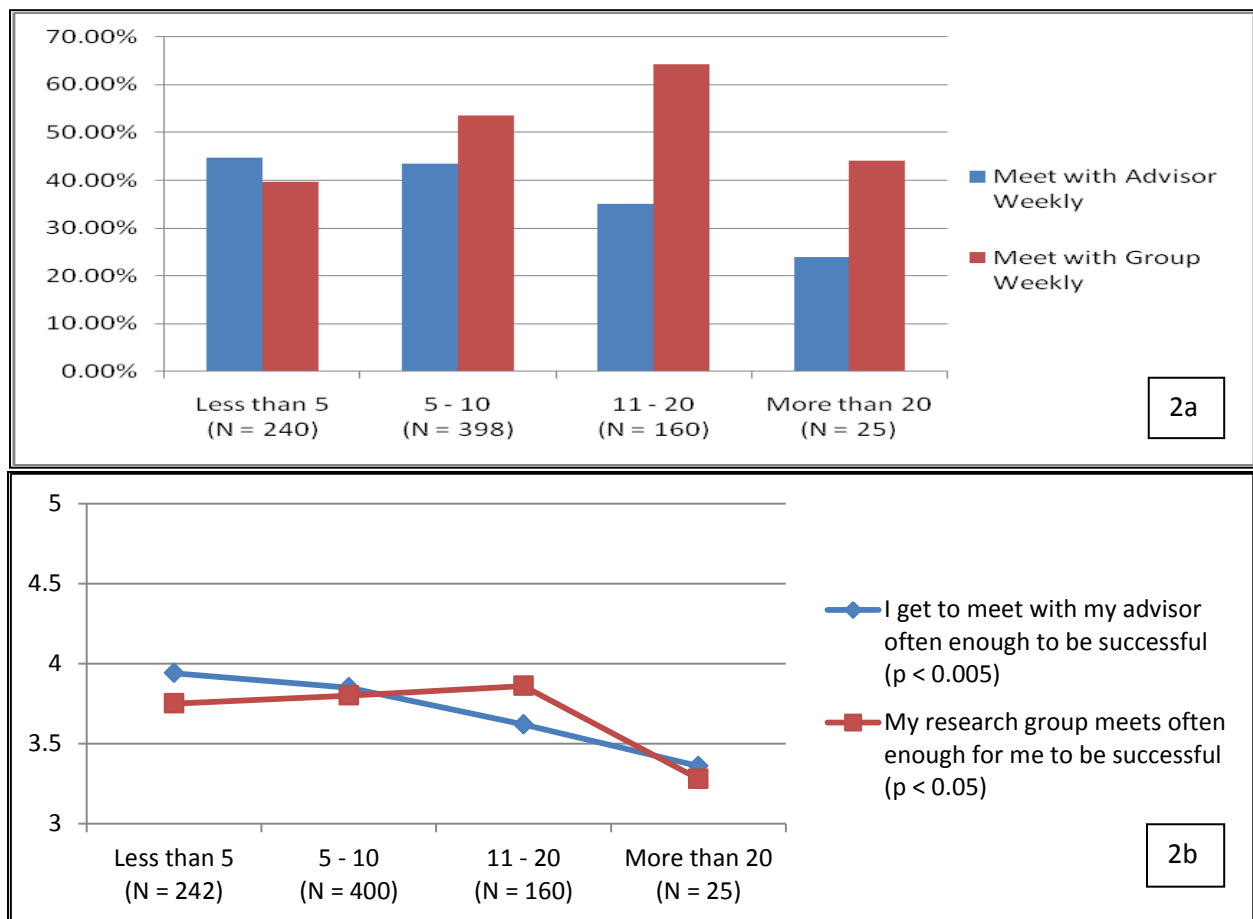


Figure 4.2. Survey Results Group and Advisor Meetings as a Function of Group Size. (a) Actual Frequency of Meetings. (b) Perceived Adequacy of Meetings (1 = Strongly Disagree, 5 = Strongly Agree).

As demonstrated in Figure 4.2a, weekly group and individual advisor meetings are the norm regardless of group size, with the sole exception of groups of over 20 members, in which students met their advisor monthly (28%). As can be expected from previously discussed results, the percentage of students who report meeting with their advisor weekly decreases as the group size increases. The opposite trend is evident for group meetings, which tend to increase with group size. The outlier of less frequent meetings of groups larger than 20 suggests that as group size moves beyond a certain point, full group meetings may become difficult. Large research groups are most likely to meet twice a month (16%), which is consistent with our large research group observations.

Our findings indicated that larger research groups have higher power distance, as evidenced by the gap between students and faculty members. Students in high power distance groups were less positive about being able to meet with their advisor as often as they would like (Figure 4.2b). This result is consistent with our observations and the comparison across all means is statistically significant ($p < 0.005$). On the other hand, as the size of the group increases, students report increasing levels of success supported by frequent group meetings, up until the largest group (more than 20 students). It is likely that as groups move beyond a certain size, not all students may have a chance to present and solicit feedback as often as they would like. Comparison across all means shows these results are also significant at $p < 0.05$.

The related survey item for communication (Figure 4.3) considered a student's comfort level speaking up during a research group meeting. While these results are not statistically significant, as the group size increases, students are less comfortable speaking up during research group meetings.

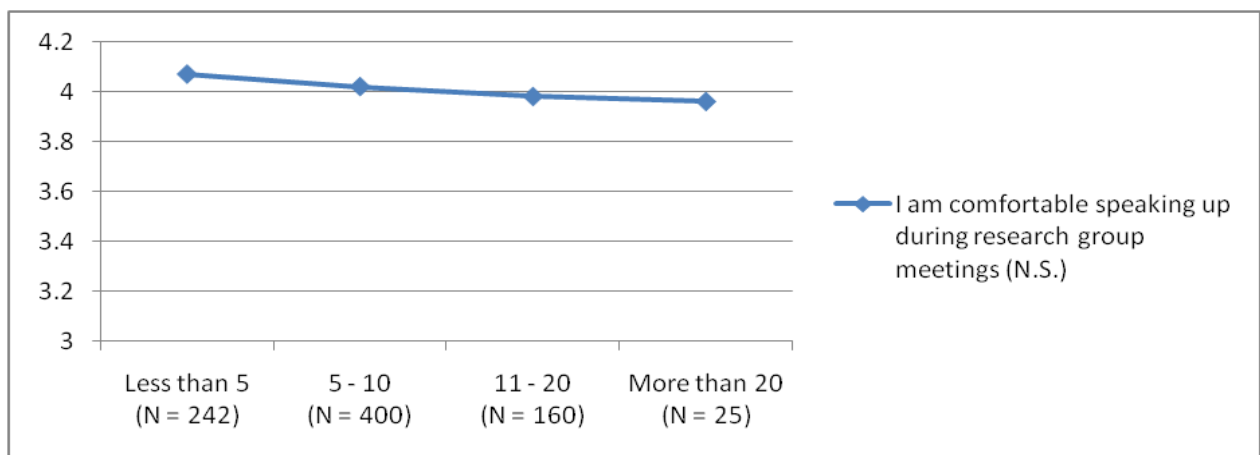


Figure 4.3. Survey Results for Communication as a Function of Group Size (1 = Strongly Disagree, 5 = Strongly Agree).

4.4.2 Student Access to Resources

The size of the group plays an important role in the resources available to graduate students. Some of the resources considered in this study include group organizational space, materials and equipment, access to other students and faculty, and availability of funding.

Several types of physical space were observed in this study, ranging from large open lab areas where multiple students had work space to individual offices or no space at all. The largest research group we observed had an expansive common lab and workroom, in addition to some smaller offices with desks shared by multiple students. The lab area included a kitchen, workshop, large meeting table with whiteboard and projector, and more than ten student desks and workstations. Students could use this space to socialize, work in teams on homework problems, discuss research or meet as a large group with the faculty members. A fifth-year student in this group noted that being present in the lab space was “how new students get involved in the group; it’s a way to get face time.” This was confirmed by a first-year student, who said of the common workspace,

[The lab] is a huge part. I have somewhere to go. If there is a conversation going on, then I can learn something and take something out of it. To have that space is a real big part. If we didn’t have a place to go with tables and enough room, things would be a whole lot different. We would not be as close, or whoever is close would not be as close. It’s where people spend their time together.

The smallest newly formed research group we observed did not have a common space where students can socialize and learn from peers. They had one office shared by three students: two from the same group and one from another research group who needed a desk. The mid-sized group had a medium-sized common lab space with a small kitchen, and the majority of the students were paired up in smaller adjacent offices. While students were able to see each other in the lab space, the majority worked alone in their offices. In addition, the faculty advisor had his office adjoining the lab area, so while students used this space for meeting and discussing research, there was less informal socializing than in the large group.

Other significant resources include equipment and materials needed to conduct research. In this study, resource availability varied by the size of the research group as well as the nature of the research being conducted. For example, the small newly formed group was just establishing a research base; there was little previous equipment or published results to start with. The mid-sized and larger research groups had considerably more materials and equipment; however, there was the potential for conflict if more than one student needed access to a specific resource at the same time. Similarly, the large and mid-sized groups often had multiple students working on large funded projects, limiting the funding available for new equipment and conference travel. As a fifth-year student from the large group noted “there is a hierarchy for conference attendance; the most senior student gets their own [hotel] room. If there is only space for one, [I] get to go.”

In addition, the availability of funding was observed to be larger in the smaller research groups. Students generally did not join a small group without a project lined up prior to starting. This was not the case in the large group, where students may “join” the group and wait up to a year to be assigned a funded project. A third-year student in the large group confirmed that “a lot of new students are not really involved in projects yet. They are waiting for a project and may have an advisor, but they just sit in the lab and observe. They are passive participants waiting on funding.”

Regardless of the group size, the establishment of the research project was seen as a key mechanism for acceptance into the research group. It was especially obvious in the large research group, where students were viewed as “passive participants” until they were assigned to a funded project. Students in mid-sized groups generally spent less time waiting on a project, and students in the smaller groups had funding lined up before beginning graduate study; generally beginning a project rather quickly.

Finally, peers and faculty members can also be viewed as group resources. Not surprisingly, the larger the group the more students are available for peer learning and interaction. However, the *availability* of the resource does not mean that students will take advantage of it, as a fifth year

student noted, “Some people never really assimilate into the group, the ones that only work at home. This affects the individual more than the group; it’s harder to go it alone in graduate school.”

