ABSTRACT

SCHNEIDER, JENNIFER. A Multivariate Study of Graduate Student Satisfaction and Other Outcomes within Cooperative Research Centers. (Under the direction of Denis O. Gray.)

Graduate students who participate in Cooperative Research Centers are perceived as having educational advantages such as interactions with industry members, career opportunities, increased scholarly production, and development of soft skills (teamwork, communication, leadership). However, these educational advantages are mostly speculative assumptions. Evaluation of Cooperative Research Centers occurs regularly on several components of the program; yet, there is a lack of information and analysis concerning graduate students involved with the centers. Consequently, center programs are missing opportunities to enhance their educational outcomes.

A cross-sectional predictive analysis was conducted to identify which individual center mechanisms positively or negatively influence graduate student outcomes. Data was collected from graduate students (n=190, 37% useable response rate) working in National Science Foundation's Industry-University Cooperative Research Centers and Science and Technology Centers programs (34 centers, 87% response rate) via a web-based questionnaire. Student outcomes include satisfaction, perceived skills, organizational commitment, scholarly achievements, career goals, and feelings of a competitive advantage. Results indicate that consistent and powerful predictive variables include: Multidisciplinary Center Experience, Experiential Expanded Center Experiences, Technical Project Involvement, and frequency of interactions with thesis committee members and Center industry members. Another major finding of the study was that students' center experiences predict outcomes but individual centers do not.

A MULTIVARIATE STUDY OF GRADUATE STUDENT SATISFACTION AND OTHER OUTCOMES WITHIN COOPERATIVE RESEARCH CENTERS

by
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A thesis submitted to the Graduate Faculty
of North Carolina State University in partial
fulfillment of the requirements for the
Degree of Master of Science

PSYCHOLOGY

Raleigh, North Carolina

2007

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DEDICATION

This work is dedicated to my mother and father.

Their encouragement, love, and support enabled me to become who I am today and continues to push me to be a better person.

BIOGRAPHY

Jennifer Schneider was born on June 5, 1979 in Rochester, Michigan. After graduating from Troy High School in 1997, she attended Miami University in Oxford, Ohio, graduating in May of 2001 with a bachelor's degree in psychology. From 2001 to 2003 she worked as a project manager in a marketing research firm in Cincinnati, Ohio. In August of 2003, she moved to Raleigh, North Carolina to begin graduate studies in psychology at North Carolina State University. For the first three years of her graduate studies, Jennifer worked as a project manager for the National Science Foundation Industry University Cooperative Research Center's Program Evaluation Project under the direction of Dr. Denis O. Gray. Currently, Jennifer is working as a project manager for the National Science Foundation Stereotypes Laboratory under the direction of Dr. Mary Wyer.

ACKNOWLEDGEMENTS

I would like to thank the following people for their help and support that have allowed me to complete this degree:

My advisor, Denis Gray, gave me guidance and assistance throughout the entire four-year process. My committee members, Robert Serow and Lori Foster Thompson, provided valuable advice and feedback. Additionally, I'd like to thank Cathy Zimmer for her patience and assistance with the data analysis.

My mentors, peers, and officemates, Beth, Drew, Laura, Cassandra, Andrea, Lindsey, Amy, and Diane, helped immensely with their mentoring, advice, and support. Also, my friends, Jennifer, Mara, Anita, Annie, and Andrea, provided great outlets and were always there to listen.

Additionally, I owe a big thank you to my cat, Cirrus, who spent countless hours sitting on my lap while I worked to ensure that I would not give up.

Finally, and most importantly, I would like to thank my mom, dad, and brother. I could not imagine a more loving and supportive family.

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INTRODUCTION

> Graduate education contributes directly to the broader national goals of technological, economic, and cultural development. We increasingly depend on people with advanced scientific and technological knowledge in our collective efforts in developing new technologies and industries, reducing environmental pollution, combating disease and hunger, developing new sources of energy, and maintaining the competitiveness of industry (COSEPUP, 1995, p.1).

Science and engineering (S&E) employment has demonstrated substantial growth over the past twenty years and is predicted to continue to grow three times faster than other occupations in the next decade, forecasting a possible 47% increase in S&E employment (National Science Board, 2004). The number of S&E occupations outside of academia increased by 159% between 1980 and 2000. This is a 4.9% annual growth rate compared to a 1.1% average annual growth rate for the traditional labor force (National Science Board, 2004). These labor force statistics predict a promising future for science and engineering students entering careers outside of academia.

Science and engineering graduate students play a vital role in the nation's S&E research. The number of graduate students enrolled in S&E programs was at a near record high in 2001 following a decline in the mid 1990s. This growth can be mainly attributed to computer science and engineering enrollments, which are also the areas that primarily reflect the enrollment increases of foreign graduate students. Engineering and computer science fields explain 70% of the growth in the number of foreign graduate students in S&E.

"U.S. higher education has benefited from an influx of foreign S&E enrollees, who play a large role in graduate education and as research and teaching assistants on U.S. campuses" (National Science Board, 2004, p. 2-6). By 2001, foreign citizens represented almost half of all graduate students in engineering (47%) and over half (56%) of the engineering doctorate students. Furthermore, foreign-born scientists and engineers account for over a quarter of the S&E doctorate holders in the U.S. (National Science Board, 2004). This provides the United States with opportunities to employ the best and brightest of the world since the majority of non-U.S. citizens enrolled in U.S. universities and colleges plan to seek careers in the U.S. This dramatically demonstrates the significant role foreign graduate students have in U.S. engineering and the reliance academia and the labor force have on foreign engineering talent.

The U.S. has traditionally been a world leader in higher education; however, graduate educational opportunities have increased globally and countries such as India and China have improved their recruitment of foreign students through increasingly competitive facilities and programs (National Academy of Engineering, 2004). In the 1990s, there was a worldwide increase in the number of students leaving their native countries to go abroad for higher education (National Science Board, 2004). The United States, however, has decreased the number of student visas and exchange visas granted since 2003 as part of a security crackdown resulting from the attacks on September 11, 2001. This trend, combined with security concerns and attractive opportunities elsewhere, has made the United States less attractive as an option for migrating engineering students (National Science Board, 2004). Since the U.S. relies on foreign enrollment for their engineering programs and also expects many of these students to stay in America to become engineering leaders for the nation, these changes may have a negative impact on the advancement of the nation's engineering prospects.

However, it is important to remember that the nation's ability to compete globally depends on the quality and not just the quantity of the S&E graduates. That is, the continued national global prominence in technology and science sectors depends on enhancing U.S. engineering education to prepare students to be leaders in established and emerging engineering fields. "Scientific, technological, and demographic changes are altering the face of higher education. As science changes to become more interdisciplinary and mathematical, higher education must adapt to demands for new skills" (National Science Board, 2004, p. 2-6). There are concerns, however, that educators are struggling to prepare well-rounded engineers for today's workforce. Demand for engineering education reform is growing and innovative techniques are needed to adequately prepare engineering leaders who will maintain national competitiveness in a time of global developments and advancements (National Academy of Engineering, 2004).

As the workforce adapts to meet the needs of the changing global engineering environment, education needs to transform as well to adequately prepare students to meet the demands of the workplace. There is a gap occurring between what skills engineering education programs are imparting to students and what competencies industry and society needs entry-level engineers to have (DeLange, 1996; Tong, 2003). With over half of new doctorate holders entering careers outside of academia, educational institutions must emphasize the needs of employers and society in addition to the key curriculum elements they view as essential (COSEPUP, 1995).

Industrial entities seek entry-level engineers educated in technical areas, but also those competent in soft or non-technical skills. “Employers complain that new PhDs are often too specialized for the range of tasks that they will confront and that they have a difficult time in adapting to the demands of nonacademic work” (COSEPUP, 1995, p. 3). Soft (or non-technical) skills can be defined as “…the skills that are required to complement job content skills to effectively perform acts in a workplace environment” (De Lange, 1996, p. 23). Studies examining which non-technical or soft skills employers desire entry-level engineers to have specified communication skills as a top priority (DeLange, 1996; Tong, 2003). In addition, other non-technical or soft skills such as creativity, problem solving, project planning, project management, cost control, teamwork, organization, information management, leadership, self-management, and project planning are perceived as important (DeLange, 1996; Tong, 2003).

Engineering employers voice concerns that universities do not place sufficient focus on practical results that teach students how to employ the knowledge they are obtaining. Employees express concerns that their entry-level technical skills and knowledge are not effectively utilized since they lack proficiency in communicating, working in teams, and managing projects (Tong, 2003). Employers also complain of a performance gap in the skills demonstrated by their entry-level engineering employees in comparison to the expected skill performance. The biggest performance gap is in interpersonal communication, but problem solving, project planning/scheduling, project management, and leadership are also viewed as being well below expectations (Tong, 2003). This demonstrates a serious learning discontinuity between expectations and performance.

There is a need for traditional curriculum to be revitalized in order to keep up with the pace of global engineering expectations. The National Academy of Engineering (2004) specifies the following key attributes needed for future engineers: analytical skills, practical ingenuity, creativity, communication, business and management, leadership, high ethical standards, professionalism, dynamism, agility, resilience, flexibility, and life long learning. It is the ultimate responsibility of the university to establish educational objectives that will prepare students to fulfill the demands of society (COSEPUP, 1995; Rompelman, 2000); thus, the university should develop educational objectives that incorporate university, industry, and societal needs (Rompelman, 2000). To ensure educational goals are comprehensive of all these stakeholders, industry should be actively involved in curriculum design in order to keep engineering education current and reflective of prospective developments in the engineering world and to ensure that entry-level engineers are well prepared for careers in technical fields (Rompelman, 2000). Engineering education has to encompass both the traditional focus on knowledge as well as a more contemporary focus on understanding and general skills. This shift calls for new educational approaches in order to adequately prepare students for the workforce.

One popular suggestion for implementing this shift is a focus on active and cooperative learning methods over the traditional lecture/discussion format (De Graff & Ravesteijn, 2001; Fellers, 1996; Meyers & Ernst, 1995; Rompelman, 2000). Active learning focuses the education on the student instead of the teacher. This allows students to take an active interest in their education, while the cooperative aspects support diverse perspectives, knowledge transfer, communication, teamwork skills, and diversity (De Graff & Ravesteijn, 2001; Fellers, 1996; Meyers & Ernst, 1995; Terenzini, Cabreara, Colbeck, Parente, & Bjorklund, 2001). Active learning includes a variety of educational approaches such as cooperative learning, experiential education, hands-on approaches, experiments, group work, lifelong learning, and students taking responsibility for their learning. The primary focus of these active learning methods is to position the student as an active participant in the learning process (Meyers & Ernst, 1995).

Active and collaborative educational methods are perceived as effective in reducing the performance discrepancy between expectations for entry-level engineers' skills and their actual abilities, by complementing their developing technical skills with soft skills (Terenzini et al., 2001). Collaborative educational methods develop engineering students' soft skills more effectively than traditional learning methods. Terenzini et al. (2001) found students involved in collaborative group work courses reported significantly higher gains in communication, design, and group skills than students not participating in a collaborative learning environment. Furthermore, student learning is enhanced when students take an active interest in their learning. Active and collaborative learning methods have a positive and substantial effect on student learning. These techniques may prove valuable by enhancing students' soft skills and consequently helping to close the performance gap between what skills entry-level engineers have and what skills engineering employers desire.

Cooperative Research Centers

Cooperative Research Centers (CRCs) provides an educational method centered on active and collaborative learning approaches focusing on hands-on experiences, teamwork, and real-world problem solving. CRCs are collaborative environments that unite industry and university in order to provide a more efficient means of research and technology transfer. The engineering graduate students involved in CRCs work on “real-world” research projects and are exposed to industry members, multiple disciplines, and diverse team associates. Teamwork, management skills, experiential learning, interdisciplinary experiences, communication opportunities, and leadership are all thought to be expected outcomes of the center education.

Industry and university collaboration has emerged as a significant contemporary phenomenon. Cohen, Florida, & Goe (1994) reported on 1,056 industry university Cooperative Research Centers across the nation in 1990, spending $2.53 billion solely on research and development. During the 1990 fiscal year, the Cooperative Research Centers were associated with 213 American universities and colleges and involved a mean of 17.6 industry members per center. In addition, Cohen et al. (1994) found these centers involved an estimated 12,000 university faculty, 22,300 doctoral level research scientists, and 16,800 graduate students (15.9 per center). On average, one CRC produced more than four PhD degrees and seven master’s degrees. In addition, approximately six students per center were permanently employed by center industry members during the 1990 fiscal year (Cohen et al., 1994).

Historical Background

Cooperative Research Centers (CRCs) are broadly defined as centers that partner industry, academia and, in some instances, government for research. CRCs are intended to improve the transfer of research, technology, and knowledge, while “bridging the gap” between industry and academia’s research. These types of collaborations are touted as “…‘win-win’ partnerships that have strengthened the ability of [the nation’s] universities to conduct high-quality and relevant research and the ability of industry to compete globally" (Gray & Walters, 1998, p. 3). CRCs typically operate independent of academic departments, involve multiple disciplines, and are organized by interests that can range from fundamental to applied research. Centers usually have an organizational structure, management team, facilities, laboratories, equipment, and area-specific technological devices (Gray, 2000). CRCs are expected to provide benefits such as improved technology transfer and economic development and are hypothesized to provide students with opportunities and education that goes above and beyond that of traditional engineering programs.