Students’ access to resources was also examined through the survey. Figure 4.4 shows the results of these resource items as a function of group size as well as the statistical significance for a comparison of means between the groups. The availability of more experienced students to ask questions was statistically significant ($p < 0.0001$) with small groups reporting considerably lower availability than medium and large groups. Students also reported increasing competition for resources as the size of the group increased (not significant).

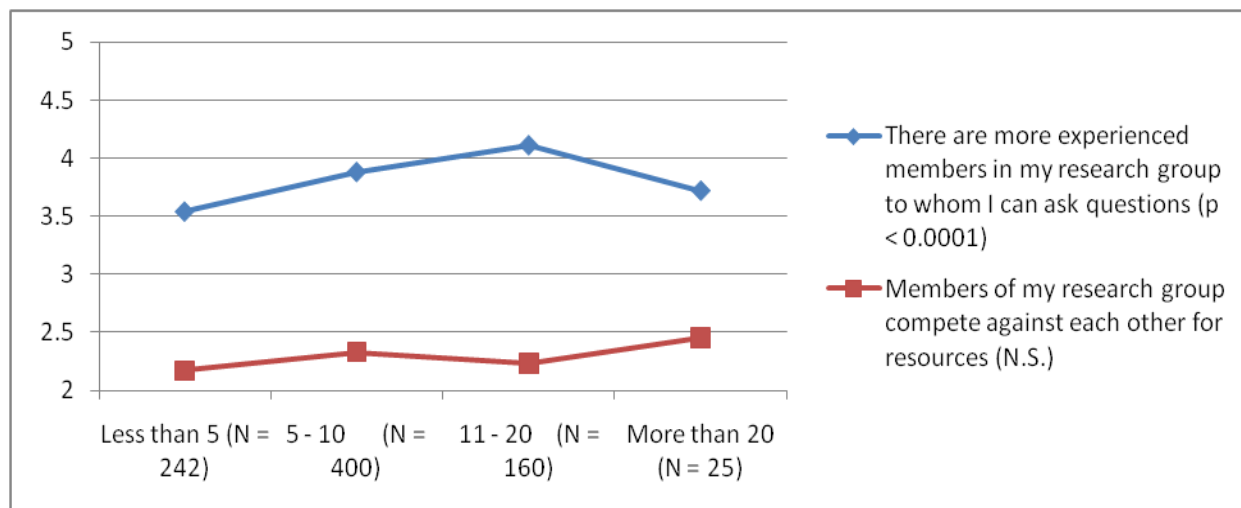


Figure 4.4. Survey Results for Student Access to Resources as a Function of Group Size (1 = Strongly Disagree, 5 = Strongly Agree).

The type of workspace allotted to the research group or to individual students is presented in Figure 4.5. Students were allowed to select more than one option if they had multiple workspaces. For example, we observed students in the medium-sized group with both individual offices and a common lab space.

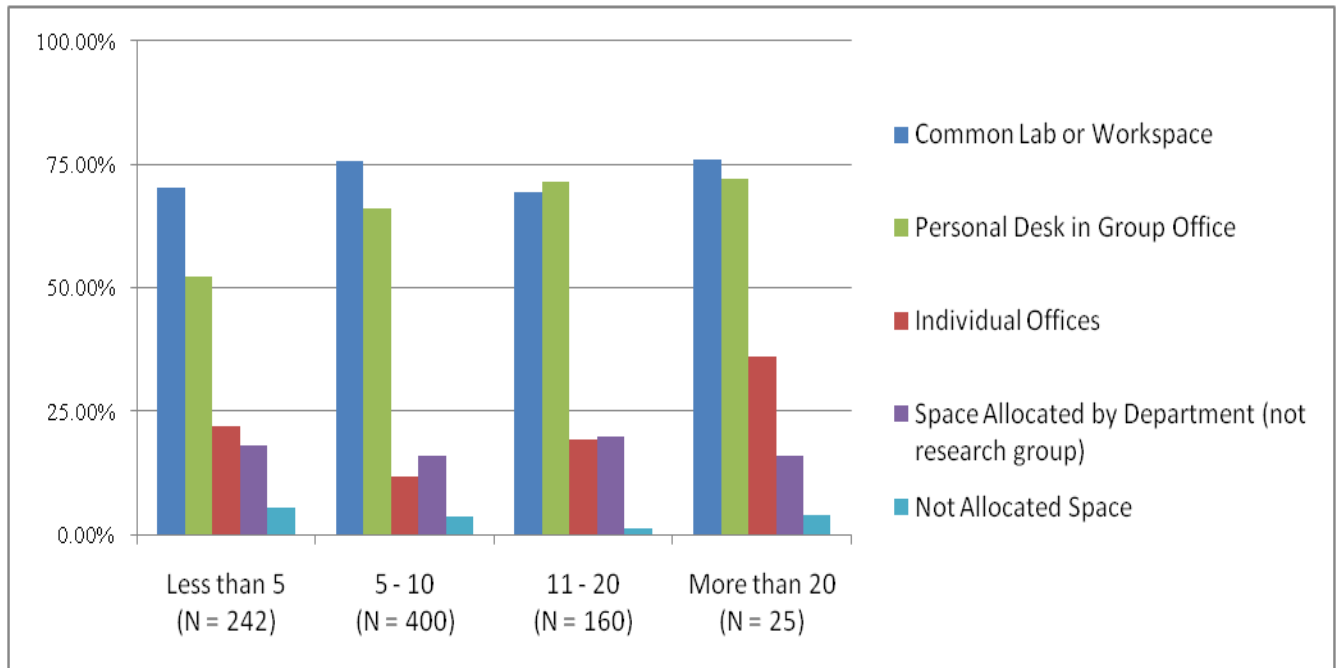


Figure 4.5. Organizational Space as a Function of Group Size

With the exception of the groups of 11-20 students, the majority of participants indicated their research groups were allotted a common lab or workspace (70 to 76 percent). This was followed closely by a personal desk in a group office, which may or may not have been the same as the common workspace. Students from the smallest research groups (less than five students) were the most likely to not be allocated space. This is consistent with observations regarding the space assigned to the three research groups.

4.4.3 The Role of the Advisor

For the research groups we observed, we examined how the role of the supervisor varies with the size of the group. Using Anne Lee's (2008) framework we have organized the characteristics of faculty advisors for small, medium and large research groups (refer to Table 4.1 for role descriptions). In large research groups, the faculty advisors take on more of a functional or managerial role in the administration of the group: one of supervision and project management. For the large research group we observed, the faculty advisors ran the large group meetings much like a business: asking about deliverables, checking on the status of certain aspects of the project, and generally keeping things on a schedule. Students actively participated in the

conversation during these meetings, which ran like those of an engineering design team at a for-profit company. The faculty advisors were unsure of the details of each project but managed the overall big picture to keep the research group moving forward. As new grants were added to the existing project base, new students were assigned a task. Overall, this supervisory role enables students to develop via a rational progression through tasks; however, students may follow this progression blindly without trying to develop beyond it (Lee, 2008).

The role of the advisor in the mid-sized groups was observed to be more of a gatekeeper. The faculty member was attempting to acculturate the students into the group and made time to take a more personal interest in the work of individual students. Faculty advisors in the medium-sized group actively engaged students during group meetings and gave students advice on ways to approach their research. Additional sub-group meetings were held with students working on aspects of the same project so that the faculty advisors could work with students more often and in a more personal environment than the large group meeting. This enculturation mindset is one that seeks to bring students into a community of practice by focusing more on the mentoring and coaching aspects of supervision, rather than the business end (Lee, 2008). In medium-sized groups the balance between faculty advisor involvement and peer relationships provides students with support and guidance to fully participate in the community of practice.

Advisory practices in the smaller research group also encouraged enculturation to the discipline. Small groups, however, differ in the role of the supervisor in that there is less gatekeeping and more critical thinking (Lee, 2008). In small groups (less than approximately five students), the advisor is very involved in the student's research, and while still mentoring the student, he or she offers a more evaluative perspective, encouraging arguments and challenging analysis. Observations and interviews with students in the newly formed research group indicate that graduate students were highly dependent on the advice and time of their advisor. These students did not really have a shared lab or office space and only saw each other during the group meetings when the faculty advisor, both graduate students, and two undergraduate students were present. With a newly formed research group, the faculty advisor did not have a firmly established research program, or direction for research, and would challenge his students to develop ideas of their own to pursue. While this level of supervision enables students to develop

into thoughtful and critical researchers, the level of constant inquiry may make students feel a “fight or flight” response, especially with few outlets for peer support (Lee, 2008).

The corresponding survey item reflecting advisory practices is shown in Figure 6. While there was no significant difference by group size, groups with more than 20 students were the least likely to agree that expectations for satisfactory participation were made clear, while groups with between five and ten students were the most likely to agree. The outlier of groups less than five may be because individual interactions dominate and the concept of a “group” might hold little meaning to students and faculty members.

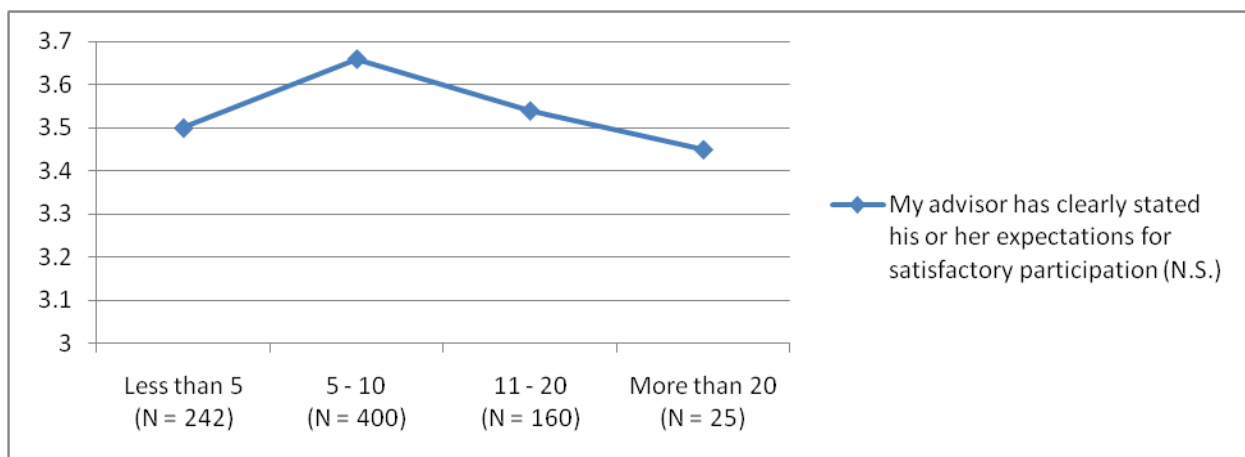


Figure 4.6. Survey Results for the Role of the Advisor as a Function of Group Size (1 = Strongly Disagree, 5 = Strongly Agree).

4.5 Discussion and Implications for Practice

The three overarching themes which emerged from the data included the power distance and communication, students’ access to resources, and the role of the advisor. Although this presentation emphasizes differences for groups of varying size, there is considerable overlap between the themes and among the groups. Not all research groups fall squarely into one category, or are limited to those that are described here. It should also be noted that labels such as high, low and medium are meant to be considered as a points on a continuum, representing relationships to other groups rather than discrete values. With these results in mind we offer the

following summary descriptions of each representative size and recommendations for both new and continuing faculty members creating and sustaining productive engineering research groups.

4.5.1 Small Research Groups

Small research groups (Figure 4.7) may traditionally have five or fewer students and feature a short power distance, which leads to advisor-dominated patterns of communication, in which student-advisor relationships are much stronger than peer relationships. Consequently, students in small research groups have fewer peer resources to draw upon. The role of the advisor in small research groups tends to be enculturation to the discipline with a mix of critical thinking (Table 4.1), where the faculty member may be heavily involved in the students' research (especially if it is an extension of his or her own). Small research groups are likely to be found with new faculty members just starting a research program, or in small departments or graduate programs.

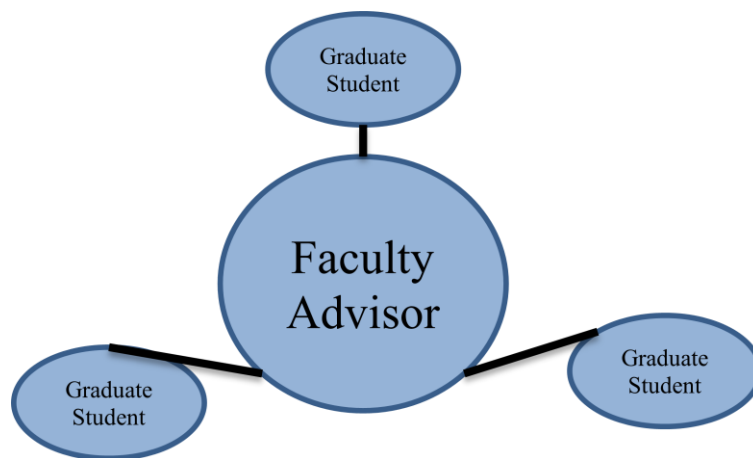


Figure 4.7. Structure of a Small Research Group

In small groups, advisors should try to find ways for students to interact with other graduate students to increase opportunities for learning through peer interactions. This might be accomplished through establishing shared office space for all of the students in the degree program (or related group) or providing a lab space or other common areas for students to use together. This provides students a chance to informally discuss research-related topics and meet

socially within a research setting. In addition, research group meetings are often overlooked in small groups, so it is important for faculty advisors to hold regular research group meetings where the entire group is present. These meetings might be short, but will remind students about the research being conducted by other members of their group and provide increased potential for peer interactions. Establishing group meetings and common work areas will lay a strong foundation if the intention is for continued growth of the research group.

4.5.2 Medium-Sized Research Groups

Medium-sized research groups (Figure 4.8) generally have between six and fourteen students under the direction of one or more faculty members. The power distance in medium sized groups is moderate, meaning that students are at least as likely to go to their peers for support or information as they are to their faculty advisors. This leads to moderate access to peer and faculty resources because students are not necessarily forced to compete for faculty time. Faculty advisors of medium research groups may will be slightly less dominant than in smaller research groups and take on more of a coaching or mentoring role. Finally, because of the larger number of students present in the group, communication will be mixed between student-initiated and advisor-initiated. Students will start to take initiative to accomplish some of the more routine tasks within the group.

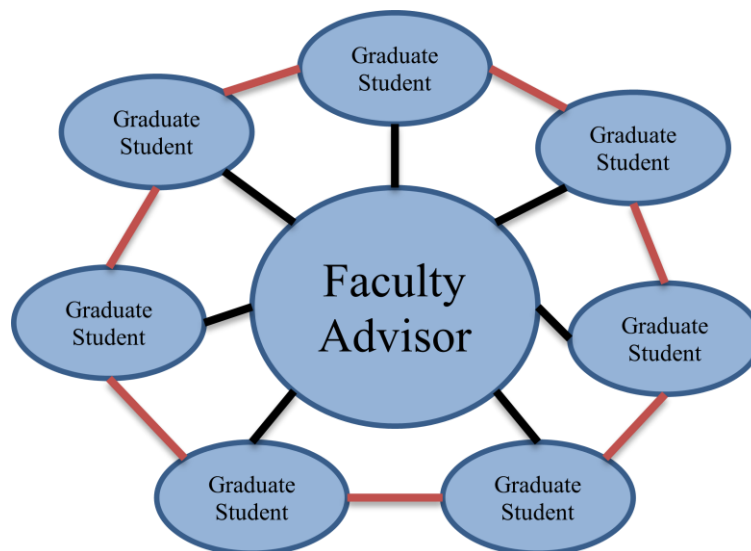


Figure 4.8. Structure of a Medium Sized Research Group

According to students in this study, 6-10 students was perhaps the ideal size for a research group, because students have easy access to both peers and faculty advisors. However, it is still critical for advisors to encourage students to develop peer networks. In particular, they should ensure new students are introduced to the group in a way that allows them to assimilate into the existing structure. Like the small group, communal office space or a lab area where students can work together on homework or research or simply socialize is an important aspect for establishing a sense of community. In addition, large group meetings should be held often enough for everyone to get a chance to speak, but each meeting should not be exceedingly long. This might be accomplished by holding bi-weekly meetings where several students present so that every student has an opportunity to present his or her research at least once a month. As the group size continues to grow, the more experienced students should be encouraged to serve as mentors for the newer students learning how to use equipment, navigate the lab space, and meet other students in the department. This role may need to be made explicit to students and postdocs. This would provide avenues for increased peer interaction and learning among the many members of the research group.

4.5.3 Large Research Groups

Large research groups (Figure 4.9) generally have more than 15 students and have a high power distance, meaning that students will navigate layers of more experienced students before approaching a faculty advisor for assistance. Despite the fact that this size group may have multiple faculty advisors, students will have expanded peer resources but fewer faculty resources. The role of the faculty advisor(s) in this group is more functional; they oversee the management and function of the group, but they are less involved in the details of individual students' research projects. Communication in these groups is student-dominated. There is likely an implicit student network that disseminates information and acculturates new students into the group. Large research groups are often run by very senior faculty members who have access to considerable resources, are well known in their academic community, and attract a large number of students who want to work with them.

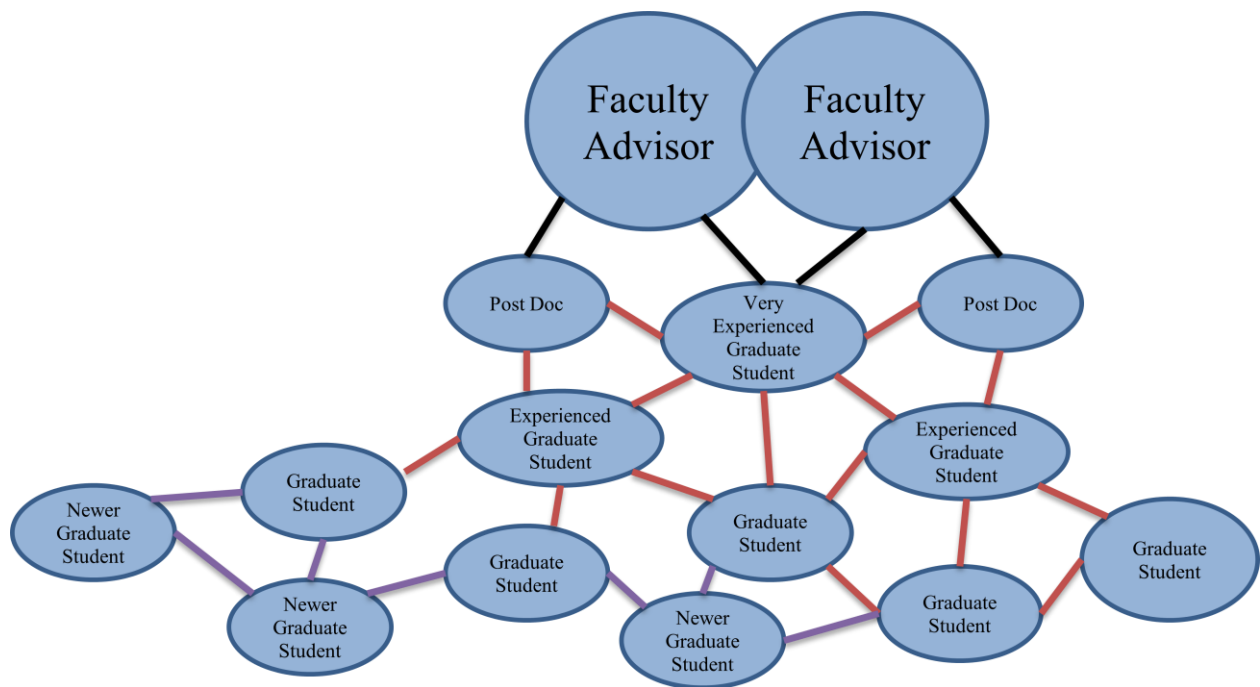


Figure 4.9. Structure of a Large Research Group

As the size of the research group moves beyond 20 students, several aspects of group structure shift in comparison to the small and mid-sized groups. Large research groups often attract many students at one time and could have as many as three to five (or more) students beginning each semester or academic year. When this happens, faculty advisors should introduce the new students to the group during a large research group meeting, and ensure that students understand the expectations for participation in the group. If possible, these students should be advised to enroll in the same classes their first semester to develop peer connections within the research group. Additionally, more senior members of the research group should be encouraged to serve as mentors for newer students so that entering students have a greater chance of gaining acceptance by the rest of the group. Unlike small and medium groups, large groups may seem intimidating to many students and present the greatest opportunity for new students to avoid the research group and try and “go it alone.” The first semester is critical for new students; the decisions they make regarding participation in the group are difficult to change after this point. Much of the learning in large research groups occurs via the informal interactions that students have around the whiteboard and computer screens, so having a lab space where all the students

can meet and work together is highly desired. Finally, research group meetings may become increasingly long for large research groups, and advisors should take precautions to set agendas ahead of time so students know when they are required to present to the large group and when they are there to give feedback. As in medium-sized groups, group meetings held twice a month should provide students a chance to present at least once a month, but would not run too long in one sitting.