Although Cooperative Research Center programs all have similarities in the sense they partner industry and universities to enhance research and education, the centers and their programs are actually quite heterogeneous. The programs/centers vary by their research area, source of funding, life span, educational emphasis, industry involvement, size, and structure. This heterogeneity becomes problematic when comparing programs and attempting to draw universal conclusions. However, for the purpose of this research, the National Science Foundation's (NSF) programs will be of principal interest. NSF encourages university and industry cooperation through three primary programs.

Science and Technology Centers (STCs)**:** STCs were created in 1987 to promote research, improve education, and enhance technology transfer.

> The Science and Technology Centers' (STC) Integrative Partnerships program enables innovative research and education projects of national importance that require a Center mode of support to achieve the research, education, and knowledge-transfer goals shared by the partners. STCs conduct world-class research in partnerships among academic institutions, national laboratories,

> industrial organizations, and/or other public/private entities to create new and meaningful knowledge of significant benefit to society (NSF STCs, 2005, ¶ 1).

There are eleven STCs (NSF STCs, 2005) that involve roughly 1,000 graduate students, approximately 40% of whom are not U.S. citizens (Fitzsimmons et al., 1996). On average, a typical center involves four universities, seven private sector firms, two federal labs, and thirty faculty members. Although industry plays a role in STCs, their role is usually indirect (Gray, 2000). STCs' educational objective is to use integrative learning to adequately prepare students for a broad set of career paths (Fitzsimmons, Grad, & Lal, 1996; NSF STCs, 2005).

Engineering Research Centers (ERCs): ERCs were established in 1985 with 20 in existence in 2005 (NSF ERCs Fact Sheet, 2005). "ERC faculty, students and industry partners integrate discovery and learning in an interdisciplinary environment that reflects the complexities and realities of real-world technology" (NSF ERCs, 2005, ¶ 1). ERCs have more than 700 industrial partnerships and have graduated substantially more than 3,000 post baccalaureate students (Parker, 1997). Industry members play a moderate role in the functioning of this program (Gray, 2000). ERCs emphasize education as a primary objective, more so than the other two NSF center programs (Parker, 1997). "Because ERCs play critical roles in academe by integrating research, education, diversity, outreach, and industrial collaboration, NSF views ERCs as change agents for academic engineering programs and the engineering community at large" (NSF ERCs 2005, ¶ 1).

Industry/University Cooperative Research Centers (I/UCRCs): The I/UCRC program began in 1980 and today represents one of the largest examples of industry/academia cooperative research (Gray & Walters, 1998).

> NSF supports the Centers through a cooperative leveraging mechanism. NSF's financial contribution to the Centers is relatively small--about $5.2 million in FY 2000, as compared to funding from other sources that totaled more than $68 million in FY 2000. Currently, the Centers have over 700 partners. Of these, about 90 percent are industrial firms; the remaining 10 percent include state governments, National Laboratories, and other Federal agencies. In addition, the majority of the universities provide direct and/or indirect support, such as cost sharing, for their Centers. These Centers are truly cooperative (NSF I/UCRCs: Model Partnerships, 2005, ¶ 4).

I/UCRCs have primary objectives that include enhancing technology transfer and promoting national competitiveness with global industry (Scott, Schaad, & Brock, 1991). Industry holds an active and formal role in the program and their center membership fee is the primary source of funding (Gray, 2000). “The total industrial R&D investment attributable to the I/UCRCs in FY 2000 came to almost $100 million” (I/UCRCs: Model Partnerships, 2005, ¶ 14), affirming industry’s perception of I/UCRCs as effective and successful at technology transfer. In 2003-2004, there were 44 active centers, with 652 industrial members, approximately 867 graduate students, and 208 undergraduates. In just the 2003-2004 year in the I/UCRC program, 259 graduate students completed their degrees (Gray, Schneider, &, Lloyd, 2005). Although I/UCRCs do not have a specific educational objective (I/UCRCs: Model Partnerships, 2005; Scott, Schaad, & Brock, 1991), the I/UCRC program is said to be “…providing the next generation of scientists and engineers with a broad, industrially oriented perspective on engineering research and practice” (I/UCRCs: Model Partnerships, 2005, ¶ 1).

Evaluation Efforts

Industry, faculty, the university, and graduate students all have various stakes in CRCs and reap diverse benefits. Cooperative Research Centers are perceived as providing advantages to all components involved. Industrial organizations pay a center membership fee in exchange for high-tech information, access to new research, a relationship with the university, patents, technology transfer, innovative approaches, access to center equipment and facilities, interactions with other industrial members, and the opportunity to recruit center graduate students (Ailes, Roessner, & Feller, 1997; Gray & Walters, 1998). The university benefits from the increased revenue from industry members, patents, current activities of industry, knowledge on modern practical technology, and the leverage to recruit new students interested in the center's specialized science and engineering fields. Faculty members also receive benefits by continuing to produce pertinent publications, adding social and economic value, and actively transferring technology and knowledge.

In particular, the benefits graduate students receive by participating in CRCs are of interest. Graduate students are perceived as having educational advantages such as interactions with industry members, career and internship opportunities, increased scholarly production, and development of soft skills (teamwork, communication, leadership). In addition, the exposure to industry educates students on industry working conditions, career education, the requirements of entry-level engineers, and the benefits of working with industry (Stephan, 2001). This unique education is anticipated to better prepare students to become leaders in their field and to have a competitive advantage over other entry-level engineers.

These three programs all undergo fairly intensive interim, ex-ante, and outcome evaluations (Gray, 2000). These evaluations include assessing industry members, faculty members, center directors, and center structural information. However, despite the fact that graduate students execute most of the center research projects, very little research has focused on graduate students themselves. For all the admirable evaluation efforts of the center programs, it is surprising graduate student participation lacks standard assessment and evaluation, especially for those programs that cite education as a primary objective. In order to determine if objectives are being met and determine how the program can be enhanced, assessment and evaluation is essential and recommended for all areas and stages of the educational process (Rompelman, 2000). In a similar vein, a National Science Foundation conference on undergraduate engineering education recommended utilizing evaluations and assessments to recognize strengths and weaknesses of the whole educational system (Meyers & Ernst, 1995).

Over fifteen thousand graduate students are participating in Cooperative Research Centers (Cohen et al., 1994) and while they are considered the driving force behind the research being conducted, little is known about their participation, experiences, and benefits within the center structure. Although, the three NSF center programs list education as a primary or secondary objective, there is an absence of research evaluating whether these objectives are being satisfied. Thus, while research studies have proven most of the stakeholders benefit from CRC participation, little is known on the actual benefits and consequences of graduate students who participate in CRCs.

Graduate students are perceived as benefiting from their center experiences through industry interactions, a “hands-on” education, real-world problem solving, contributing to society, internship and career opportunities, increased scholarly production, and training in soft or non-technical skills (e.g.: communication, teamwork, leadership); however, these advantages are for the most part speculative. Although some preliminary research has been conducted concerning center graduates' job performance, there is little data examining graduate students during their actual center involvement. Consequently, Cooperative Research Centers are missing opportunities to enhance their educational outcomes by receiving real-time feedback on their current educational practices. Gaining an understanding of graduate student experiences and outcomes will assist in:

- Strengthening the education of current graduate students by identifying strengths and weaknesses of the center education
- Recruiting the best and the brightest students
- Reinforcing the contributions of the center to industry members
- Providing stronger leaders to the increasingly competitive engineering field
- Assessing whether centers are meeting their original educational objectives
- Creating a tool for analyzing which mechanisms should be emphasized or de-emphasized in order to enhance center graduate student education and training

The potential value of these benefits and the lack of current research on graduate students prompt a need to explore graduate student experiences, advantages, and perceived satisfaction within the Cooperative Research Center environment.

Purpose of Research

Science and engineering education is ultimately responsible for preparing students to be the nation's future leaders. The nation's global science and engineering competitiveness depends on how adequately these leaders are prepared. In particular, there is considerable concern among employers that education is focusing only on technical skills, while soft or non-technical skills, such as communication, cooperation, and leadership, are not being sufficiently addressed. Cooperative Research Centers are said to emphasize teamwork, multiple disciplines, communication, experiential education, and collaboration. Since CRC education is thought to include training in soft or non-technical skills in addition to technical skills, center-based training of science and engineering students seems to be an educational innovation that may prove to be an efficient tool for addressing employers' concerns that students are inadequately prepared with soft skills. However, the effectiveness of an education within a Cooperative Research Center has yet to be thoroughly examined. Thus, it is of interest to examine the impact a center-based education has on graduate students, while exploring graduate students' experiences, benefits, and satisfaction within the Cooperative Research Center environment. The next section will review the literature on various elements of engineering education before presenting literature that will examine educational components specifically within CRCs.

LITERATURE REVIEW

After introducing the concept of a center education, the broader literature on engineering education reform will be presented before proceeding with the few studies that have been conducted on education in NSF centers. The purpose of examining this broader literature is to identify and discuss a variety of engineering education mechanisms, processes, and outcomes that may or may not be addressed in a center education. A literature search was conducted in an attempt to find studies that were able to identify the various components forming a graduate student's "center education." A thorough search was performed in relevant journals, web libraries, websites, and the NCSU library databases using the following key words: experiential education, cooperative learning, co-op, internship, graduate student, undergraduate student, mentoring, leadership, multidisciplinary, interdisciplinary, cooperative center, industry university, center, engineering, engineering education, National Science Foundation, student, organizational commitment, satisfaction, and collaboration.

Although none of the studies examined students involved in centers, literature concerning relevant engineering education processes was found in such journals as *Technology Transfer, Research Policy, Journal of Professional Issues in Engineering Education and Practice, Journal of Engineering Education, Journal of Cooperative Education, Journal of Higher Education,* and *Research in Higher Education.* Center literature was obtained through National Science Foundation contacts and contractors. The National Science Foundation's technical reports on graduate students within the NSF Cooperative Research Program were then used as primary resources.

Non-Empirical Engineering Education Reform Literature

There is a need for engineering education reform to produce well-rounded students who are better prepared for the engineering workforce in an increasingly competitive environment. The 2004-2005 Accreditation Board of Engineering and Technology (ABET) criteria for accrediting engineering programs specify students must be proficient in both technical and soft skills. ABET's standards demonstrate their belief that a complete engineer cannot be just technically savvy anymore. Accredited institutions must demonstrate that their students are competent in non-technical areas such as functioning on multidisciplinary teams, problem solving, professional and ethical responsibility, communication, life long learning, and knowledge of current issues in the field (ABET, 2003). These benchmarks are helpful in alerting or reminding programs how essential soft skills are in the curriculum.

The National Science Foundation's Division of Undergraduate Education and the Division of Engineering Education Centers held a conference on June 6-9, 1994 to discuss the needs of engineering education for the twenty-first century (Meyers & Ernst, 1995). The conference addressed the need for a comprehensive reform of engineering education to keep pace with global growth in the engineering field. The recommendations and discussions identified the gaps in current undergraduate engineering education. The identified objectives support general curriculum reform and specify certain mechanisms that need emphasis: leadership, teamwork, lifelong learning, technological literacy, professionalism, industry interactions, and exposure to multiple departments. The recommendations also provide support for cooperative learning and assessment that is relevant to the NSF center education (Meyers & Ernst, 1995).

The emphasis on non-technical or soft skills is a prevalent recommendation for engineering education reform, but may not be easily integrated into the curriculum. Hannon of ASEE *Prism* magazine (2004) addresses the struggles institutions face in preparing well-rounded engineers for the workplace.

> The Achilles' heel here is that schools are just not quite sure what the best methods to teach communication skills are likely to be and how to execute them without undo expense. In all fairness, the type of person that is attracted to

> engineering is not necessarily the one who is the life of the party and naturally proficient at these set of skills (Hannon, 2004, p. 2).

This indicates that while the need to emphasize professional or soft skills is acknowledged, there is still uncertainly surrounding how to best convey this expertise.

One method advocated by the literature is to teach soft skills via cooperative learning. Literature has shown cooperative learning promotes achievement, interpersonal relationships, and self-esteem more than traditional teaching methods and has been deemed successful for all levels of education (Fellers, 1996). The NSF workshop (Meyers & Ernst, 1995) is one of many sources to recommend active learning techniques (e.g.: cooperative learning and/or experiential learning) as an effective engineering education method. "Cooperative learning is defined as: '…the instructional use of small groups so that students work together to maximize their own and each other's learning' [Johnson, Johnson, and Smith, 1991b; p.1:3]" (Fellers, 1996, p.43).

Fellers (1996) presents a cooperative learning model focused on a student-centered learning process where students assume more responsibility for their own learning and the education of others. The cooperative learning model focuses on training students to work well with others, creating an interest in self-learning, and generating a basis for lifelong learning.

Fellers (1996) proposes there are five critical elements needed for the cooperative learning model to work effectively. The first is *positive interdependence*. It is essential that cooperative learning groups be structured to ensure one person's performance is tied to another's. This component is typically the principal element that distinguishes cooperative learning from general group work. The second element in the cooperative learning model is *face-to-face interactions*. Interactions ensure students are able to exchange or transfer knowledge and resources to one another, while receiving feedback and support. Enough time needs to be permitted for these interactions and feedback to occur. The third element is *individual accountability*. Students should be responsible for their own and their team's learning.