4.6 Conclusions

These descriptions are not absolutes, and individual faculty members should use these as guidelines for creating research group environments which engage graduate students and support learning. An understanding of the differences among groups of varying sizes can be used by university administrators, faculty and graduate students to create an environment that fosters successful learning and professional development for graduate engineering programs, and may ultimately reduce attrition from engineering graduate programs.

Chapter 5

Characterizing the Influence of International Diversity on Graduate Engineering Student Retention

Abstract

The purpose of this study is to better understand the differences in retention constructs by student nationality in U.S. engineering graduate programs. Results from more than 600 engineering Ph.D students (from 6 international regions) were examined to characterize demographic differences in participant responses for intention to complete the degree.

5.1 Introduction

Doctoral education provides the labor force not only for top positions within the professoriate, but also in scientific laboratories and research facilities, educational administration, and business and industry (Haworth, 1996). Despite this need for skilled labor, 40 to 60 percent of students who begin their doctoral studies in the United States do not persist to graduation (Berelson, 1960; Bowen & Rudenstine, 1992; Nerad & Cerny, 1993). This attrition rate has prompted increasingly prevalent research on retaining students in graduate programs in the last 30 years (Bair & Haworth, 1999). This research has focused on disciplinary differences (Gardner, 2009; Golde, 2005; Nettles & Millett, 2006), the role of the faculty advisor and mentoring (Frehill, *et al.*, 2007; Lee, 2008; Malfroy, 2005), socialization to the community (Boden, Borrego, & Newswander, 2011; Lovitts, 1996; Pilbeam & Denyer, 2009; Weidman & Stein, 2003), and demographic considerations (Cuny & Aspray, 2002; McAfee & Ferguson, 2006), among others. The lack of funding has often been touted as a predominant reason students leave their doctoral programs (Golde, 1998, 2005; Nerad & Miller, 1996). However, this falls short of explaining all of the variance in student retention. As we discuss in a later section, engineering programs have the highest percentage (75-80%) of students receiving financial assistantships, yet the past ten years have seen only 64% completion from Ph.D programs (Council of Graduate Schools, 2007).

Notably absent from the literature on retention in graduate programs are studies considering the differing backgrounds and expectations of domestic and international students. For example, Gardner (2009) examined the experiences of doctoral students in high and low completing departments. This study considered the disciplinary differences in doctoral education, noting that electrical and computer engineering was often considerably different than the other five departments studied, and represented the lowest completing department. Interestingly, the author found that engineering students (unlike all of the other disciplines studied) depended more on faculty for support than their peers, and she attributes this to the high percentage (over 50%) of international students in the engineering department. In addition to the above instances, Gardner makes multiple mentions of the high percentage of international students in engineering, arguing that considerable research needs to be done to understand how they influence the graduate student experience (Gardner, 2009).

Anderson and Lewis (1994) studied how a variety of science and engineering graduate students subscribe to the norms of science. Engineering students showed the strongest support for the counter norms compared to the other disciplines surveyed. The largest gap between any two groups is found in the case of U.S. versus non-U.S. student support for scientific counter norms such as solitariness, self interestedness and particularism. The authors conclude that the data suggest the need to incorporate broader cultural theories into our understanding of the value system of science. They further argue that it would be useful to determine whether or not there are sub cultural differences within the group of U.S. citizens, which might have implications for efforts to recruit and retain students from diverse backgrounds in the sciences and engineering.

The high prevalence of international students is a defining feature of engineering graduate programs, making this an ideal population to conduct a study regarding differences in retention for a diverse student population. Although the growth of graduate engineers in the U.S. has declined slightly over the period from 1983 to 2005, India has seen its growth of engineers holding graduate degrees nearly double, and China has seen a 300% increase in the same period (Banerjee & Muley, 2007). Many of these students receive their graduate degrees from universities in the United States (Burrelli, 2010); in 2002, international students received 58.7

percent of graduate degrees awarded by U.S engineering programs (Committee on Science Engineering and Public Policy, 2005).

Several studies have identified the differences between engineering and other disciplines, noting that a potential reason was the high percentage of international students (Anderson & Lewis, 1994; Gardner, 2009; Nettles & Millett, 2006). This study addresses the limitations and future work described in these and other studies, which have identified international diversity as an increasingly important issue in graduate education in need of further exploration.

This study aims to examine the variation in graduate student retention as a function of nationality and background. Through the development of a survey instrument specific to engineering graduate students, we will be able to gather data on a large population of international students, which will allow for potential generalizability to more specific countries and regions, rather than grouping all international students into a single, monolithic category. By considering the issue of retention, we are also able to compare the results to other national surveys of doctoral student retention which may have excluded engineering students or failed to fully explore the nuances of an internationally diverse population.

The purpose of this study is to better understand the differences, if any, in selected retention constructs by student nationality in U.S. engineering programs. This is accomplished through addressing the following research questions:

1. What group interaction aspects of the graduate experience help foster retention of students in U.S. graduate engineering programs?
2. What, if any, are the differences by student nationality in the intention to complete the degree for students in U.S. doctoral engineering programs?

For this study we chose to focus specifically on nationality as a variable to examine student responses to survey questions about their intention to complete their degree. The following sections discuss the broader literature on graduate student retention which was coupled with ethnographic data collection and analysis to develop the survey instrument (Chapter 3). We then

briefly discuss the internet-based survey instrument developed for this study, as well as demographics on the nearly 700 responses which comprise our data set. We present detailed results on the constructs used to measure students' intention to complete their degrees and examine differences in these constructs based on respondent nationality. Finally we discuss these results in light of the implications for programs with similar levels of international diversity.

5.2 Literature on Doctoral Student Retention

The experiences of graduate students reflect a complex series of interactions between various cultures, networks and organizational structures (Cumming, 2010). The conditions under which students work, study, and develop their capacity for research can either encourage their interest or discourage them from program completion (Cross, 2001). The issue of retention is not a new topic in doctoral education. Several large studies have considered student retention, focusing on disciplinary differences, gender, and ethnicity on attrition from doctoral programs and offer a variety of factors relevant to research on doctoral student's retention. For this study we used the following factors from the literature to develop our retention constructs: expectations, climate and organization, belonging to the community and individual considerations.

5.2.1 Expectations

Cooke *et al.* (1995) explored the relationship between graduate student attitudes and attrition in an effort to find areas where plausible changes could be made to increase retention in graduate programs. They found that students whose expectations had been met were more likely to continue, whereas a lower need for achievement led to dropping out, which has been documented by previous research (Bair & Haworth, 1999). Nerad and Miller (1996) focused a retention study on the interplay of institutional, disciplinary, and student characteristics. They indicated several reasons that students may leave their degree programs before completion, including frustrated expectations.

5.2.2 Climate and Organization

In retention literature, climate often refers to the “feel” of the environment in which students are working to complete their graduate degrees. Gregg (1972) considered factors affecting graduate student satisfaction, arguing that student satisfaction was linked to degree completion. This study centered on the relationship between faculty and students (collegiality), and peer relationships among students (competitiveness). Litzler *et al.* (2005) investigated the climate for graduate students in science and engineering departments and found that the degree of competition is highly and negatively correlated to degree progress. In *Leaving the Ivory Tower*, Lovitts (2001) found several levels of interaction relevant to students’ satisfaction in their degree programs, including: peer interactions, students and faculty interactions, and social interactions outside of the research environment.

Organization can encompass a number of factors in retention literature, notably the ability of faculty advisors to provide sufficient funding for students to complete their degree programs. The need for universities to have intentional structures that support the academic and social integration of doctoral students is grounded largely on an outcome of Golde’s work (Golde, 1998). Lovitt’s (2001) considered the importance of organization, specifically access to resources. She concludes that access to resources is a key difference between completers and non completers, which may ultimately affect their level of participation, and consequently integration, into the community. The *PhD Complete Project* is a seven-year, two-phase project that addresses the issues surrounding Ph.D. completion and attrition (Council of Graduate Schools, 2009). The survey, which included engineering students, asked respondents about the main factors that contributed to their ability to complete the degree. The results indicate that financial support was a factor salient for most students, however close to four-fifths (78%) of engineering graduates had received a research assistantship compared with much lower values for humanities and life sciences. They also found that international students consistently had the highest completion rates in all fields and in all cohorts, but do not understand the difference as it relates to retention.

Nettles and Millet saw similar results for financial support in their survey of nearly 9000 graduate students (2006). They further argue that across multiple dimensions international students have different experiences than their domestic counterparts. The authors comment that the high representation of international students in engineering contributes to differences in the demographic makeup of departments, which may have consequences for student experiences. The authors go on to suggest directions for future work including a better understanding of how the variation in the socialization of students from different cultural backgrounds impacts research productivity and other dimensions of the graduate experience, including retention.

5.2.3 Socialization to the Community

A series of works on doctoral attrition have demonstrated that involvement with the program, or socialization to the community, is a strong predictor of doctoral retention (Bair & Haworth, 1999; Lovitts, 2001; Mendoza, 2007). The concept of socialization to the discipline is not new to graduate education, and it is one of the most common theoretical lenses in qualitative studies of graduate students. Socialization is the process through which an individual learns to adopt the values, skills, attitudes, norms, and knowledge needed for membership in a community (Bess, 1978; Kuh & Whitt, 1988; Merton, 1957; Pruitt, 1978; Salomon & Perkins, 1998; J Van Maanen & Schein, 1979; Ward & Kennedy, 1993). Examples include the four stages presented by Weidman and coworkers (anticipatory, formal, informal and personal) (2003; 2001) and Lovitts (2001) that express socialization in regard to prior anticipatory socialization to the graduate school environment, through culmination of the degree and entrance into the profession. Lovitts considers several reasons students may leave graduate programs, including: the absence of community, and disappointment with the learning experience (Lovitts, 1996, 2001).

The vast majority of students entering science and engineering graduate programs will participate in a research group during the course of their program (Alberts, 2009; Altbach, *et al.*, 1999; Deem & Brehony, 2000; Louis, *et al.*, 2007); therefore, attention to the learning environment is critical for understanding student development and ultimately persistence (Cross, 2001).

5.2.4 Individual Considerations

Individual differences in students are also salient in studies of graduate student retention, specifically as it pertains to an internationally diverse sample of students. In their meta-synthesis of retention research in graduate education, Bair and Haworth (1999) found four personal and psychological variables shown to relate to persistence, including: student motivation, goal directedness, self-concept, and well-being.

These studies highlight several variables of interest in the study of graduate education, but lack clarity on how students from different countries would experience each, or understand the variation in responses from an internationally diverse population. A deeper understanding of the experiences of students in these internationally diverse research groups will highlight new ways to examine attrition from graduate engineering programs, and may ultimately aid in retaining new students.

5.3 Research Methodology

In order to validate the constructs developed to measure graduate student retention and examine the influence of international diversity on respondent's views on retention, a mixed methods design was selected for this study (Creswell, 2009; Creswell & Plano Clark, 2007) with priority given to the quantitative results. During the spring of 2010 we developed a survey instrument using previously gathered qualitative data, and administered this survey to doctoral students at four institutions across the United States. The following sections discuss details on the instrument development and data collection, the respondents, and the quantitative analysis plan.

5.3.1 Instrument Development

During the instrument development phase we isolated several independent variables of interest that would enable us to better understand the experiences of graduate engineering students in research groups; specifically focusing on the issue of retention. The final constructs from the survey instrument used to examine intention to complete the degree are shown in Table 5.1. A

detailed description of how these constructs were determined and how they were implemented into specific survey items is discussed in (Author, 2011).

Table 5.1

Constructs used to measure intention to complete the graduate degree

Construct	Description
Project Ownership	The extent to which students felt they “owned”, or felt responsible for the success of the project they were working on
Expectations	Did students feel they were prepared for graduate school, were their expectations were met, and was their advisor clear in his or her expectations for participation in the research group?
Climate	The “feel” of the research group. This could include the presence of cliques of students, the level of competitiveness, and whether students feel like they fit in or not.
Organization	Items like the presence of more experienced students, availability of resources, research group meetings, advisor meetings, and clear expectations for participation in the group.
Individual Preferences	Students’ personal beliefs about the importance of various activities. These include: valuing international diversity, working in a team environment, speaking up in group meetings, and taking initiative to accomplish a task.
Feeling Valued	Students’ sense of their value to the group, project value, and value of their work to other group members and faculty advisor.

The dependent variable, intention to complete the graduate degree, was chosen to reflect student self-reported measures of attrition, and to identify where improvements to graduate programs might be made immediately. Demographic items were also included in the instrument to capture variations between and among different student populations.

Validity and reliability measures were taken into account during instrument development and administration. A draft of the completed instrument was reviewed by both international and domestic students at one institution to address content validity as well as language and question

clarity. The instrument was also reviewed by a panel of experts in the field of engineering education, and graduate education from the participating survey institutions as an additional measure of content validity. Finally, a pilot test was conducted in the summer of 2010 with a sample of 50 students from one institution to determine initial internal consistency metrics. The student and expert reviews, along with the internal consistency results from the pilot test, were used to make modifications to the instrument before it was administered to the entire survey sample in the fall of 2010.

The completed survey instrument contained a total of 63 questions. There are 42 Likert-style questions that use a scale from 1 – 5 where 1 is strongly disagree and 5 is strongly agree. Nineteen items were used to gather individual demographic information as well as data on the research group. Internal consistency values for each construct from those respondents who completed the survey during the data collection phase are shown in Table 5.2.

Table 5.2

Internal Consistency Analysis for Final Instrument

Construct	Number of Items	Cronbachs Alpha
Feeling Valued	5	0.86
Organization	7	0.73
Climate	7	0.66
Individual Preferences	6	0.64
Expectations	6	0.63

In addition to internal consistency analysis for the entire survey population, we also considered the internal consistency for each participating university and nationality group. There was almost no variation in internal consistency for the different universities, and little variation for students from different world regions. For a detailed discussion on the internal consistency or other aspects of the instrument development see Crede and Borrego (2011, in review).

5.3.2 Respondents

The respondents were current graduate students at four universities purposefully selected based on their Carnegie classification of RU/VH (very high research university). From the complete list of RU/VH universities, the four in this study were selected to diversify the sample based on relative size of the university, engineering departments offering graduate degrees, and their status as a public or private university. While the universities sampled in this study are representative of other RU/VH institutions, the results may not be as applicable for doctoral institutions which are not research intensive. A summary of the four participating institutions is shown in Table 5.3 and the consolidated description of the complete sample of the respondents from these four universities is shown in Table 5.4.

Table 5.3 *Universities selected as part of the sample (data from 2010 U.S. News and World Report)*

Institution	Selected Engineering Departments	Engineering Graduate Students	Engineering Undergraduate Students
Large Public East Coast University	Aerospace, Chemical, Civil, Electrical and Computer, Industrial and Systems, Materials Science, Mechanical	2,000	5,800
Small Public East Coast University	Chemical and Biochemical, Civil, Computer Science, Electrical, Mechanical, and Systems	950	1,500
Large Private Midwest University	Aerospace, Chemical, Civil, Electrical and Computer, Industrial and Systems, Materials Science, Mechanical	2,600	5,300
Large Private West Coast University	Aerospace, Chemical, Civil, Electrical and Computer, Mechanical	4,100	1,900

Table 5.4

Demographic Information for Survey Respondents at Participating Institutions.

Age							
	24 or Younger	25 to 30	31 to 35	36 and Older	Total		
EPUB 1	131	143	23	21	318		
EPUB 2	8	35	7	9	59		
MPUB	112	133	10	5	260		
WPRI	57	107	16	6	186		
Total	308	418	56	41	823		
Year in Program							
	First	Second	Third	Fourth	Fifth or More	Total	
EPUB 1	89	104	54	37	30	314	
EPUB 2	4	20	12	6	17	59	
MPUB	58	67	42	49	43	259	
WPRI	56	37	31	29	32	185	
Total	207	228	139	121	122	817	
Nationality							
	U.S	Asia	China	India	Middle East	Other	Total
EPUB 1	179	16	35	45	18	22	315
EPUB 2	31	3	6	11	4	4	59
MPUB	164	12	32	27	10	15	260
WPRI	64	18	40	21	21	20	184
Total	438	49	113	104	53	61	818
Gender							
	Male	Female				Total	
EPUB 1	228	89				317	
EPUB 2	33	26				59	
MPUB	179	82				261	
WPRI	136	49				185	
Total	576	246				822	

The individual respondents in the sample chosen for analysis are all doctoral students, completing their degrees as full time students who are part of a research group. In total there were more than 50 countries represented by respondents in the sample. These were further grouped into the countries and regions shown in Table 5.4 to maintain subsample sizes large enough for statistical comparisons. Asia consisted of students from countries like Taiwan, Singapore and South Korea. Students from the Middle East hailed from Lebanon, Saudi Arabia and Israel. Southern Asia included Indonesia, Thailand, and the Philippines.

5.3.3 Survey Administration

Data were collected via online surveys (one version for each institution) administered through email solicitations with a link to the corresponding survey. An administrator from each of the participating institutions sent one survey invitation and two reminders through graduate student listservs. The survey sites were open for 3 weeks. Following the recommendations of Laguilles *et al.*, incentives were to increase the response rate (2010). Online surveys have a volunteer response rate of approximately 10 percent (Dillman, *et al.*, 2008), but through the use of incentives we were able to obtain response rates of 6-29% percent at the survey sites, with an overall response rate of 16% which is shown in Table 5.5.

Table 5.5
Survey Response Rates for Participating Institutions

	Usable Surveys	Attempted Surveys	Possible Respondents	Overall Response Rate
Large Public East Coast University	327	590	2000	29
Small Public East Coast University	263	565	2600	21
Large Private Midwest University	60	145	950	15
Large Private West Coast University	186	262	4100	6.5
Total	836	1562	9650	16

*Numbers were rounded to protect identities of institutions and may not exactly match

The survey remained active at each participating institution for a period of three weeks, with two reminder emails sent during that timeframe. Although data was gathered from all levels of graduate students (MS and Ph.D) we chose to limit the scope of this study to doctoral students only. Of the 1562 students who attempted the survey, only 836 met the criteria for on campus students actively participating in a research group. Of these 836 participants who met the selection criteria, we consider the 695 Ph.D students whose information is reflected in Table 5.

5.3.4 Data Analysis

In order to characterize the influence of international diversity on retention in graduate engineering programs we considered two levels of data analysis. In the first level we examined each of the constructs for the population as a whole, using a linear regression model to examine how each construct relates to students intent to complete their degree program (Keith, 2006). Constructs were kept in the model which were significant at the $p < 0.05$ level. In the second round of analysis we used an ANOVA model to compare the means for these constructs across the nationality categories to explore variations within and among respondents from different nationalities (Pedhazur & Schmelkin, 1991). Following the ANOVA comparisons, a Tukey's post hoc test was accomplished to determine specific pair wise differences among nationality groups for the significant constructs (Montgomery, 2009). All significance testing was done at the $p < 0.05$ level. Summary information for each of the significant variables is presented in the results section.

5.3.5 Limitations

In determining the generalizability of this study, the reader should consider the following limitations. First, an advantage of using multiple universities from across the United States is that the results can be generalized to a similar population. The results of this study can only be generalized to doctoral students from research intensive universities (Carnegie Classification RU/VH), and readers should consider the demographics of other institutions in light of the reported sample to gage the representativeness of the data before drawing conclusions. Despite a large sample size, a number of cases were lost due to missing values in the variables of interest. This was especially pronounced in gathering demographic information, as many respondents failed to complete these sections. Between 15 and 20 respondents failed to complete the demographic information in its entirety, which slightly reduced the final sample size.

5.4 Results

5.4.1 Intention to Complete

A linear regression analysis of the constructs listed in Table 5.1 was used to highlight specific constructs that might explain students' responses to their intention to complete their degree. Constructs with a p value less than 0.05 were considered significant for the regression model. These results, along with the mean, standard deviation, and regression coefficient value for each construct are presented in Table 5.6.