The last two elements are *social skills* and *group processing*. Social skills may be taught through individual courses (e.g.: communication, group work, etc.), but also should be continually reinforced throughout the education system. These skills should not be taught solely as general skills, but also within the student's specific area of study. This will allow the skills to be directed to relevant applications and will give students an understanding of the skills. This element seems to be critical to successfully addressing the need for soft skills in engineering education. Lastly, group processing, which the author defines as group discussions and critiques or feedback, is important because knowledge of the skills is insufficient. Processing and feedback is needed to understand the project's applications and relevance (Fellers, 1996). The five critical elements are insightful and could prove to be valuable mechanisms when evaluating the NSF center education program.

Fairweather (1990) asserts that an industry university alliance addresses economic development through education and training. Students working in a cooperative alliance between industry and university are trained in high demand disciplines and their education focuses on basic skills such as writing, math, critical thinking, and problem solving. In essence, center education has a strong experiential element. The focus and exposure to soft skills is perceived to be due to the cooperative nature of the partnerships.

Students are a part of a cooperative learning environment since their research projects are primarily team-based and they rely on their group members. This environment and structure assist in educating students on personal interactions, communication, multiple disciplines, mentoring, and leadership (Fairweather, 1990).

Cooperative learning is perceived to prepare students to be well-rounded engineers. This education method may be able to address industry desires for entry-level engineers equipped with interpersonal skills in addition to technical proficiency. Interpersonal or soft skills include a broad set of skills that are not emphasized in the engineering literature. However, two interpersonal mechanisms that the engineering education literature does recognize that are also thought to be important to include in the reform of engineering education are leadership and mentoring.

ASCE members Bowman & Farr (2000) propose that after technical skills, leadership is the most important trait needed by young engineers. A leader influences an organized group to accomplish its goals. Leadership can advance an engineer's career through team building, communication, and decision-making skills. Leadership abilities also prepare engineers to be knowledgeable in areas of risk taking, power usage, and ethics. The authors suggest that teaching leadership skills is best done through "real" problems and situations. A project creates opportunities for students to lead and develop soft skills such as communication, interpersonal relations, and marketing. Leadership is an essential outcome that should be emphasized when reforming engineering education and, per the authors' suggestions, should be incorporated into the curriculum through experiential learning approaches (Bowman & Farr, 2000).

A second key mechanism engineering education should address is mentoring, an element that will help transfer strong leadership skills from engineers to students. A mentor is the "…person directly responsible for the professional development of a research trainee" (Guston, 1993, p. 51). A mentor is more than a role model or one who provides financial support or oversees a paper. The relationship between a mentor and student may be repeated when the student becomes the mentor; thus, the role of a mentor is believed to play a critical role in the development of the trainee and the trainee's career. In addition the mentor is thought to play a vital role in developing not only the technical skills of the student, but also professional skills. The model mentor is thought to assist a student in their career goals, technical achievements, education, and even socialize the trainee into their field's engineering community. The student, in return, ideally provides continuity to the mentor's work (Guston, 1993).

Guston (1993) points out there is controversy when determining if mentoring is a successful mechanism in engineering programs, as students are forced to choose a mentor or are assigned to mentors early on in their educational program. In addition, mentors may not be a formal relationship, expectations of the relationship are rarely discussed, and faculty members are not typically rewarded for training graduate students. There is also concern students are forced to "clone" their mentors in areas that may not fit with their interests. Students may be coerced into extremely specialized and narrow focuses, which potentially could hinder their other interests and broad knowledge base (Guston, 1993).

Mentors can be faculty members, advisors, industry members, and/or peers; regardless, interactions with a person who is perceived formally or informally to be a mentor can hold great impact on a student's development. This crucial interaction is thought to be a mechanism that holds great influence on student satisfaction, career goals, program commitment, and even technical and soft skills. Mentoring may be an important mechanism to explore as part of a student's NSF center education.

Unintended Consequences

Fairweather (1989) raises concerns regarding the effects of industry-university cooperation on graduate students. Quality of instruction, decreasing involvement of students in their own educational programs, increasingly specialized programs, and a reward structure that de-emphasizes the importance of instruction in the promotion and tenure process are all potential consequences of industry-university cooperation. There is a dearth of qualified faculty in science and engineering disciplines. PhD students, potential future faculty members, are perceived to choose careers in industry over academia due to salary discrepancies. Also students may not be entering doctoral programs at all due to lack of funding. Industry university cooperation may result in research that can be applied to real-world situations, but the basic research on which the university traditionally has focused may be impeded. Shifting the focus from instruction to research may hamper student education. The author raises the point that universities may not be able to pursue liaisons with industry without interfering with instructional goals, especially with a faculty reward structure that praises research more than instruction (Fairweather, 1989).

Looking more closely at the benefits and consequences of technology transfer, Stephan (2001) contemplates the impact of technology transfer on the curriculum of students in a paper presented at an "Organization Issues in University-Industry

Technology Transfer" conference. Stephan defines technology transfer as the interactions between industry and universities. This includes funding of research, licensing of patents, establishment of start-up companies, and formation of strategic partnerships.

Stephan (2001) first notes the effect technology transfer has on curriculum. Looking at positive effects, industry members can inform the educational institution of the characteristics they desire in entry-level engineers and on current technological happenings. This information can then be used to keep the curriculum up-to-date and relevant to the climate outside the institution. Potential negative effects on curriculum from industry and university interactions were also discussed and are listed below:

- Less attention is given to the curriculum because faculty attention is diverted to the collaborative research.
- A delay in publications due to industry's confidentiality concerns, hindering the development of future research ideas.
- The suggestion that research cannot be freely discussed (due to industry concerns) hinders student learning and suggests that withholding information is part of the research process.
- Industry may hire faculty, which causes the educational system to lose experts in specialized fields, including those capable of transferring their specialty's knowledge to the next generation. This reduction in technology transfer could result in fewer leaders and stymied growth in that area.

In addition to looking at the impact of technology transfer on curriculum, Stephan (2001) specifies positive and negative effects on students. The positive aspects of technology transfer on students include such things as internships, job opportunities, and career education. Exposure to industry is another major benefit to students as well as faculty, advising them of the needed skills of entry-level engineers, industry working conditions, and the benefits of working for industry (e.g.: salaries, publishing opportunities, less time spent raising funds). Furthermore, technology transfer has the opportunity to provide funds and revenue for students and education programs. Despite the collaborative environment, industry involvement potentially jeopardizes relationships by creating issues of trust, competition, and secrecy; thus, student relationships with faculty and peers may be hindered. The research may also emphasize economic gain instead of knowledge sharing (Stephan, 2001).

Stephan's paper provides a thorough overview of potential benefits and consequences of technology transfer on curriculum and students. A determination should be made whether there is a relative advantage to using industry and university collaboration as an educational approach. This innovation is in need of empirical assessment before a conclusion can be reached, and to ensure the advantages are maximized and the consequences are minimized. The information presented provides a detailed overview of where research focus should be when assessing if education within industry and university collaborative environments will meet the demands of industry, society, and students (Stephan, 2001). The section on center literature will describe an empirical study by Behrens & Gray (2001) examining some of these issues.

The non-empirical literature has indicated there is a demand for soft skills from entry-level engineering employees. Cooperative learning is thought to prepare well-rounded engineers by incorporating elements of positive interdependence, face-to-face interactions, individual accountability, social skills, and group processing. In addition, mentoring and leadership are thought to be important mechanisms that should be incorporated into engineering curriculum. Student collaboration with industry and diverse faculty members may result in benefits, such as soft skills, but it is also important to keep in mind graduate students may experience unintended consequences as a result of their CRC experiences.

Empirical Engineering Educational Reform Literature

This section presents empirical literature on the various components of engineering education. First, research is presented enumerating those soft skills lacking in entry-level engineering employees, according to engineering employers. Next, the experiences and benefits of students in co-ops are reported; co-ops are thought to be similar to CRCs in that students are exposed to industry, experience real-world applications, and engage in teamwork. Finally, evaluations of cooperative learning programs are provided to show how soft skills are associated with students involved in cooperative group work.

Soft Skills

Katz (1993) conducted qualitative interviews with professional engineers in supervisory roles. The professionals specified that entry-level engineering employees were not meeting expectations in areas of teamwork, communication, and awareness of workplace expectations (Katz, 1993). This supports the notion that there is a gap between what industry desires of entry-level engineers and the skills institutions are emphasizing. The following two empirical studies expand on which skill areas entry-level engineers are lacking.

DeLange (1996) asserts that there is a gap between what employers require and what is addressed in the engineering education curriculum. The purpose of the study was to specify non-technical or soft skills that employers desire engineers to possess before they enter the workforce or undergo experiential training (such as a co-op program). Employers of engineering students in an experiential training program at Port Elizabeth Technikon in South Africa rated seven skill clusters (using a four-point scale 1 = “not important” to 4 = “extremely important”), comprised of 15-20 items (n = 312; response rate = 67%). The clusters were ranked according to the percentage of employers who rated the skills within the cluster as “extremely important” or “important.” The ranked clusters are listed below with the composite percentage of rated importance.

1. Communication (98%)
2. Creative thinking and problem solving (96%)
3. Group effectiveness and teamwork (92%)
4. Work related dispositions and attitudes (91%)
5. Self-management and personal style (87%)
6. Organizational effectiveness and leadership (85%)
7. Information management (84%)

Communication and *creative thinking and problem solving* were rated as the two most important clusters. The author categorizes both of these clusters as “functional skills” because they are skills that are applied to basic career tasks. Within the cluster *communication*, the top three (of fifteen) highest rated skills were verbal communication, listening skills, and the ability to explain things. Problem analysis, observe acutely, and questioning skills were the top rated skills within the *creative thinking and problem* *solving* cluster. *Group effectiveness and teamwork, work related dispositions and attitudes*, and *self-management and personal style* are categorized as “adaptive skills” since they are needed to contribute and adjust to the workplace.

DeLange gives four specific recommendations with regard to the results. The first is to incorporate the cluster of skills deemed as important by employers when developing engineering education curriculum. The second is to introduce and prepare students in soft skills before placing them in a co-op or experiential training program; however, no suggestions on how to do to this are given. It is important for students to have an adequate skill foundation on which to expand so that the work atmosphere does not stymie them. Next, the educational program should encourage students to develop their soft skills independently, in addition to relying on the academic institution. Lastly, engineering students should take part in student societies, which could further help them develop soft skills (DeLange, 1996).

A study similar to DeLange’s was conducted to determine which project management skills are perceived important by major engineering organizations in Malaysia. Tong (2003) surveyed six hundred of Malaysia’s major engineering companies with a variety of engineering specialties. Senior engineers, managers, or directors who were project oriented and who had experience with data collection and assessing soft skills and technical knowledge were mailed questionnaires after an initial consenting phone call (n = 312; response rate = 52%). Twenty-two specific skill attributes were assessed using a multiple-choice format with a few open-ended questions. Follow-up telephone interviews were conducted to assess employers’ perceptions of the importance of project management skills in entry-level engineering employees. In addition, other issues such as recruitment, hiring, and expectations were discussed.

The majority of the organizations perceived six skill attributes as important (seven-point scale where 1 = “not important” to 7 = “extremely important”). Interpersonal-communication is ranked as the most important skill (mean = 6.34) followed by project planning/schedule (mean = 6.28), people management (mean = 6.24), problem solving (mean = 6.21), team management (mean = 6.24), and cost control (mean = 6.09). Of the twenty-two tested, the three skills employers perceived as least important are law for engineers, product marketing, and international perspective (means ranged from 4.5 to 4.9) (Tong, 2003).

When employers were asked to rate the skill performance of their entry-level engineering employees in comparison to what they initially expected of their employees skill performance, the biggest gap was in interpersonal communication (45% deficiency). Problem solving (37%), project planning/scheduling (36%) people management (32%) and leadership (30%) were also viewed as being well below expectations. This demonstrates a serious learning discontinuity between expectations and performance. In particular, Tong (2003) points out employers’ alarming disappointment with interpersonal-communication skills.

The follow-up interviews reveal that almost three-fourths (70%) of the employers think university programs accentuate scientific theories and technical knowledge excessively and do not place enough focus on practical results that teach students how to utilize the knowledge. Employers also expressed that project management skills are critical in engineering careers and should be incorporated into the curriculum, not exclusively in one course, but throughout the educational program. Employers expressed project failure of entry-level engineers due to factors involving schedule, costs, resource selection, team inspiration, management expectations, and poor team communication. Industry members perceived stronger project management skills would have prevented these failures. Employers suggested improving the engineering education by having industry take an expanded role in student learning and the curriculum as they do in some centers. Other suggestions include an emphasis on soft skills and student involvement in various extra-curricular activities to enhance their communication and teamwork (Tong, 2003).

Although identifying soft skills required by industry members is an efficient approach to begin to close the gap between student curriculum and what industry demands of entry-level engineers, study conclusions are difficult to generalize to the U.S. since the industry members surveyed were located in South Africa and Malaysia. Also, these studies look at the broad category of "entry-level" engineers. Neither DeLange (1996) nor Tong (2003) distinguishes if these expectations are for entry-level engineers with an undergraduate or graduate education. Overall, the studies are thought to be beneficial by demonstrating the need for engineering education innovation to address skill deficiencies and identify skill areas engineering education programs can focus on when integrating soft skills into their curriculums.

Co-Op Studies

The literature suggests cooperative and/or active learning educational methods may be efficient tools when incorporating soft skills into the engineering education curriculum. The following studies present findings on a collaborative educational program that involves students in a co-op or internship placement.