Table 5.6

Linear Regression Results for Constructs used to Examine Intention to Complete the Degree

Construct	Mean	Standard Deviation	Significance	Coefficients
Project Ownership	4.21	0.87	< 0.0001	0.136
Individual Preferences	4.06	0.50	< 0.0001	0.208
Perception of Value	3.84	0.69	0.020	0.100
Expectations	3.84	0.59	< 0.0001	0.206
Organization	3.68	0.62	0.005	-0.125
Climate	3.61	0.60	0.005	0.100

These six constructs were all significantly related students' intention to complete their degree (mean = 4.7) for the entire sample. Organization was the only construct which negatively impacted a student's intention to complete their degree. This indicates that students reported a need for better organization in their research groups, which included items such as funding, the presence of more experienced students to talk to, and access to resources such as advisor time. Individual preferences and Expectations had the largest impact on intention to complete the degree; positive responses in these two constructs were the largest contributors to a student's choice regarding degree completion. Students responding positively to Project Ownership had the highest mean for intention to complete the degree, meaning that students who felt responsible for the success of their project were highly likely to see their program through to completion.

Using this model we found an R^2 value of 0.279, indicating these constructs were able to explain 28% of the variance in student responses regarding their intention to finish their program.

5.4.2 International Diversity

Overall, students who completed the survey were very confident they would complete their programs (mean = 4.7). We then considered the responses for each nationality or region represented in the sample. Table 5.7 shows the overall mean and standard deviation for intention to complete the degree for each region or nationality grouping, starting with the highest overall mean.

Table 5.7

Mean and Standard Deviation for Intention to Complete the Degree by Nationality

Nationality	Mean	Standard Deviation	N
Other	4.878	0.331	49
Middle East	4.788	0.457	52
India	4.774	0.523	84
U.S.	4.733	0.558	348
Asia*	4.706	0.502	51
China	4.505	0.783	101
Total	4.703	0.616	685

*Asia excludes China and India, but includes all other countries in the region such as South Korea, Taiwan , Thailand and Indonesia

The majority of region means were near the population average of 4.7. The notable exceptions are students from the Other region, with a intent to complete average of 4.88 and those from China, with an average of 4.5.

In addition to significant differences in student's intention to complete the degree, we were also interested in potentially significant differences in the constructs used to consider degree completion as a function of the international diversity of the sample. Using an analysis of

variance comparison for each of the six nationalities in our study, we were able identify several constructs with significant differences at the $p < 0.05$ level. These results are given in Table 5.8.

Table 5.8

ANOVA Results for Independent Variables by Nationality¹

Nationality		Project					
		Climate	Individual	Organization	Value	Ownership	Expectations
Significance		< 0.0001	< 0.0001	0.053	< 0.0001	< 0.0001	< 0.0001
U.S. (351)	Mean	3.75 ^{abcg}	4.00 ^{cf}	3.65	3.79 ^{ad}	4.25 ^a	3.77 ^{ab}
	Std. Dev	0.56	0.47	0.63	0.69	0.83	0.60
Asia* (51)	Mean	3.37 ^{ad}	3.97 ^{ad}	3.64	3.76	4.04	3.84
	Std. Dev	0.63	0.50	0.44	0.66	0.92	0.56
China (102)	Mean	3.41 ^{cef}	3.99 ^{be}	3.74	3.79 ^b	3.90 ^{ab}	3.92
	Std. Dev	0.61	0.59	0.64	0.67	1.07	0.61
India (84)	Mean	3.70 ^{def}	4.30 ^{abc}	3.85	4.06 ^{de}	4.42 ^b	4.00 ^{ac}
	Std. Dev	0.57	0.46	0.60	0.61	0.79	0.57
Middle East (52)	Mean	3.50 ^g	4.29 ^{def}	3.77	4.12 ^{abc}	4.29	4.06 ^{bd}
	Std. Dev	0.63	0.41	0.56	0.59	0.85	0.53
Other (50)	Mean	3.38 ^b	4.09	3.56	3.71 ^{ce}	4.32	3.70 ^{cd}
	Std. Dev	0.61	0.50	0.70	0.76	0.74	0.53
Total	Mean	3.60	4.05	3.67	3.83	4.20	3.83
	Std. Dev	0.60	0.50	0.62	0.69	0.87	0.59

*Asia excludes China and India, but includes all other countries in the region such as South Korea, Taiwan , Thailand and Indonesia

1. The letters a through f are used to indicate significant differences in individual pair wise comparisons between the nationality groups

Five of the six constructs showed highly statistically significant differences based on the nationality or regional origin of the respondent. Individual pair wise comparisons were performed using a Tukey's post hoc test (Montgomery, 2009) and are highlighted for each construct using the superscripts letters a through f. For example, in the Project Ownership construct, China was significantly different than both the U.S. (a) and the Middle East (b). For

Expectations, the U.S. (a,b) and Other (c,d) were significantly different from India (a, c) and the Middle East (b, d). All significant results are at the $p < 0.05$ level. Students from the U.S. responded most positively to the climate of their research group (mean = 3.75), with students from the Other and Asia regions responding with the lowest agreement at 3.38 and 3.37 respectively. Individual preferences were strongest in students from the Middle East and India, and the least pronounced for students from Asia. This may indicate stronger cultural differences in students from the Middle East and India. The construct of organization had smaller variation between nationality groups, with the exception of students from the Other region with a mean of 3.56. This is below the population average of 3.67, which might be the result of these students requiring more organizational structure in their research groups. Students from the Middle East (mean = 4.12) perceived their value to the group to be the strongest, followed by students from India (mean = 4.06). All other nationality groups were below the population for perception of value at 3.83. This might indicate that students from the Middle East and India feel they make larger contributions than other students in their research group. All regions showed high levels of project ownership; students from India indicating the highest agreement with project ownership (mean = 4.42) and Chinese students the lowest (mean = 3.9). These results are highly correlates with reported values for intend to complete the degree program. Clarity of expectations was the highest in students from the Middle East and India and lowest for students from the U.S and Other.

5.5 Discussion

Through careful consideration of several important characteristics of the graduate student's experiences in their research group we were able to create six constructs relevant to student's intention to complete their degree program. These constructs included: expectations, individual preferences, climate and organization, perception of value, and project ownership. Combining these constructs in a linear regression, we were able to account for over half of the variance in student's intention to complete their degree. Students from the Other region reported the highest level of overall intention to complete their degree, and students from China the lowest average. Comparing the means for individual constructs across nationality groups showed significant differences across every construct.

A student's level of project ownership, their individual preferences for group participation, and the degree to which their expectations were met were found to be the largest predictors of a student's intent to complete their degree program. The climate of the research group and how students perceived their work was valued by the advisor and research group were also positive predictors, however not as critical as the previous three. Climate includes the "feel" of the research group, such as whether students feel comfortable speaking up or approaching other students with questions. The organization of the research group was the only negative predictor of intention to complete. Organization items include whether students feel the research group meets often enough for them to be successful, and whether they have enough access to their advisor. Students perceived varying levels of satisfaction with the frequency of group meetings and advisor meetings depending on their country of origin. This may indicate a stronger reliance on faculty advisor versus peer interactions in different cultural groups. Organization also includes the presence of peer interactions among students, which includes formal and informal group activities such as the availability of older students to mentor the newcomers. Students often responded negatively to questions about the organization of the group, specifically regarding frequency of group meetings and accountability to the group, which consequently lowered their overall intention to complete their degree.

The second layer of interest was the influence of international diversity in students' experiences in their graduate programs. When the mean for each of the nationality groups was compared for each construct, we saw significant differences in all six constructs. Perhaps not surprisingly, students from the U.S responded the most positively to the climate in their research groups. U.S students made up nearly 50% of the survey sample, which is consistent with the average levels of international diversity in engineering departments (Council of Graduate Schools, 2007). These students are likely the majority nationality in many of the larger research groups and therefore dominate the climate. Students from Asia and the Other region showed the least agreement in a positive climate indicating students from countries in these regions may have felt like they did not fit in, weren't comfortable speaking up in group meetings, or they were in the minority in the research group. The level of competitiveness in the research group was another strong predictor of the climate in the group. Students perceiving higher levels of competitiveness of resources

such as faculty time, funding, or equipment, would be less likely to complete their degree. Other researchers have discussed climate as well, including Litzler *et al.* (2005) who investigated the climate for graduate students in science and engineering departments and found that the degree of competition is highly and negatively correlated to degree progress.

Students from each of the nationality groups also reported varying levels of agreement about how individual preferences shaped their graduate school experience. The population average for individual preferences was 4.05, indicating that students largely agree with the statements pertaining to them as an individual. Items in the individual preferences construct centered on beliefs and values that students have as individuals, which may be rooted in their cultural understanding. These may be beliefs about the importance of working in a research team, of their comfort with speaking up in front of others. Other items included valuing international diversity, or the importance of being able to work in a diverse research team.

The organization of the research group was also significant for respondents from each of the six regions. Organization dealt with items such as the frequency of meetings with the research group and the faculty advisor, and whether there are experienced students available to help the new students. Students from the U.S and Asia were just below the population mean (3.67) and students from India, China and the Middle East were above the average. Responses from students in the Middle East, India and China may have been above the population average due to the way their undergraduate programs prepared them for graduate school. Culturally, the education system of these countries is highly competitive, so when students come to the U.S for graduate school they may perceive more support than they had previously encountered in their undergraduate programs.

Student expectations were also considered explicitly as a construct. Specifically we were interested in whether students felt their expectations prior to starting their programs were met. One example would be if they felt their undergraduate education prepared them for graduate school. We also considered expectations during graduate study, such as could they expect secure funding for the duration of their program, and were their advisors clear about his or her expectations for satisfactory participation in the research group. Finally we considered

expectations after leaving graduate study, such as preparation for their future career and if they would make the same decision about attending graduate school if they could do it over again. Students from the Middle East indicated the most positive agreement that their expectations about graduate school were met, followed by students from India, while students in the Other category were the lowest. American students were below the average as well. These results indicate the importance of clear and consistently expressed expectations for all students and at multiple points in their graduate programs.

Finally there were differences in how students perceived their work was valued by the faculty advisor and other members of the research group, as well as whether students felt they had “ownership” of their project. Students from the Middle East and India indicated the highest agreement with their work being valued by their research advisor and members of their research group as well as two of the highest levels of reported project ownership. If students feel they are working on something that both their advisor and peers value as a contribution to the research community at large, this will help solidify their position in the group and encourage them to complete their degree. Students from China experienced the lowest levels of project ownership and lower levels of perceived value to the group than the average (although still positive). Although largely positive, Chinese students also reported the lowest overall value for their intention to complete their degree compared with all other nationality groups.

5.6 Implications for Graduate Programs

The constructs used to examine intent to complete the degree program suggest that faculty advisors should ensure that they have clear expectations for satisfactory participation in the research group, and make these available to students often during their graduate degree. These expectations may be things like hours spent in the lab, number of publications, training other students and conference attendance. Also, ensuring that advisors are aware of students’ career goals, may help keep students motivated during their degree programs by ensuring their expectation of career preparation is met. The extent to which students feel their expectations are met about graduate school was also important indicating students may not know exactly what to expect when beginning their graduate programs. Meeting with the students often, or having

more senior students mentor new group members may help mitigate misconceptions about what is expected in the research group.

Understanding the individual preferences of individual graduate students provide information faculty members can use to develop an understanding of how each of their individual students interacts with the group as a whole. This will enable research advisors to better understand potential cultural differences in students from a wide variety of backgrounds.

As indicated by the largely positive agreement about valuing international diversity and understanding the importance of working in international teams, faculty members can take advantage of the diversity of their groups by encouraging students to share aspects of their culture with the other group members. It is important however to ensure that “cliques” of students do not form in highly diverse groups because this may negatively impact the climate. These may hinder participation from newer students if they perceive barriers to entrance into the community as a result of the group climate.

5.7 Conclusions

This study considered several constructs used to examine student reported retention in graduate engineering programs. These constructs represented a mix of individual student characteristics, features of the research group, and the community formed by the interaction of the two. Specifically we found that students need to feel ownership of their project, and that their work is valued by their faculty advisor, research group peers, and the larger research community as a whole. Students bring their own individual characteristics and preferences into the research group, which in turn affects the climate and organization of the group. Finally student retention is influenced by their expectations prior to joining the research group, their experiences in the research group, and how they are prepared for their future careers.

Within the context of student retention we also considered the influence of a highly diverse population of students in graduate engineering research groups. We found there were statistically significant differences based on a student’s nationality in all six constructs used to

measure intention to complete the degree. While this cultural diversity was positively valued by students, it has implications for how faculty advisors manage their research groups. An awareness of how students from a variety of national and regional backgrounds value clear expectations, research group climate, and group organization, can help faculty members encourage a productive and successful research group inclusive to all students.

Future work for this project will be making some modifications to the survey instrument and administering the instrument to another few universities to increase the sample size within nationality categories. This data will be used to create individual regression models for national or regional groupings that can account for cultural variations within each group. A better understanding of how specific cultural differences impact a student's intention to complete their degree will enable faculty members to provide more specific guidance to their research groups with large international populations. Additional research questions will include analysis of the study data using multilevel techniques, considering nationality first and followed by other demographic variables such as gender, year in program, age and ethnicity for U.S. students.

Chapter 6

Summary and Conclusions

6.1 Conclusions

This project addressed several important issues in graduate engineering education. The first was the importance of the research group for training graduate students. Specifically the influence of group size was explored, which resulted in the following three themes: power distance and communication, access to resources, and the role of the supervisor. A summary of the findings for small, medium and large groups is shown in Table 4.5, and reproduced here.

Table 3.5
Summary Characteristics of Graduate Research Groups

	Small (less than 5 students)	Medium (5-20 students)	Large (More than 20 students)
Power-Distance and Communication	Low Advisor Dominated	Moderate Mixed	High Student/Group Dominated
	Peer-Low	Peer-Moderate	Peer-High
Resources	Faculty-High Funding-Moderate	Faculty-Moderate Funding-High	Faculty-Low Funding -High
Supervisor Role	Enculturation, Critical Thinking	Enculturation, Gatekeeper	Functional

An understanding of the differences among groups of varying sizes can be used by university administrators, faculty and graduate students to create an environment that fosters successful learning and professional development for graduate engineering programs, and may ultimately reduce attrition from engineering graduate programs.

After developing an understanding of the influence of the research group on the graduate student experience, a survey instrument was created to explore the influence of international diversity on

how engineering doctoral students responded to their intention to complete their degree. This survey was created using a mixed methods approach that integrated the qualitative findings into questions and themes that were found in the instrument, with a special eye to ensuring international diversity was a variable of interest, not just a control measure. A thorough methodological presentation of the development of the instrument was discussed, and validity and reliability tests confirm the usability of the instrument.

This instrument was administered to four universities across the United States, resulting in more than 830 usable responses for graduate students participating in research groups. Survey data were analyzed using a linear regression model to examine significant factors which corresponded to student's intention to complete their degree. Six factors were significant including those shown in Table 5.1, which is reproduced below. These factors included Project Ownership, Expectations, Climate and Organization, Perception of Value and Individual Preferences. Results from the linear regression were able to explain 28 percent of the variance in student responses regarding their intention to complete their degree. Comparing these constructs among the six nationality groups represented in this survey showed significant differences in all six constructs. These constructs were further analyzed as a function of nationality, and differences were highlighted with the aim of providing recommendations for faculty advisors working with similarly diverse groups of students.

Table 5.1

Constructs used to measure intention to complete the graduate degree

Construct	Description
Project Ownership	The extent to which students felt they “owned”, or felt responsible for the success of the project they were working on
Expectations	Did students feel they were prepared for graduate school, were their expectations were met, and was their advisor clear in his or her expectations for participation in the research group?
Climate	The “feel” of the research group. This could include the presence of cliques of students, the level of competitiveness, and whether students feel like they fit in or not.
Organization	Items like the presence of more experienced students, availability of resources, research group meetings, advisor meetings, and clear expectations for participation in the group.
Individual Preferences	Students’ personal beliefs about the importance of various activities. These include: valuing international diversity, working in a team environment, speaking up in group meetings, and taking initiative to accomplish a task.
Feeling Valued	Students’ sense of their value to the group, project value, and value of their work to other group members and faculty advisor.

In summary, this study aimed to examine student retention in engineering programs by shedding light on two characteristics that distinguish engineering from other disciplines: the organization of students into groups and the presence of a highly internationally diverse population. Through the ethnographic exploration of three graduate engineering research groups we were able to develop a valid and reliable survey instrument that was understandable by students from a wide range of universities, national backgrounds, and engineering disciplines. This survey was able to account for 53% of the variance in student’s indication of their intention to complete their graduate degree, and highlighted differences in responses from six national and regional groups across the world.

This study also serves as an example of the successful use of mixed methods techniques to study a complicated program in graduate education. The detailed and qualitatively rich ethnographic findings from three groups at one institution enabled the creation of a valid and reliable instrument, the depth of which would not have been possible through a review of the literature alone. Creating this instrument made expanding the study to a national sample possible, and provided an avenue to examine the transferability of the qualitative results on a larger scale. This national sample also provided the volume of quantitative data necessary to study relationships not previously considered in other research studies. Finally, qualitative data collected via the quantitative instrument can be compared to the original ethnographic data as well as used to further refine the instrument; showcasing data integration on multiple levels and maximizing the potential of a mixed methods approach.

6.2 Future Work

Future work for this specific data set will include using multilevel analysis techniques to explore variations within the nationality groupings for several other demographic variables such as year in program and gender. This analysis will provide additional information to fully characterize the international diversity of the graduate engineering population at research intensive universities. Second, the qualitative data collected as part of the survey administration will be analyzed both to triangulate back to the quantitative findings and to further revise the instrument, closing the loop on this mixed methods design. This will follow the recommendations of mixed methods researchers for integrating qualitative data back into the quantitative instrument, and should increase the reliability in subsequent uses. The findings and results from this study also suggest several avenues for continued research outside of this data set, including: detailed regression analysis for other demographic variables, data collection from universities in other Carnegie classification categories, and how international diversity influences the undergraduate decision to enroll in graduate school.

The combination of regression and ANOVA analysis performed as part of this study highlighted the differences in responses from students from a variety of nationality backgrounds. Future research should explore how the regression model differs for students from these various

national backgrounds. This may highlight how cultural differences influence the students' perceptions of the graduate school experience as well as enable the graduate education faculty to better understand areas where actionable changes can be made immediately in their research groups. Similar analysis should also be conducted for a variety of other demographic variables, notably gender, year in program, engineering discipline, and ethnicity for U.S. students. Other potential variables of interest might include time to establish research project, group size and type of degree program (MS versus Ph.D).

In addition to the demographic comparisons mentioned above, future work should also include administering the survey to other graduate engineering student populations. Specifically the focus should be on understanding the experiences of students at non research intensive universities based on the Carnegie Classification system. The high reported level of intention to complete in this study may be a result of the institutions surveyed, and adding students from other programs such as doctoral granting institutions (DRU's), and other smaller research universities will aid in the generalizability of the results. Data collected from these universities may provide different responses for intention to complete the degree, and other nationality regions, which will yield more detailed insights into actionable changes for these universities.

Along with additional student populations, future work should explore a more accurate estimate of intention to complete the degree programs and compare these results with the survey results from this study to evaluate the degree of response bias. The extremely high levels of intention to complete the degree from the students in this sample are greater than the previously determined average in engineering programs. Surveying additional engineering populations from other universities and exploring a more concrete way to gather completion data would provide useful information for furthering retention research.

Results from this study may also be useful in retention research in the STEM disciplines, especially in areas where students are trained in research groups or teams. This is especially prevalent in the laboratory sciences, but in some social science and interdisciplinary settings, especially larger research centers, faculty members are increasingly using research teams for training students. Findings from the ethnographic phase of this study highlighted some

engineering specific groups dynamics as a function of size, and future research could explore the transferability of these themes to other STEM disciplines and doctoral training in the social sciences.

Finally the results from this study could be used to inform the development of additional studies to understand how the international diversity in graduate school may influence the undergraduate decision to enroll in graduate engineering programs. Experiences like interactions with graduate teaching assistants, international faculty in the classroom, and working with graduate researchers on undergraduate research should be explored to understand how these interactions may influence the decision process of undergraduate students. This could serve as a study on its own, or combine the international diversity construct with other student decision constructs to look at potential interactions and conflicts in the decision process.

This research project has also highlighted some interesting areas for future research in the field of graduate engineering education. While this study focused on the student experience in research groups, future work should consider the experiences of faculty advisors, and how their perceptions of management compare with the student experience. Additional research could track a research group longitudinally as it expands, to better understand how these groups evolve over time. This would help shape recommendations for faculty members as they transition from new faculty members to more experienced mentors.