Hayward & Horvath (2001) compared undergraduate university students from the university's 1998 "Cooperative Education and Internship Placements" list to students enrolled in the university's traditional program. Seventy-nine undergraduates volunteered to participate (cooperative n = 39; traditional n = 40). Respondents completed an adapted version of the Career Beliefs Inventory, which consisted of 11 belief statements rated on a five point Likert scale (1 = "strongly disagree" and 5 = "strongly agree." Univariate ANCOVAs for each of the 11 measures were conducted.

Findings support the hypothesis that students enrolled in cooperative educational programs hold significantly more positive work beliefs and values than those students in traditional programs (F (11, 62) = 2.91, p < . 01). Cooperative education students were found to show a more proactive work ethic than traditional students by exploring job options, taking risks, and expecting success to follow difficult work assignments (F (1, 72) = 4.66, p < .05). Also, students in cooperative programs were more likely than the students in traditional programs to display motivation to develop career paths and job skills and to engage in the pursuit of self-improvement (F (1, 72) = 4.42, p < .05). Lastly, students in cooperative education programs were more likely to be interested in learning job skills than students in the traditional education program (F (11, 62) = 11.38, p < .01). Students in both groups reported employers place a strong emphasis on work experience and they perceive the co-op program as providing an opportunity to gain that highly valued background. This study supports that participation in a cooperative education program is associated with desirable work values, attitudes, and beliefs of the students involved, which is thought to provide students with cooperative education experience a competitive edge in the field (Hayward & Horvath, 2001).

Limitations of this study make it difficult to generalize the results to engineering education. This study is subject to concerns of selection bias since participants volunteered. Also, the traditional education program students were all undergraduate students who lived on campus. This factor was not specified as being controlled for. In addition, the study did not indicate what field of studies these students were in or if the traditional students were in the same fields of study as the cooperative group.

Two research studies examine cooperative education methods by surveying universities that are a part of a coalition sponsored by the National Science Foundation. Universities participating in the Engineering Coalitions of Schools for Excellence in Education and Leadership (ECSEL) incorporate design projects that relate to real-world or professional problems. Many of the ECSEL schools have students work in groups on actual engineering problems.

Colbeck, Cabrera, & Terenzini (2001) utilize seven ECSEL universities to examine teaching practices and self-perceptions of undergraduate engineering students in ECSEL courses and those in non-ECSEL courses (students self-enrolled in the courses). Participants were asked to complete a questionnaire examining four categories of questions: background characteristics, teaching practices in the particular course, perceptions of classroom climate, and the extent to which students' academic and career self-perceptions were affected by this course (ECSEL students n = 936; non-ECSEL students n = 322).

After running a regression analysis, collaborative learning and faculty interaction and feedback was demonstrated to be significantly and positively associated with gains in all five academic and career self-perceptions: intention to persist in engineering, perceived responsibility, expected grade, confidence, and motivation. In particular, frequent interactions, feedback, and opportunities for collaboration between faculty and students were associated with a higher sense of responsibility for students' own learning and higher confidence and motivation to become engineers. When examining instructor interactions and feedback by gender, instructor interactions and feedback were significantly associated with males gaining confidence in their engineering abilities ($B = .198$, $p < .05$), but were not found associated with females' confidence level ($B = .178$, $p > .05$). On the other hand, clear and organized assignments and assignments that could be related to class activities were associated with higher female confidence ($B = .22$, $p < .05$), but were not associated with higher male confidence ($B = .047$, $p > .05$). Although both males and females perceived faculty to treat students equally, the more the students reported perceiving equal treatment, the more likely those students felt they had a sense of control over their own learning, which resulted in higher career motivations (Colbeck et al., 2001). This study demonstrates the value of faculty interactions and collaborative learning on students' self-perceptions. The study also raises the possibility that gender interactions may exist.

In another study examining ECSEL courses, Terenzini, Cabrera, Colbeck, Parente, & Bjorklund (2001) empirically test the common belief that active and collaborative instructional methods develop soft skills better than traditional instructional methods. Participants came from six colleges that are a part of the ECSEL system. Four hundred and eighty undergraduate engineering students (71% in ECSEL courses; 29% in non-ECSEL courses), enrolled in seventeen ECSEL undergraduate engineering courses (collaborative learning) and six non-ECSEL (traditional learning) courses, were given a four-page multiple-choice questionnaire looking at course characteristics and learning outcomes.

Results for course characteristics significantly differ for 18 out of the 24 items (a four point scale where 1 = "never" and 4 = "very often" is used). Seventeen of those significant differences favor ECSEL students ($p < .01$). ECSEL students reported significantly more collaborative/group learning experiences (8 items), greater course emphasis on design process and problem-solving activities (2 items), more feedback and encouragement from faculty and peers (3 items), and interactions with faculty members and peers (4 items) than non-ECSEL students. However, when students were asked to rate how often male and female students are treated equally, non-ECSEL students perceived their instructors to treat students differently depending on their gender (mean = 3.75) significantly less than ECSEL students reported instructor's treatment changed because of gender (mean = 3.63) ($p < .05$). The authors hypothesize this is probably because there was less opportunity for a treatment difference to occur due to minimal interactions in the traditional course environment (Terenzini et al., 2001).

Respondents were asked to self-report on the progress they had made in the 27 areas as a "consequence of the course they were taking" using a four point scale where 1 = "none" and 4 = "a great deal." Four factors were identified from the twenty-seven learning outcomes after running principal component factor analysis. The four factors (communication, problem solving, group work, and design skills) explain about two-thirds of the total variance (67%). ECSEL course participants self-reported significantly more progress in three out of the four factors: communication (mean = 2.84), design (mean = 2.84), and group skills (mean = 2.96) than non-ECSEL participants (means = 2.57, 2.38, and 2.09 respectively) ($p < .01$). ECSEL participants also displayed a higher problem solving skill advantage than non-ECSEL participants, but the difference is non-significant. Overall, the authors conclude ECSEL courses have a positive and substantial effect on student learning and more collaborative and active educational methods need to be implemented in order to expose students to soft skills that will benefit them in their careers. Although educational changes that focus more on collaborative educational methods will require significant effort to implement, the benefits students and society will reap make the changes worthwhile (Terenzini et al., 2001).

The studies using students in ECSEL courses have some limitations. Neither of the studies addresses whether the traditional students (used for as a comparison group) have ever been in an ECSEL course. Also, the results are subject to a self-selection bias since students were able to choose their courses. Not only is the data self-reporting, but Terenzini et al. (2001) asked students how much they progressed as a result of that one class. This is a very difficult assessment to make and may include numerous extraneous variables during their class and previous training and education.

Industry-University Environment Studies

There is a debate among interested parties concerning the role of industry in higher education. A study was conducted that expands on the minimal data examining engineering faculty perceptions of industry university collaboration. In the process, faculty perceptions of the impact of industry university collaboration on engineering education are examined. Specifically, faculty perceptions of graduate student outcomes from working on industry sponsored or federally sponsored research are compared. Participants were surveyed from the Center for Technology Assessment and Policy's national probability sample of engineering faculty from the 200 institutions with the highest ASEE research expenditures. Strickland, Kannankutty, & Morgan (1996) screened faculty members to ensure participants were currently engaged in university-based engineering research. The final sample consists of 1,727 usable questionnaires (61% response rate). The scales used were not reported.

Faculty members reported supervising five graduate students on average (including students seeking master and doctoral degrees); however, faculty with high federally supported research reported supervising significantly more doctoral students (mean = 3.1) and significantly less master degreed students (mean = 2.1) than high industry supported faculty (mean = 2.1 and 2.8 respectively). Graduate students were reported by almost all faculty participants (95%) as being somewhat or to a great extent involved in their research. Looking at involvement by support, high federally supported research is perceived to receive a greater amount of graduate involvement (97%) than high industry supported research (93%). The authors point out that although this is a significant difference, it is inconsequential (Strickland et al., 1996).

When faculty were asked the benefits students receive by participating in industry or federally funded research, faculty working on industry supported research reported students benefit largely or to a great extent by acquiring specialized knowledge (94%), problem solving skills (92%), maturity and confidence as an independent researcher (88%), and communication skills (74%). Faculty working on research that has high federal support perceived their students as more likely than those working on high industry supported research to say that "…research involvement helps students acquire fundamental research skills (93% vs. 88%), utilize cutting-edge technologies (63% vs. 55%), gain cross-disciplinary research experience (50% vs. 37%), and, not surprisingly, interact with government researchers (19% vs. 5%)" (Strickland et al., 1996, p. 7). On the other hand, faculty with industry supported research indicated students receive a better comprehension of real-world problems (61% vs. 33%) and are exposed to interactions with industry researchers (44% vs. 13%) more than students working on federally supported research (Strickland et al., 1996).

Federally supported research is perceived to provide a basis for fundamental skills, involvement with cutting edge technologies, and cross-disciplinary knowledge, while industry supported research allows for a better understanding of real-world industrial problems and exposes students to industry researchers. A consequence of industry and university collaboration includes the perception that industry's influence on the research topics supersedes faculty research interests, which may also lead to the hypothesis that graduate students' research interests may be overlooked as well. Another consequence the article raises is a concern that the short span of industry research may utilize master degreed students and not provide the same benefits to doctoral students. These conclusions suggest results may vary depending on the degree sought, such as providing different skill sets to engineers (Strickland et al., 1996).

Even if Strickland et al. (1996) did not look specifically at NSF center education, their findings are valuable because it is one of the few studies that examines graduate students and the actual innovation of engineering education from industry and university collaboration. Since the innovation is evaluated from faculty perceptions, the graduate student outcomes identified are actually only perceived

Another study examining industry's influence on students investigates the effects of graduate students (master and PhD level) and post-doctoral fellows being sponsored by industry (Gluck, Blumenthal, & Stoto, 1987). One thousand graduate students (63%) and post-doctoral fellows (27%) were randomly selected from six research-intensive universities (one public, five private) and mailed a four-page questionnaire (n = 693; response rate = 71.5%). Nineteen percent of the students and fellows received direct industry support for their research and training and 15% worked with faculty advisors on supported industrial funds.

Gluck et al. (1987) hypothesize that industry support may be related to more students entering careers in industry; however, findings show career paths do not significantly differ for respondents who are and are not receiving industry support. Conversely, other outcomes of students and fellows do differ depending on whether they received direct funding from industry. Respondents who were directly supported by industry were more likely to report patents or patent applications (12.1%) than those students without industry involvement (3.7%) ($p < .01$). However, students with direct support from industry reported significantly fewer publications (mean = 2.62) on average than those with other support or those whose advisors received funds from industry (mean = 3.91) ($p < .01$). Gluck et al. (1987) hypothesized that the number of academic publications might be smaller because industry supports more applied research.

Using a five point scale where 1 = "poor" and 5 = "excellent", over half of the respondents rated their educational experiences as "excellent" and another 45% rate them as “good” or “very good”. There were no significant differences found between industry funded and non-funded students. When respondents funded by industry were asked if “the benefits of university-industry relationships in biotechnology outweigh the risks”, over half of the respondents, regardless of support, believed the benefits from working with industry “slightly” or “far” outweigh the risks (four point scale where 1 = “risks far outweigh benefits” to 4 = “benefits far outweigh risks”). Data suggests the benefits from working with industry include funding opportunities and increased number of patents, which imply an accelerated transfer of research for application purposes. The study suggests there are several unintended consequences, such as fewer number or delayed publications and faculty misconduct, which may occur as a result of industry and student collaboration (Gluck et al., 1987).

Entry-level employees are not meeting the expectations of engineering employers. The literature shows a skill deficit among entry-level engineering employees’ soft skills. In particular, employers would like entry-level engineers to have the following skills: verbal communication, listening skills, creativity, problem solving, and group skills. Literature also shows active and collaborative instructional methods may develop soft skills better than traditional instructional methods, which would provide students with cooperative education experience a competitive edge in the field. In addition, research indicates students may experience numerous benefits from working with industry; however, unintended consequences of industry collaboration may also occur.

Center Empirical Literature Review

The goal of examining center empirical literature is to try and understand what is known and not known concerning the effects of centers on students. The remainder of the literature review will focus specifically on the National Science Foundation's Cooperative Research Centers. Literature findings are presented from the three main cooperative programs: STC, I/UCRC, and ERC. Studies are organized by methodology with descriptive studies presented first and the most sophisticated methodology last. Due to the different focal areas, educational components, and objectives of these center programs, the studies cannot be satisfactorily collapsed for the purpose of generalizing to all cooperative research students.

Descriptive Studies

ERC Industry Perception of Students

Ailes, Roessner, & Feller (1997) were contracted by NSF to assess the impact of the cooperative partnership on industry members. Industry members who served as the primary representative to their ERC were asked to complete a mail survey on their experiences and interactions with the ERC program (n = 355; 71% response rate) (Ailes et al., 1997). One component of this survey explored industry members' interactions and experiences with ERC students. As noted previously, interaction with industry is assumed to be a primary benefit for students.

Although ERC industry members report being involved in mentoring, sharing research projects, and having access to their center's students, the number of interactions between industry members and students varies considerably. Looking specifically at the mechanism of industry interactions, the majority of industry members reported they had contacted ERC students in the past year at least once via phone or email (66%) and had at least one face-to-face contact with students (73%). A small percentage even reported five or more contacts with ERC students either by phone/email (15.7%) or face-to-face contact (13.2%). Only a few industry members reported supervising a former or current ERC student in their company (17.5%), working jointly for publication or invention purposes (14.3%), or serving as committee members for a student's thesis/dissertation (6.9%) (Ailes et al., 1997). These findings confirm that students are interacting with industry, but the majority of industry members do not have frequent or substantive interactions or roles with students throughout the year.

Most of the companies who reported hiring ERC students (40%) hired only one student in the past five years; however, five companies did report hiring 10-25 ERC students as full-time employees. Industry members who hired ERC students for temporary or full-time positions were asked to rate ERC students/graduates compared to their equally leveled non-ERC employees (a hypothetical comparison). Using a five-point scale (1 = "much worse" and 5 = "much better"), the majority of industry representatives rated ERC trained employees to be "much better" or "somewhat better" than their non-ERC trained peers in the following outcomes: depth of their technical knowledge (80%), overall preparedness for working in industry (80%), contribution to company's technical work (77%), breadth of their technical knowledge (74%), ability to apply knowledge from different disciplines and use technologies in an integrated fashion to solve problems (72%), knowledge of how to develop technology (66%), ability to work in interdisciplinary teams (64%), engineering systems approach (63%), and ability to solve problems within constraints of time, money, and human resources (59%). Over half of the industry members (53%) perceived ERC trained employees as needing less company training before becoming a net contributor to the industry. About a quarter (23%) of industry members even specified that the ERC trained employee works in a position that requires abilities that only an ERC education and training could provide (Ailes et al., 1997).

A major finding of the study emerges when industry members were asked to rate how much they valued the various outcomes of being a part of the ERC program. Industry members who hired ERC students rated the access to ERC students for employment opportunities more valuable than any other benefit of their ERC membership (Ailes et al., 1997). This is a noteworthy outcome as it may provide a marketable benefit for encouraging industry collaboration and for recruiting students.

The industry members who were surveyed varied considerably in how long they had been members. Some industry members were current members while others were members at the time the ERC program began. The database containing industry names underwent a major revision in 1994 and there is confusion and discrepancies when seeking a complete and accurate list of industry members; thus, not all members are represented. Another cautionary note with regard to the findings is that the study interviewed industry members who served as the organization's main contact to the ERC program, but these contacts may not have been the actual direct supervisors of the ERC employee and/or may not have had substantial contact with the student. Since industry members rated center graduates hypothetically to other employees, it is of concern whether ratings were inflated and/or they were trying to please experimenters. A comparison group would have provided more internal validity. In addition, this data is only descriptive statistics; therefore, these are preliminary results that should be used as a basis for further research rather than as conclusive evidence of trends.

ERC Data Collection Methodology

Scott (1992) conducted an ERC study that was only briefly reported. This study parallels the ERC effectiveness study presented by a later study by Parker (1997). ERC alumni who obtained a BS (n = 39) or a MS/PhD doctoral degree (n = 178) from one of the five ERCs sampled completed a mail survey (n = 217; response rate = 81%), while their current employment supervisors completed a telephone interview (n = 101; response rate = 62%). The study was conducted primarily to determine the most efficient way to collect information regarding the educational component of the ERCs. The pilot study was intended to suggest avenues for future research, develop a foundation for educational experiences within the ERCs, and most importantly explore data collection on ERC graduates (Scott, 1992).

Over three-fourths (81%) of ERC graduates were willing to share their experiences and opinions and provide contact information for their employment supervisors via a mail survey. This collaboration is a finding in itself as it suggests students will cooperate in providing feedback on their experiences and satisfaction with the program. The author proposes a standard data collection process of ERC graduate students. Instruments were developed and included in the report, but the instrument development, reliability, or overall success is never discussed. The author gives methodological recommendations proposing collecting contact information from ERC graduate students at graduation time and again collecting data on their ERC experiences after a few years of employment. It is recommended that ERCs should not be required to collect data on graduate students, but the instruments and instructions should be available (Scott, 1992).

One of the most compelling findings of this preliminary study is that ERC supervisors of ERC graduates were not particularly educated about the ERC program. First, some employers were not able to identify which of their employees were ERC graduates; thus, they could not compare ERC employees to non-ERC employees and so over a third (38%) had to be terminated from the study. In addition, over three-fourths of the supervisors who were not terminated did not know or did not respond when asked if they knew the reasons why ERCs were established (76.4%) and less than half of supervisors were aware of ERC goals and/or sponsors (42.6%). The researcher suggests one of the program's outcomes should be that before ERC students graduate they should be educated in the differences between the ERC program and other graduate programs and how to effectively market ERC skills while job seeking (Scott, 1992).

The significance of the problem is demonstrated by the fact that although 99% of the supervisors agreed to be interviewed, over a third (38%) of the interviews had to be terminated because supervisors did not know which employees were ERC trained (interviewers were instructed not to give specific identifying information). This is a substantial percent of interviews that could not be used and may bias the results significantly. Results may exclude supervisors who do not think the ERC is a prominent characteristic of their employee and/or alumni who may not advertise their ERC experiences for various reasons (e.g. the alumni's perception that the ERC did not have a substantial or positive impact on their education or careers or because the person is not well versed in how to use the experience to their advantage). Also, since the report is a pilot instrument and focuses on the feasibility of collecting data, ERC graduate data is inadequately summarized, the design lacks a comparison group, and the report provides little information on center activities, mechanism, and outcomes. Lastly, this data is very descriptive and no reliability, validity, or statistical analyses were presented.

Primarily Descriptive Studies

STC Evaluation:

Fitzsimmons, Grad, & Lal (1996) conducted a large-scale assessment on the STC program in the mid-1990s. One element of the broader assessment examined the impact of an STC center education on STC alumni's subsequent careers. A mail survey was sent to STC alumni who had earned their graduate degrees (master's and doctorate degree holders) while affiliated with the center program. In addition, STC alumni's current supervisors completed a questionnaire evaluating various aspects of the STC alumni's job performance. Supervisors (n = 257, 93% response rate) and STC alumni (n = 217, 53% response rate) were instructed to rate aspects of the STC alumni's job performance in comparison to their equally leveled organizational peers.[1] About half of the STC alumni held careers in industry, while about a third of STC graduates were in academia. Factors determining motivation to enter their current career sector were not analyzed (Fitzsimmons et al., 1996).

The program's educational component included numerous center activities. STCs have developed innovative degree programs, STC specific courses, mentoring programs, internships and career opportunities, and advanced scientific professional training. Common STC activities students reported engaging in are collaborative research, short courses, STC developed or sponsored courses, and an STC seminar series. As part of some centers seminar series, a televideo system connects partner universities to allow

[1] The discrepancy in the number of respondents between supervisors and STC alumni exists because supervisors of STC alumni could respond even if their STC employee did not respond (Fitzsimmons et al., 1996).

them to share research ideas, technological happenings, and to discuss problems. The televideo system also allows student presentations to be shared with partner universities. The majority of STC alumni reported attending more than half of the offered seminars (51%) and just under half presented research at the seminar series (45%). In addition to the opportunity to participate in many of the activities, the vast majority (80%) reported the opportunity to work with state-of-the-art computational resources, instrumentation, and advanced laboratories. Individual centers differ on which STC activities are offered and/or encouraged; thus, STC alumni reported a range of activities and levels of involvement depending on the individual center and the student's involvement with the program (Fitzsimmons et al., 1996).

STC alumni were asked to recall which center mechanisms were emphasized throughout their center education. Using a five point scale where 1 = "extremely low" emphasis and 5 = "extremely high" emphasis, STC graduates reported "extremely high" emphasis on the following training focuses: integrating/synthesizing information from different fields (31%), understanding the application of research (29%), working with people outside of their technical area (29%), systems approach to solving problems (22%), computer-based modeling skills (22%), and working in teams (19%). STC alumni specified the following skills were emphasized more by their STC related activities by than their non-STC related activities: understanding the application of research, prototyping skills, computer based modeling skills, working with people outside of major/technical area, integrating and synthesizing information from different fields in solving problems, systems approach to problem solving, and working in teams (Fitzsimmons et al., 1996). These results indicate STC's educational emphasis on mechanisms such as application, teamwork, and multiple disciplinary exposures is beneficial to students' future careers; however, it is also possible that graduates are hired or drawn to positions that value those skills.

Over a quarter reported working with STC sponsors on research projects (29%) and fewer than 8% of respondents reported STC corporate sponsor representation on their thesis committees. However, over three-fourths of STC alumni reported having multidisciplinary thesis committees. About half of STC alumni reported two departments were represented on their thesis committees (48%), while 30% of respondents reported three or more departments. When asked what aspect of STC had the greatest impact on their career, STC alumni specified exposure to different multiple disciplines (43%) and teamwork (25%) had the greatest impact. These are noteworthy findings since hypothesized center mechanisms include industry interaction, multidisciplinary exposure, and teamwork.

The most prevalent STC outcome that graduate students reported was in areas of scholarly production. Well-over three-fourths of graduate students published papers in referred journals (83.3%) and reported presenting papers at professional society meetings (84.7%). Sixty-two percent of the publications were based on STC research and 15.7% were co-authored by an STC corporate or federal sponsor. One-quarter reported presenting their research to STC sponsors and over a third presented research to other industrial audiences (36.1%). Roughly 8% of students reported applying for patents.

Two potential benefits graduate students receive from their participation in CRCs is access to technical equipment and internship opportunities. The majority (80%) of STC alumni reported they had the opportunity to work with state-of-the art facilities and equipment. However, less than 20% of the participants interned with a company and only about half of those that had interned did so with an STC industry sponsors (Fitzsimmons et al., 1996).

STC alumni's job performance, on average, was rated more positively when compared to their hypothetical organizational peers for all career paths and performance components by both self-ratings from STC alumni and supervisors' ratings. Using a five point scale where 1 = "much worse than average" and 5 = "much better than average, supervisors rated STC alumni as "much better than average" with regard to depth (41%) and breadth (39%) of technical understanding, overall ability to carry out job responsibilities (39%), grasping new problems (37%), creativity and innovativeness (36%), and interdisciplinary teamwork (33%) (Fitzsimmons et al., 1996).

Supervisors were asked to identify the three most essential skills or personal qualities needed for their STC trained employee's job. Supervisors desired new employees to have the following three components: interpersonal skills, job specific credentials, and good grades. When STC alumni in industry and their supervisors were asked how much training they or their STC trained employees needed before benefiting the organization in comparison to their non-STC trained employees (five point scale: 1 = "much less than average training" and 5 = "much more than average training"), both supervisors (mean = 2) and STC alumni (mean = 2) indicated STC graduates need less training on average before becoming beneficial to the company. This could prove to be a particularly positive finding when used to market STC students searching for jobs and/or internships (Fitzsimmons et al., 1996).

Frequently, STC alumni employed in industry, who took STC sponsored courses, gave themselves higher job performance ratings in numerous areas than those participants who did not take the STC courses. A five point Likert scale was used (1 = "very negative" to 5 = "very positive" impact). For example, more than half of those STC alumni (52%) employed in industry who took STC sponsored courses indicated the STC program had a "very positive impact" on their ability to contribute to their company's technical work, while only 40% of STC alumni in industry who did not take an STC sponsored course specified such an impact. Also, 21% of STC alumni in industry who took STC courses specified STC had a "very positive impact" on their leadership abilities; however, only 12% who did not take STC sponsored courses indicated such an impact (Fitzsimmons et al., 1996). Although descriptive statistics were presented, no statistics or statistical analyses were reported.

Examining STC alumni employed in academia, 20% of STC alumni who reported their center education placed an "extremely high" emphasis on teamwork tended to rate themselves better than average in transferring technology to or from outside entities; however, less than ten percent of those STC alumni who said their center education placed a "moderate" or "somewhat higher" emphasis on teamwork self-rated themselves better than average (five-point scale 1 = "extremely low" and 5 = "extremely high"). Also, STC alumni in academia who collaborated with STC industry sponsors were associated with stronger self-ratings in numerous areas of job performance than those participants who had not collaborated with STC industry sponsors. STC alumni in academia who reported collaboration with STC corporate sponsors rated themselves significantly better than those STC alumni without such collaborations in the following areas: contributions to research field (38% vs. 24% respectively), ability to grasp quickly the key features of new research problems (62% vs. 32%), ability to identify and transfer useful technical results to or from entities such as industry or national labs (29% vs. 16%), skill at networking within research field (33% vs. 24%), creativity and innovativeness (33% vs. 27%), and ability to work in interdisciplinary teams (57% vs. 41%) (Fitzsimmons et al., 1996). Since these findings were conditional on participation in certain STC educational activities, it suggests that if these activities are employed in STC centers, it is likely that they will be correlated with a positive impact on STC graduate students' job performance.

When asked for suggestions to improve the center program, the primary suggestion of STC graduates, regardless of their career sector, was the need to increase student involvement with industry (59%). STC alumni also desired more support and resources for job placements and easing of requirements regarding thesis or dissertation committees in order to allow faculty from collaborating universities and/or industry members the opportunity to serve on students' committees (Fitzsimmons et al., 1996).

While suggestive, this study should be interpreted with caution due to the numerous limitations. First and most importantly, this data is primarily descriptive data. Second, this data is based on self-ratings and supervisors' hypothetical comparisons to STC alumni's peers. The study could have been improved by using a comparison group of non-center employees instead of having employees and supervisors use a hypothetical comparison group, which may have resulted in more favorable ratings in order to please the STC program.