Appendix A

Graduate Survey

The purpose of this research study is to explore the experiences of engineering students in graduate research groups. This questionnaire should take approximately 20 minutes to complete and the results of this will be used to improve the graduate experience for future students

[Informed Consent Question]

Filter Questions:

Are you currently pursuing your degree on campus (i.e. courses are not primarily online)?

- ☐ Yes
- ☐ No

A research group is a collection of students working under the guidance of a faculty advisor (or a team of faculty advisors) that share similar research interests, equipment or collaborate on research projects. Are you currently a member of a research group?

- ☐ Yes
- ☐ No

Instructions:

The survey below is organized into three sections. The first two sections contain questions related to your experiences as a graduate student at [University] with the final section containing questions about you as an individual.

Section 1:

Please indicate the level to which you agree or disagree with each statement using a scale of 1-5 with five being strongly agree and 1 being strongly disagree as shown in the table below. At the end of this survey there is a place for you to add any additional comments relating to your experiences in your research group.

1	2	3	4	5
Strongly Disagree	Tend to Disagree	Neither Agree or Disagree	Tend to Agree	Strongly Agree

1. My undergraduate education prepared me for graduate school
2. It is important to me to be able to work in a research team
3. The amount of work in graduate school was more than I expected
4. My research group is made up of students from several countries
5. My experiences in my research group have prepared me to work in international teams
6. Graduate school is easier than I thought it would be
7. I spend time with members of my research group outside of the work setting
8. I have ownership (feel responsible for the success) of the project I am working on
9. I intend to complete my graduate degree
10. I am satisfied with my experience in my graduate research group
11. I have secure funding for the duration of my graduate degree
12. I am in the minority in my research group
13. I feel accountable to other members of my research group

14. There are more experienced students in my research group to whom I can ask questions
15. I prefer to meet one on one with my faculty advisor than in a large group meeting
16. I get to meet with my faculty advisor often enough to be successful
17. If I had it to do over again, I would decide to attend graduate school
18. Members of my research group compete against each other for resources
19. My research group has cliques (subgroups) of students that primarily interact with each other.
20. The ability to work in internationally diverse teams after graduation is important
21. My experiences in my research group have helped me grow into a more well rounded person
22. I feel like I am a valuable member of my research group
23. My advisor has clearly stated his or her expectations for satisfactory participation in the research group
24. I consider members of my research group to be my friends
25. I feel like I don't fit into my research group
26. My work is valued by my faculty advisor
27. I value international diversity in my research group

- 28. My research group meets often enough for me to be successful
- 29. Working with my research group has made me to consider employment outside of my home country
- 30. My experiences with my research group have increased my critical thinking skills
- 31. My research is valued by members of my research group
- 32. I am comfortable speaking up during research group meetings
- 33. I wish I had established my research project earlier than I did
- 34. I wish I had more interaction with other students outside of my research group
- 35. My experiences in my research group have prepared me for the career I want
- 36. My research group environment is overly competitive
- 37. My experiences in my research group have taught me how to manage a project
- 38. I wish I had more interaction with other students outside of my research group
- 39. My experiences in my research group have helped me learn to teach myself new things
- 40. My work is valued by members of my research group
- 41. I am comfortable taking the initiative to accomplish a task
- 42. My experiences in my research group have increased my self confidence

Section 2: Research Group Description

1. My research group has approximately _____ students
 - ☐ Less than 5
 - ☐ 6-10
 - ☐ 11-20
 - ☐ More than 20

2. My research group includes students or faculty from multiple departments or colleges
 - ☐ Yes
 - ☐ No

3. I was given a research project _____ after joining the research group
 - ☐ Immediately
 - ☐ Within 6 months
 - ☐ Within a year
 - ☐ I don't have a project yet

4. I have individual meetings with my advisor _____
 - ☐ Weekly
 - ☐ Three times a month
 - ☐ Twice a month
 - ☐ Once a month
 - ☐ Never
 - ☐ Other _____

5. How often do you have research group meetings (the majority of the group is present)?
 - ☐ Weekly
 - ☐ Three times a month
 - ☐ Twice a month
 - ☐ Once a month

- ☐ Never
- ☐ Other_____

6. How is the workspace for students in your research group organized? [Check all that apply]

- ☐ We have a common lab/work room
- ☐ We each have individual offices
- ☐ We each have our own desk in a group office
- ☐ We are not allocated office/desk space
- ☐ Space is allocated by the department or program, not the research group
- ☐ Other:

7. My level of participation in my research group is:

- ☐ Less than average
- ☐ Average
- ☐ More than average

Section 3: Demographic Information

1. Age

- ☐ under 25
- ☐ 26-30
- ☐ 31-35
- ☐ 36 and older

2. Gender

- ☐ Male
- ☐ Female
- ☐ Prefer not to answer

3. Nationality

- ☐ United States
- ☐ India
- ☐ China
- ☐ United Kingdom
- ☐ Germany
- ☐ Mexico
- ☐ Canada
- ☐ Other _____ (please fill in)

4. My degree will be in _____

- ☐ Aerospace Engineering
- ☐ Biomedical Engineering
- ☐ Chemical and Biochemical Engineering
- ☐ Civil Engineering
- ☐ Computer Engineering
- ☐ Computer Science
- ☐ Electrical Engineering
- ☐ Engineering Science and Mechanics
- ☐ Industrial Engineering
- ☐ Mechanical Engineering
- ☐ Systems Engineering
- ☐ Other _____

5. My research is primarily conducted:

- ☐ Using equipment in a lab
- ☐ Using a computer in an office
- ☐ Other:

6. My research group is primarily associated with:

- ☐ An engineering department
- ☐ A larger research center

7. What degree do you expect to leave with?

- ☐ Masters degree
- ☐ MS then Ph.D
- ☐ Ph.D Degree

8. Year in graduate program

- ☐ First year
- ☐ Second year
- ☐ Third year
- ☐ Fourth year
- ☐ Fifth or more

9. I participated in undergraduate research

- ☐ Yes
- ☐ No

10. I completed my undergraduate degree_____

- ☐ At my current institution
- ☐ At a different institution in the U.S.
- ☐ At an institution in another country

Appendix B

Question Mapping

Overarching Research Question:

1. How does the research group impact retention of engineering graduate students?
2. Are there differences in retention factors for international and domestic students?

Sample

On-campus MS and Ph.D Students completing thesis or dissertation work as part of a research group

Research Question: How do students view international diversity in engineering graduate programs?

Hypothesis: *Highly valued international diversity in the lab/group setting contribute to individual satisfaction and retention of both international and domestic students*

Dependent Variable(s): satisfaction (#31), intent to complete (#6)

Independent Variables:

8. There is a dominant cultural majority in my research group
 18. The ability to work in internationally diverse teams is important
 20. My experiences in my research group have prepared me to work in international teams
 24. I value the international diversity of my research group
 26. Working with my research group has caused me to consider work in international settings
 27. I plan to stay in the United States after graduation
-

Research Question: How does the time for students to establish their project contribute to their perception of value within the research group?

Hypothesis: *The time it takes for students to get a project and establish ownership is correlated to their sense of belonging to the group and satisfaction with their program (short time is positively correlated to satisfaction)*

Dependent Variable(s): satisfaction (31), intent to complete (6)

Independent Variables:

- 5. I have ownership of the project I am working on
- 19. I feel like I am a valuable member of my research group
- 28. My work is valued by members of my research group
- 29. My work is valued by my faculty advisor(s)
- 32. I wish had gotten a research project earlier

Also question 3 from section 2

- 3. I found a research project __[amount of time choices]__ after joining the research group
-

Research Question: Is there a mismatch between student expectations regarding graduate school and the actual experience, and how does this influence retention?

Hypothesis: *The degree to which students' had realistic expectations regarding graduate school is correlated to retention*

Dependent Variable(s): satisfaction (31), intent to complete (6)

Independent Variables:

- 1. My undergraduate education prepared me for graduate school
- 3. The amount of work in graduate school was more than I expected
- 5. Graduate school is easier than I thought it would be
- 14. If I had to do graduate school over again I would make the same decisions
- 21. My advisor is clear about his or her expectations for participation in the research group

Research Question: How does the climate and organization of a graduate research group contribute to retention?

Hypothesis: *High level of collaborative environment within the lab/group contributes to high student level of comfort and satisfaction. Students in the minority (if dominant cultural majority) will be less comfortable.*

Dependent Variable(s): satisfaction (31), intent to complete (6)

Independent Variables:

8. There is a dominant cultural majority in my research group
10. There are older students in the research group to whom I can ask questions
13. I get to meet with my faculty advisor often enough
15. Members of my research group compete against each other for resources
27. My research group environment is overly competitive
21. My advisor is clear about his or her expectations for participation in the research group
22. I consider members of my research group to be my friends
23. I feel like I am different from other members of my research group
25. My research group meets often enough
30. I am comfortable speaking up during research group meetings

Also questions from section 2

1. My research group has approximately_____ students (with choices)
 5. How often do you have research group meetings, (the majority of the group is present)?
 6. How is the workspace for students in your research group organized? (with choices)
-

Research Question: How do individual student preferences influence participation in research group activities?

Hypothesis: *Individual student comfort level influences their level of participation in research group activities. Differences between international students (from some regions) prefer to work more independently than domestic students*

Dependent Variable(s): satisfaction (31), intent to complete (6)

Independent Variables:

- 4. I spend time with my research group outside of the work setting
 - 9. It is important to me to be able to work in a research team
 - 11. I feel comfortable approaching students in my research group with questions
 - 12. I prefer to meet one on one with my faculty advisor than in a large group meeting
 - 17. I am comfortable working in a group environment
 - 22. I consider members of my research group to be my friends
 - 23. I feel like I am different from other members of my research group
 - 30. I am comfortable speaking up during research group meetings
 - 33. I wish I had more interaction with other students
-

Research Question: How do students perceive their value to the research group and how does this relate to their intent to complete their degree?

Hypothesis: *Students who feel valued on a project or in a research group are more likely to be retained in their programs.*

Dependent Variable(s): satisfaction (31), intent to complete (6)

Independent Variables:

- 7. I feel accountable to other members of my research group
- 19. I feel like I am a valuable member of my research group
- 28. My work is valued by members of my research group
- 24. My work is valued by my faculty advisor(s)

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