Another variable that may be influential in the results and requires critical review is the duration of time between the student's STC program participation and completing the questionnaire. This retrospective data may impact their maturation, job experience, and recollection. These confounding variables may produce different values, perceptions, and perceived skills resulting from the STC program. In addition, generalizability is of concern since those STC alumni who did not respond may have negative feelings toward the STC, were not in ideal job circumstances at the time of the survey, or other reasons that could provide more insight to the experiences of an STC education. The gaps and deficiencies are troubling, but results provide a broad and diverse starting point for further exploration.

<u>ERC Graduate Effectiveness Study</u>

Abt Associates Inc. was contracted by the NSF to conduct a study assessing whether ERC center alumni are more effective in their employment than their organization's peers (Parker, 1997). ERC alumni's center activities and the impact of the ERC on their current careers were also examined. ERC alumni (master's degree and PhD) completed a written survey (n = 433, response rate = 60%), while supervisors of ERC alumni were asked to evaluate the job performance of ERC alumni in comparison to their organizational peers via a telephone survey (n = 477, response rate = 86%). Similar to Fitzsimmons et al.'s STC study (1996), the sample size is greater for supervisors than ERC alumni because the ERC supervisors could be included in the study regardless if their ERC trained employee completed the survey. The primary focus was on ERC alumni in industry, but those in academia and government were also assessed. The average ERC graduate student alumnus was employed by their current organization for four years (Parker, 1997).

ERC alumni were asked to create a list of ERC features that have had the greatest impact on their careers. Real-world experiences (31%) and internships with industry (31%) were the ERC mechanisms that had the greatest impact on ERC alumni's careers; thus, it is not surprising that the majority of ERC alumni (75%) reported a desire for more industry involvement. Other ERC mechanisms ERC alumni specified as impacting their careers were ERC specific courses (23%), exposure to different disciplines (21%), good equipment/facilities (19%), teamwork (16%), networking (12%), and communication skills (7%) (Parker, 1997). Thus, mechanisms such as teamwork, communication, multidisciplinary exposure, state-of-the art equipment, interactions with industry, and internships may be worthwhile mechanisms centers should be employing.

ERC alumni were asked to specify various outcomes during their time with the ERC center. Over three-fourths of the ERC alumni with a PhD published papers in a journal (88%), attended one or more professional society meetings (86%), and made presentations at professional society meetings (78%). In addition, the majority of ERC alumni with a PhD reported the following outcomes: doing their thesis on an ERC sponsored research project (61%), publishing papers on an ERC research project (61%), and presenting research to an ERC industrial audience (55%). ERC alumni with a master's degree were much less likely to report these outcomes. The most popular outcome for ERC alumni with a masters' degree was attending one or more professional society meetings (51%). Less than a third of ERC alumni with a masters' degree reported publishing papers in a journal (36%), making presentations at professional society meetings (26%), presenting to an ERC industrial audience (24%), and publishing a paper based on an ERC research project (21%) (Parker, 1997).

A significant finding of the study indicates that the more time graduate students spend engaged in certain ERC activities, the more those experiences correlate with positive ratings of ERC related job performance activities. Stepwise regression was used to identify significant relationships between graduate school experiences and job performance; however, no statistics, such as the R^2 or beta weights, were provided. The following findings were presented:

- ERC alumni who took an ERC developed or sponsored course while pursing their degree rated their communication and leadership activities higher than those who did not take such a course.
- ERC alumni with a doctoral degree who took ERC courses rated themselves higher on interdisciplinary teamwork than those who did not take ERC courses.
- ERC alumni who participated in prototyping while involved with the ERC program were significantly more likely to rate themselves higher in technical areas, ability to carry out job responsibilities, and their breadth of technical understanding than those who did not participate in prototyping.
- Doctorate holders who published with ERC corporate sponsors as co-authors while in the ERC program, were significantly more likely to rate themselves as above average in their ability to apply knowledge from other disciplines and transfer technology to outside sources than those who did not have ERC corporate sponsors as co-authors (Parker, 1997).

ERC alumni were asked to rate the impact of ERC and non-ERC experiences on job performance for various skills (five point scale where 1 = "very negative" and 5 = "very positive"). Non-ERC experiences were found to have a slightly negative to neutral impact on their performance, while ERC experiences were rated as having a neutral to somewhat positive impact. ERC experiences were rated as having a more positive impact on performance than non-ERC experiences, particularly those in industry, in the following job outcomes: interdisciplinary teamwork, developing solutions, networking, and understanding the relationship between work and the company's customers. In contrast, non-ERC experiences were rated as having a more positive impact than ERC experiences for the following job outcomes: contribution to company's technical work, breadth and depth of technical understanding, ability to grasp key features of a new problem, ability to define steps needed to solve problems, and ability to apply knowledge from different disciplines to solve problems (Parker, 1997).

Supervisors assessed their ERC alumni's job performance on a five-point Likert scale where 1 = "much worse" and 5 = "much better" when hypothetically comparing them to their organizational peers. The vast majority of supervisors reported their overall job performance as "somewhat better" or "much better" than their peers (89%). Looking at specific skills, over there-fourths of supervisors rated their ERC alumni as having a better performance than peers in their organization in the following dimensions: contribution to technical work (85%), depth (85%) and breadth (81%) of technical understanding, and interdisciplinary work (80%). Using the same skill set as their supervisors, ERC alumni were asked to evaluate various areas of their job performance compared to their peers. ERC alumni self-rated themselves highest in their ability to grasp key features of new problems quickly, contribution to the firm's technical work, define steps needed to solve the problem, in technical understanding, and in ability to contribute to the firm's technical work (means ranged from 4.2-4.34) (Parker, 1997).

The correlations between center activities and job performance provide valuable information that should be investigated further. The STC study provided similar results concerning correlation of job performance and certain activities or level of involvement, but both studies lack supportive statistics (Fitzsimmons et al., 1996). It would be of interest to compare these post-graduate observations with those expectations and evaluations attributable to students during involvement with the centers. Assessments of active students, combined with retrospective assessments, would serve as a valuable resource to center administrators seeking to improve or adjust their program components and marketability.

A complete report of the ERC graduate effectiveness study was unavailable as the results were submitted directly to the management of each center. Instead, NSF developed a summary report of the findings that should be interpreted with caution. Since this is only a presentation of findings from a larger report, it is important that these results be looked at as preliminary. No statistical analyses, significance, measurement, reliability or validity are provided. The report specified that legal reasons prevented using a pre-test or control group so the study is exposed to internal validity threats such as maturation, history, and response bias. Results could also reflect organizational experience of the alumni, different educational programs depending on their involvement period, and ability to recall specific center experiences. In addition, the ERC project director was the author of the summary report and may bring personal biases when deciding which findings to present and how they are presented. The limitations of this study raise concerns for the overall reliability of the findings. Instead results can be viewed as a beginning premise for hypothesizing potential relationships and important aspects of the centers' educational programs.

Predictive/Comparative Studies

Follow-Up of I/UCRC Graduates

Scott, Schaad, and Brock in 1989-1990 conducted a follow-up study comparing I/UCRC graduates' and non-I/UCRC graduates' perceptions of center or departmental related educational experiences. Ten of the thirteen randomly selected I/UCRCs agreed to participate (83% response rate). I/UCRC graduate student alumni (n = 98, 88% response rate) and non-I/UCRC graduates that completed similar programs at the same universities (n = 70, 51% response rate) completed a certified mail survey. Both groups had to have obtained a master's and/or doctoral degree. Two versions of the survey were developed in order to tailor the phrasing so that I/UCRC graduate students were asked about their center experiences and non-I/UCRC graduate students were asked about their departmental experiences. Participants had to be involved with the I/UCRC program for at least 18 months in order to participate. Over 40% of the I/UCRC graduate group and 80% of the non-I/UCRC graduate group reported being involved for four or more years with their center (I/UCRC group) or department (non-I/UCRC group). About a third of I/UCRC graduate alumni specified being involved with the I/UCRC program for three years (35%) (Scott et al., 1991).

Graduates who were involved in I/UCRCs reported their graduate experiences as significantly more positive than non-I/UCRC graduates. Fourteen out of the 17 comparable items were found to be significant differences between the I/UCRC graduate group and non-I/UCRC graduate group ($p < .05$). All the significant differences were in favor of the I/UCRC graduate group. A seven-point response scale was used for all the items (Scott et al., 1991).

Looking at professional participation, students were asked the value of their work with the center or department with regard to establishing useful associations (faculty, other researchers, and industry representatives), learning about industrial settings, and participating in applied research (1 = "not very valuable" and 7 = "extremely valuable"). The overall Professional Participation Composite Score (determined by summing responses of the five items) was significantly higher in the I/UCRC graduate group than the non-I/UCRC group (t (176) = 6.8, $p < .000$). I/UCRC graduates reported they valued their center with regard to learning about research in industry settings ($p < .001$), participating in applied research ($p < .001$), and contact with industry representatives ($p < .001$) and researchers in the field ($p < .001$) more than non-I/UCRC graduates valued their departmental opportunities (Scott et al., 1991).

I/UCRC graduates' center experiences also indicated their center met their expectations for developing their knowledge and professional skills (technical knowledge, current state of field, "tricks of the trade", communication skills, teamwork skills, and broad perspective of research) (1 = center/department "not very helpful" and 7 = center/department "very helpful"). Specifically, the Professional Skills Composite Score (comprised of six items) also significantly differed, in favor of the I/UCRC graduate group, between the two groups (t (177) = 2.2, $p < .003$). I/UCRC graduates felt the emphasis on communication skills ($p < .001$), teamwork skills ($p < .05$), and a broader perspective of research ($p < .001$) "met their expectations" for professional skill knowledge (Scott et al., 1991).

When center and department education was compared to other educational experiences, the I/UCRC graduate group had a significantly more positive Comparative Value Composite Score (comprised of three items: research opportunities, outside work/internship experience, professional meeting participation) than the non-I/UCRC graduate group (t (152) = 2.1, $p < .04$). The I/UCRC group was more likely than non-center graduates to specify their center activities provided more valuable research opportunities than other research opportunities ($p < .01$) (Scott, Schaad, & Brock, 1991).

Lastly, non-parametric significant tests show I/UCRC graduates valued the opportunities I/UCRCs provided significantly more than non-I/UCRC graduates valued the opportunities provided by their departments ($p > .05$). In conclusion, all the significant differences (14 out of the 17 comparable questions) between I/UCRC graduate students and the comparison group favored I/UCRC graduate students. This implies that the perceptions of I/UCRC alumni were positive with regard to their center experiences when compared to their comparison group's perceptions of their departmental experiences. It is also noteworthy to point out that when I/UCRC graduates were asked how the center program can be improved, it was suggested that there needs to be more contact and access to faculty (Scott et al., 1991). This is unlike the STC alumni who suggested more contact with industry would be beneficial (Fitzsimmons et al., 1996).

This study's findings appear to support the belief that graduate students may be benefiting from involvement in I/UCRCs compared to more traditional graduate student experience; however, based on the study methodology, the reported advantages cannot be reliably attributed to the student's involvement in an I/UCRC based solely on the evidence provided. Interpretations and generalizations should be made with caution. First, though the study analyzed the data using t-tests, it is thought that multivariate analyses, such as a MANOVA, would have been more appropriate since it allows for multiple independent and dependent variables and assesses interactions. A higher response rate occurred for the comparison group; thus, a selection bias may be influencing the results. In addition, using departmental activities and experiences as a comparison group may not be adequate. The department encompasses many more activities than just center activities and being a part of a center is a smaller component of the larger university department to which it is being compared.

Two other potential confounding variables the study points out are the disproportionate level of financial support for non-I/UCRC students and that I/UCRCs may be recruiting more capable students for center assistantships. Since the ten centers surveyed had been established prior to 1986, it should also be kept in mind that I/UCRC education may have changed over time. Additionally, the study does not examine mechanisms of individual centers and instead the information is presented at the center program level. This prevents researchers from understanding which center practices are "good" or "bad" practices. The study also examines data retrospectively, which raises concerns that responses may be impacted by duration since center graduation, current employment experiences, and even the strength of one's memory. Thus, further research needs to be pursued in order to examine the external validity and other variables that may effect results and analysis (Scott, Schaad, & Brock, 1991).

Unintended Consequences of Cooperative Research

Although the literature has presented findings supporting educational advantages and benefits to a center education, Behrens & Gray (2001) conducted an empirical study looking at the potential unintended consequences of graduate students' participation in Cooperative Research Centers. The study assessed whether the source and form of funding for graduate student research is related to differences in research experiences or outcomes. Six universities were sampled: two were highly funded by industry, two received a medium amount of industry funding, and two received a low percentage of industry funding). A mail survey was sent to graduate students (seeking an MS, other masters, or PhD) at the six universities that were in the chemical or electrical engineering departments (n = 824; response rate = 43%) in order to gain information in the following areas: descriptor information, source of sponsorship, research areas, interactions with advisors, scholarly outcomes, and career objectives (Behrens & Gray, 2001).

The students were examined by source and form of sponsorship. Source of sponsorship looked at students sponsored by industry (I/UCRC, single company, and non-university based consortium) (45%), government (civilian and defense government) (34%), and those with no external sponsor (not funded or other university funds) (21%). These subgroups were used to examine the research question whether industry-funding sources hinder graduate student outcomes from industry sponsorship in I/UCRCs; however, this research question was not supported. Regardless, the study highlights the fact that the unintended consequences of industry-university cooperation on graduate students have not yet fully been explored. In addition, the study provides valuable information concerning autonomy within the center and the general experiences of center graduate students (Behrens & Gray, 2001).

Source of funding was found not to be a likely predictor of a student's career choice. Career goals of the students (66.9% industry, 28.9% academia) did not differ depending on whether the student was funded by industry, government, or had no external funding source. Since the majority of students reported their center research project as their thesis or dissertation research (85%), it was of interest to note that less than half (44%) of the students chose their topic and about a fifth (21%) were assigned to the research. However, students reported they were not coerced into particular projects due to sources of funding and instead indicated they perceived themselves as having the greatest influence on their research (Behrens & Gray, 2001).

Although students perceived themselves as having this influence, there was a significant difference by source of funding. Graduate students funded by a university source reported their funding source had significantly less influence on their research than industry or government sponsored students (F (2, 403) = 5.27, $p < .01$). The type of research (applied vs. basic) did not differ by source of funding and students sponsored by industry did not feel their academic freedom was any more constrained than students working on non-sponsored or government-sponsored research (Behrens & Gray, 2001).

Students funded by industry were more than twice as likely to have a committee member who worked full-time in industry (15.8%) than those students funded by government (7%) or with no external funding (6.5%; $\chi^2(2) = 9.4$, $p < .01$). Furthermore, students with an external funding source were more likely to report more technical reports and presentations than graduate students with no external funding (F (22, 435) =

8.36, $p < .00$) (Behrens & Gray, 2001). Thus, it is suggested that students with an external funding source may have more scholarly productions than those students without an external funding source and industry funded students are the most likely students to have a committee member working in industry.

Unlike most of the other center literature, this empirical study was published and provides adequate information concerning sampling, measurement and statistical analyses. It was also one of the only studies that examine graduate students while in school as opposed to retrospective data. Limitations included a potential for a non-respondent bias since it was done via mail survey.

The center literature provides a detailed overview of center activities, mechanisms, and student outcomes. However, since most of the studies provided primarily descriptive statistics and only one study was a published article, the results do not provide a strong basis for understanding which center mechanisms have an impact on student outcomes. Although the findings of the descriptive studies provided a positive evaluation of center studies, these studies are subject to concern for a variety of reasons. First, all but one study used center alumni as opposed to current center graduate students. The self-reported, retrospective data does not provide insight into the current center practices and student experiences. In addition, there were very few studies that used comparison groups. Hypothetical comparisons of center alumni to organizational peers create further suspicions of the findings. For instance, Scott (1992) had to terminate over a third of supervisor responses because the supervisors were not able to distinguish which of their employees were ERC trained. This does not generate a lot of confidence in the findings that relied on supervisors to compare ERC trained employees to non-ERC trained employees.

Most of the research concerning graduate students was conducted by individuals or firms hired to report to the centers or the NSF. Their statistical analyses and measurement developments were not universally available for review. The lack of statistical analyses and sophisticated methodology makes it difficult to draw conclusions. In addition, it appears there was an initial push to look at the effect of center experiences in job performance shortly after the creation of the centers, but a lack of subsequent research in the last decade creates a lack of up-to-date findings. There is a need for "real time" data as opposed to data that is retrospective and cannot be adequately utilized to enhance the current center educational program.

Research on engineering education has indicated there is a need to incorporate more soft skills and applications to the real world in the curriculum. Engaging students with active and cooperative learning techniques were suggested as possible solutions and Cooperative Research Centers are thought to employ some of these suggested educational methods. However, as demonstrated by the heterogeneous results of the STC study (Fitzsimmons et al, 1996), CRCs are diverse and one center's educational practices may be very different from another center's practices. Global level research has been conducted, but individual center educational practices have not been examined. Focusing on the individual center's practices, in addition to the entire program, will offer insight into which individual center's mechanisms are influencing (positively or negatively) student outcomes.

There is a dearth of comprehensive, current literature on graduate students in CRCs and whether a center education is beneficial to students. While, there is evidence that suggests different center activities and mechanisms may impact students' outcomes, the research that has been conducted has weak methodology and statistical analyses. There is almost no research on center graduate students during their time at the centers and almost no multivariate research. Programs have very little information on which center mechanisms and experiences may lead to positive outcomes. These cautionary findings and small number of studies provide a compelling motive to explore current student experiences and the benefits provided by center involvement. In particular, graduate students' experiences in a center may be enhanced by identifying which center mechanisms lead to positive outcomes so that centers can reproduce the good educational practices and minimize the bad (see Figure 1).

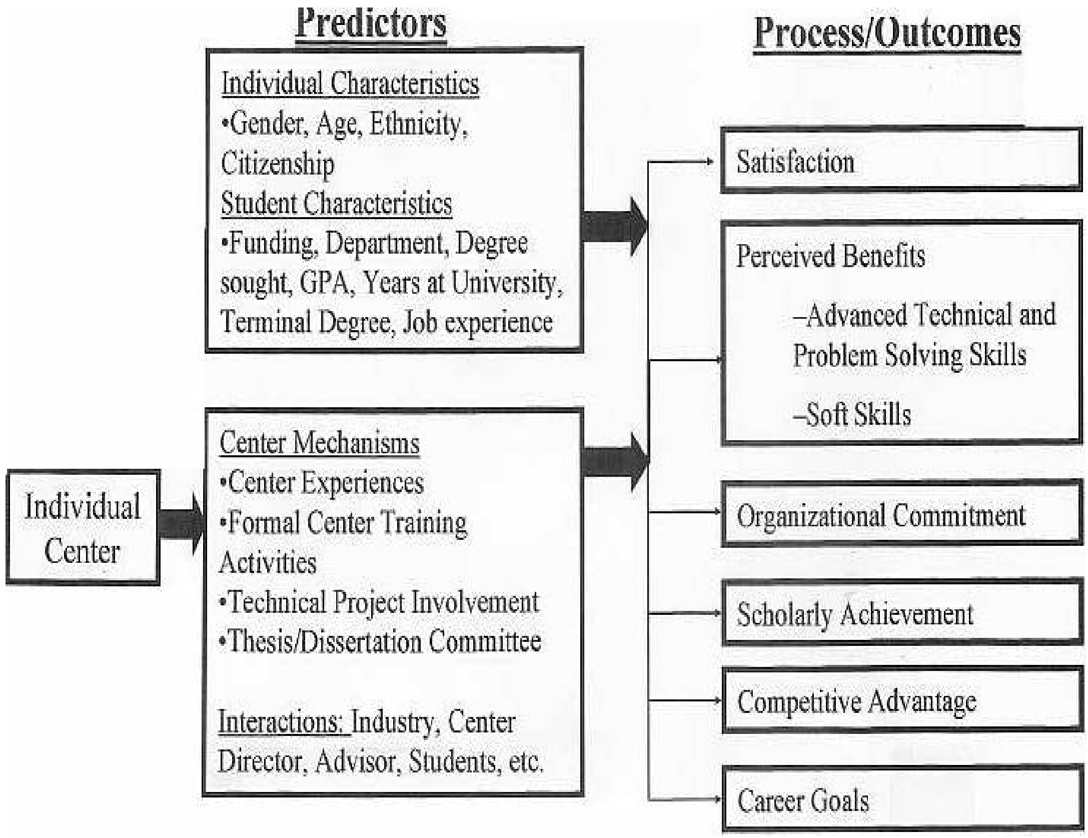

Figure 1: Model of Student Outcomes

METHOD

Research Questions

This research addressed the following questions:

1. What defines a student's center experience?
2. What formal center training mechanisms do centers offer?
3. To what extent are demographic, student, and center characteristics significantly related to graduate students' outcomes (satisfaction, self-reported skills, organizational commitment, scholarly achievements, perceived competitive advantage, and career goals)?
4. To what extent are center experiences and interactions significantly related to graduate students' outcomes (satisfaction, self-reported skills, organizational commitment, scholarly achievements, perceived competitive advantage, and career goals)?
5. After controlling for significant demographic, student, and center characteristics, to what extent are center experiences and interactions significantly related to graduate students' outcomes (satisfaction, self-reported skills, organizational commitment, scholarly achievements, perceived competitive advantage, and career goals)?

Research Design

The study is a cross-sectional predictive analysis of graduate students who are participating in Industry-University Cooperative Research Centers across the United States.

Setting and Population

Data was collected primarily from Industry University Cooperative Research Centers (I/UCRCs) across the nation. During the 2005-2006 fiscal year, there were 39 I/UCRCs (Gray, Rivers, & McGowen, 2007). Since some centers were phased out or inactive, data was collected from only 34 of these entities (87% center participation rate). In addition, data from the Science and Technology Center (STC) for Environmentally Responsible Solvents and Processes (CERSP) was collected (49 graduate students). In order to participate, centers had to be at least one year old and graduate students were required to be involved with their current center for at least six months and be actively seeking a master's or doctoral degree at their center affiliated university. These conditions were required at the time initial contact was made with the center; thus, there were a few students who had graduated by the time data collection began. These students were included in the study. There were no significant differences between the center population and those centers that participated in terms of single or multi site centers, gender, or citizenship. When examining ethnicity, Asian/Asian American, other, and those who did not indicate their ethnicity did significantly differ between the population and the sample. This is thought to be due to the high number of students who did not provide their ethnicities for this study. The number of students per center could not be statistically compared since a standard deviation could not be obtained for these statistics; however, the means seem comparable (see Table 1).

Table 1

Comparison of Population and Sample Characteristics

Characteristic	Population	Sample
Type of Center		
Single-site	35.7%	35.3%
Multi-university site	64.3%	64.7%
n =	*42*	*34*
Average number of doctoral degree students per center	12.34	13.06
n =	*506*	*431*
Average number of master's degree students per center	7.59	8.18
n =	*311*	*270*
Gender		
Male	77.6%	75.3%
Female	22.4%	24.7%
n =	*538*	*190*
Ethnicity		
Caucasian	45.15%	42.1%
Asian/Asian American	42.85%	24.7%
Other	7.49%	13.2%
Not responded	4.51%	20.0%
n =	*538*	*190*
Citizenship Status		
U.S. Citizen	56.4%	48.4%
Non-U.S. Citizen	43.6%	51.6%
n =	*538*	*190*

More specifically, more than half of the students (52.1%) were between the ages of 25 and 28 and a fifth of students were between the ages of 21 and 24. Only about 10% of students were over the age of 32. Participants had been a graduate student at their current university for an average of 3.2 years. The vast majority (89.5%) were current graduate students, while a small percentage of students (10.5%) were recently graduated center students. Center students were majoring in diverse disciplines of engineering and some science. About a quarter of respondents were in either industrial or mechanical engineering (24.2%) and about a fifth were in electrical (22.1%) or chemical (20%) engineering. Over four-fifths of students received funding from their center. The majority (53.2%) of respondents was fully funded and over a quarter received some funding (28.9%). Almost all of the students (86.8%) were seeking their doctoral degree as their terminal degree. Over four-fifths (82.6%) of the students had a GPA higher than 3.6 with almost half (46.8%) of the participating students reporting a GPA between 3.8 and 3.99 and 14.2% a GPA of 4.0. Surprisingly, over a third (34.2%) reported never working or having an internship. See Appendix B: Tables B1-B4 for descriptive statistics.

Procedures

National Science Foundation, I/UCRC evaluators, I/UCRC center directors, and the STC center director approved data collection. The center's director or administrative assistant provided the names and email addresses of their graduate students. Directors had the opportunity to review the survey on the I/UCRC evaluation project's website. Center directors sent a "heads up" email to their center's graduate students asking them to cooperate with data collection and alerting them that the questionnaire will be sent from the I/UCRC evaluation project's email address. This communication served the following purposes: reduced the chances that students will disregard the email, clearly associated the questionnaire with the center, and placed some importance on completing the questionnaire.

The questionnaire was constructed using the literature, counsel of center personnel, personal experiences with the program, and by utilizing qualitative results obtained from a focus group conducted with current center graduate students. The focus group, which included eight center graduate students from three different centers, occurred after developing an outline of the questionnaire. The focus group discussed specific center experiences and elements in order to fine-tune the instrument, items, and scales. The focus group also served to generate an open-ended discussion on center experiences in order to determine if any major elements had been left off the questionnaire. See Appendix A to view the questionnaire.

An anonymous, web-based questionnaire was sent via email to the center graduate students by the researcher. The email provided a description of the study, the expected time the questionnaire would take (approximately 15 minutes), the deadline, and the link to the survey. A web-based questionnaire allowed students to complete the questionnaire when it was convenient for them and also gave students the option to take the questionnaire in a private environment. Keeping the results anonymous was thought to reduce the likelihood of students giving socially desirable responses.

A web survey is thought to be advantageous compared to other methods since it provides immediate data and is low in cost. Although accessibility to the internet is looked at as a disadvantage to web surveys, Harris Poll® (2006) found that 77% of adults have internet access (2006) and this is an extremely conservative estimate for the student population in an academic environment. Additionally, Kaplowitz, Hadlock, and Levine (2004) found web survey response rates to be comparable to response rates of a questionnaire delivered by surface mail.

Respondents were initially given a two-week time period to complete the questionnaire, but this time frame was expanded to approximately two months in order to raise response rates. Upon completion, respondents were sent to a screen that gave them an option to submit their email address to avoid receiving future email reminders. Respondents were assured that their email information would not be linked to their questionnaire results in any way. The researcher only sent out email reminders to those respondents who did not submit their email addresses. The I/UCRC evaluation project sent several follow-up reminders and the center director or center administrator sent at least one reminder before completing data collection.

As an incentive, graduate students who completed the questionnaire and submitted their email address before the deadline were entered in a lottery. One graduate student's email address was then randomly selected to receive a $50 gift certificate to Borders bookstore. Only students who sent an email affirming their questionnaire completion were eligible. Additionally, research results were posted on the I/UCRC evaluation project's website. Demographic information such as ethnicity, gender, and citizenship may contain identifying information due to the small number of students per center. Thus, identifying data was only provided at the national level and not reported by individual center.

The 34 participating centers provided a total of 528 email addresses. Two hundred and eight students responded (39% response rate); however, eighteen respondents had to be excluded from the study since they were either ineligible for participation or returned incomplete questionnaires.[2] Thus, the useable response rate was 37% (n= 190). [3]

Measures

All of the scales were constructed for the purpose of this study. The psychometric properties, including factor analysis and reliability analysis, of each scale were examined. An exploratory factor analysis was conducted on the following measures: satisfaction, self-reported skills, formal center training mechanisms, technical project involvement, and center experiences. Principal axis based factor analysis with a varimax rotation was used to identify factors that explain a substantial portion of the variance in the measures. Variables were assigned to factors where it loaded the highest. A minimum factor-loading standard of 0.4 was used. Subsequent analysis of Cronbach's alpha ensured the measures had adequate reliability. Items that were significantly reducing the factors' reliability were removed from the factor.

In the sections below, the question numbers that correspond to questionnaire numeration are provided.

Outcome Measures

<u>Satisfaction</u>

Satisfaction is a well-researched construct and is a key outcome for evaluating the impact of center-based training on students. Satisfaction can be used in evaluating a person's job, career, product, or experience. Looking specifically at job satisfaction, Spector (1997) defines job satisfaction as "the extent to which people like (satisfaction)

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[2] Respondents had to complete at least two-thirds of the items that constituted a factor in order to be included in the study.
[3] One center used a listserv that was thought to reach approximately 100 graduate students. Their center's response rate was only 16% and this disproportionately affected the overall response rate. The response rate increased to 41% when this center was excluded when calculating the response rate.

or dislike (dissatisfaction) their jobs" (p.2). Spector suggests that job satisfaction is an overall reaction to a person's job as a whole. However, the author also asserts job satisfaction can refer to more specific dimensions within a person's job (Spector, 1997).

Satisfaction has been used as an outcome in a handful of center studies, including studies on faculty (Coberly, 2004; Gray, Rivers, & Schneider, 2006) and industry (Gray, Lindblad, & Rudolph, 2001; Gray, Rivers, & Schneider, 2006). Examining center faculty members, Coberly (2004) found job satisfaction to be a significant predictor of organizational commitment and have an indirect effect on faculty cognitions. In addition, both intrinsic and extrinsic rewards predicted faculty satisfaction (Coberly, 2004). Oshagbemi (1997) also examined what aspects predict faculty job satisfaction and dissatisfaction. Teaching and research activities were found to explain 80% of faculty's satisfaction. In addition, academic freedom and research collaboration were significant predictors. A lack of recognition was found to predict dissatisfaction (Oshagbemi, 1997).

Students could be evaluated on their satisfaction in areas such as their workload, classes, environment, and support system. However, for the purposes of this study, satisfaction is defined as whether students like or dislike their involvement in a center. A rationally created satisfaction scale was devised for this study based on hypothesized elements of a graduate student's experience in a center. The scale included the following 10 items: *center management/administrative operations, degree of autonomy, opportunities to interact with and learn about industry, frequency and quality of interactions with center personnel, financial support, supervision and support, opportunities to learn and practice soft skills, workload, quality and access to facilities and equipment,* and *relevance of the research to career goals (q.X.a-j). Overall* *satisfaction with center experience* was also asked (q.X.k). The variables were rated on a five point Likert scale ranging from 1 = "not satisfied" to 5 = "extremely satisfied". An example of an item on the satisfaction scale is: "Opportunities to interact with and learn about industry and other outside non-academic researchers" (q.X.c). All the items and the full scale are presented in Appendix A: q.X.a-X.k.

A factor analysis determined all ten items constituted one factor. The factor explained nearly half of (48.51%) the variance in students' satisfaction. Thus, the ten items were summed and averaged to create the satisfaction measure (Cronbach's Alpha = .90). The results of the factor analysis are presented in Table 2. This measure had a high correlation to the overall satisfaction item ($r = .80$). The measure's scale mean was 3.68 (S.D. = .72), while the item that asked their overall satisfaction had a mean score of 3.85 (S.D.=.86).

Table 2

Exploratory Factor Analysis Results for Satisfaction

Item	Factor Loading 1	Communality
Center management/administrative operations	.72	.51
Degree of autonomy/independence on thesis/dissertation projects (such as the freedom to discuss research, control over research)	.65	.43
Opportunities to interact with and learn about industry and other outside non-academic researchers	.67	.45
Frequency and quality of interactions with center personnel (such as access to and relationships with faculty, peers, advisors, directors)	.77	.59
Financial support (such as your amount of funding, stipend, tuition, health benefits)	.60	.36
Amount and quality of supervision and support I receive from advisors, faculty, mentors, and peers (such as feedback, recognition, guidance, availability, input)	.71	.50
Opportunities to learn and practice soft skills (such as presentations, communication, leadership)	.72	.51
Workload (such as the amount of time spent on center projects, amount of time spent on center activities, length of projects)	.77	.59
Quality and access to facilities and equipment (such as the sophistication, availability)	.76	.57
Relevance of the research to my career goals	.59	.35
Eigenvalue	4.85	Total Variance
Variance Explained		48.51%

Self-Reported Skills

Although advantages of a student being a part of the center have only been examined in a few studies, center alumni have suggested benefits include things such as: multidisciplinary interactions, access to equipment/facilities, real world experiences, internships, a team atmosphere, career advantages, helpful contacts, and soft skills (Parker, 1997). In particular, the literature appears to support soft skills as a key benefit (Fitzsimmons et al., 1996; Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001). Unfortunately, access to direct ratings of students' knowledge and skills was not available. As a consequence, like other researchers (Scott, Schaad, & Brock, 1991), results were based on students' self-ratings.

Students were asked to rate themselves on a number of items. A rationally created scale was devised for this study based on the hypothesized benefits graduate students experience in a center. The skills were rated using a five point Likert scale ranging from 1 = "beginner" to 5 = "expert". An example of a skill item is: "Collaborate well with others" (VIII.g). All the items and the full scale are presented in Appendix A: q.VIII.a-j.

A factor analysis showed the scale represents two factors: perceived advanced technical and problem solving skills and perceived soft skills. The perceived soft skills factor included four items: *Communication (written and/or oral), leadership, implication of research for application and commercialization, and collaboration*. These four items explained 23.86% of the variance in students' self-reported skills. Thus, the items of the factor were summed and averaged to create the perceived soft skills measure (Cronbach's Alpha = .80). The measure's scale mean was 3.84 (S.D. = .61).

Perceived advanced technical and problem solving skills factor include six items: *computer, technical, and/or laboratory equipment, solving technical problems, understand problems using a systems approach, solving problems within time and money constraints, depth and breadth of your technical area, and multidisciplinary approach to problem solving.* These six items explained 30.75% of the variance in students' self-reported skills. Thus, the items of the factor were summed and averaged to create the Perceived advanced technical and problem solving skills measure (Cronbach's Alpha = .88). The measure's scale mean was 3.83 (S.D. = .66). The results of the factor analysis are presented in Table 3.

Table 3

Exploratory Factor Analysis Results for Skills

Item	Factor Loading: Perceived Advanced Technical and Problem Solving Skills	Factor Loading: Perceived Soft Skills	Communality
Use and understand your area's computer, technical, and/or laboratory equipment	.57	.36	.46
Effectively solve technical problems	.79	.30	.71
Understand problems using a systems approach	.69	.29	.56
Communicate your ideas (via writing and/or oral presentations)	.35	.59	.47
Take charge in a situation and lead your team	.30	.77	.68
Understand the implications of research for application and commercialization	.27	.64	.49
Collaborate well with others	.28	.61	.45
Solve problems within time and money constraints	.62	.41	.55
Understand the depth and breadth of your technical area	.64	.35	.53
Apply the knowledge from different disciplines in an integrated fashion to solve research problems	.70	.26	.56
Eigenvalue	3.08	2.39	Total Variance
Variance Explained	30.75%	23.86%	54.61%

Organizational Commitment

Another construct that is widely used with employees, that may also have some relevance to graduate students, is organizational commitment. Mowday, Steers, and Porter (1979) define organizational commitment as “the relative strength of an individual’s identification with and involvement in a particular organization” (p. 226). Organizational commitment is being asked in addition to satisfaction since organizational commitment is thought to be of a more general construct than satisfaction and should reveal more of a response to the center as a whole (Mowday, Steers, & Porter, 1979). Although students may not have as many research opportunities as faculty, they do have some opportunity to decide where they choose to work and be educated. One center study, which looked at faculty satisfaction and commitment, found satisfaction predicted center faculty’s organizational commitment (Coberly, 2004). In addition, intrinsic rewards were found to have a direct effect on commitment, whereas commitment was found to have a direct effect on retention of faculty (Coberly, 2004).

Looking at organizational commitment outside of Cooperative Research Centers, Cook and Sims (1995) found that graduate student’s attitudes, intentions to continue their degree program, affective commitment, and need for achievement are all significant predictors for attrition. Lok and Crawford (2001) examined organizational commitment of nurses employed in hospitals. Research results indicated organizational subculture was a better predictor (positive association) for commitment than organizational culture. In addition, leadership style, age, and job satisfaction were positively associated to organizational commitment (Lok & Crawford, 2001). Students’ commitment to the center involves more than just the organizational structure, but also emphasizes the various subcultures; thus, characteristics of the team, project, or classroom may be a better predictor than center characteristics.

In order to understand the extent to which demographic, student, and center characteristics, formal center training mechanisms, center experiences, interactions, and thesis or dissertation committee are associated with a student's organizational commitment, students were asked questions assessing their commitment to the center.

Coberly (2004) found an acceptable level of fit to an eight-item organization model representing two factors: commitment (four items) and retention (four items) (χ^2 = 41.33, $p < .01$). The commitment scale had satisfactory reliability (alpha = .88). For the purposes of this study, it was necessary to use an abbreviated version of the scale and focus only on commitment. Two of the four items were selected by examining the factor analyses. The wording of each item was slightly adjusted in order to make the items relevant to graduate students. The items with the lowest loadings on each of the two factors were eliminated. The statements were rated using a five point Likert scale where 1 = "strongly disagree" to 5 = "strongly agree". The two commitment items were "I am proud to tell others I am a part of this center" and "The center really inspires the very best in me in doing research" (Appendix A: q.IX.b-c). The two items were summed and averaged to create the organizational commitment measure (Cronbach's Alpha = .89). The measure's scale mean was 3.90 (S.D. = .83).

<u>Perceived Competitive Advantage</u>

Another benefit graduate students involved with the center may experience is a career benefit. In previous research, employers rated center alumni much or somewhat better when hypothetically compared to their non-center educated employees (Ailes et al., 1997; Fitzsimmons et al., 1996). Therefore, it has been hypothesized that graduate students who receive a full center experience may have an advantage over other graduate students when seeking a job. In order to assess the extent to which students perceive this as a benefit, students were asked to agree or disagree with the following statement: "My Center experiences will give me a competitive edge over other students seeking similar jobs or education following graduation." The statement was rated using a five point Likert scale where 1 = "strongly disagree" to 5 = "strongly agree" (Appendix A: q.IX.a). The variable's mean was 3.81 (S.D. = .91).

Scholarly Achievement

Past research of graduate students in Cooperative Research Centers has reported the majority of students publish papers in refereed journals and present papers at professional society meetings (Fitzsimmons et al., 1996; Parker, 1997). Small percentages of students even report applying for patents (Fitzsimmons et al., 1996). Scholarly achievement is a key outcome for evaluating the impact of center-based training on students and has been used as an outcome in studies of center directors and faculty (Fitzsimmons et al., 1996; Gray, Schneider, & Lloyd, 2005; Parker, 1997). For the purposes of this study, scholarly achievements include publications, presentations, technical reports, publications with industry, and intellectual property events (Appendix A: q.VII.1-4).

Number of publications was determined by summing the number of *refereed journals, refereed proceedings, and not refereed proceedings* (q.VII.1a-c) reported. The number of technical reports was reported separately (VII.1e). Number of presentations was determined by summing *national/international scientific or professional meeting* and *other presentations at scientific or professional meetings that were not national or international* (q.VII.2-3). Students were also asked to indicate if any of their publications were with center industry participants as co-authors (yes/no) (q.VII.1f). Students' were recorded as producing intellectual property events based on center research if they reported any *invention disclosures, patent applications, copyrights, patents/granted/derived, licensing agreements* (q.VII.4a-e); Finally, intellectual property events were coded categorically (yes/no).

Career Goals

Career goals can be defined by where center graduate students plan to seek employment after graduation. The scale provides three career sectors ("industry", "academia", "government"), an "other (specify)", and a "didn't/don't know" option. Due to the small number of responses (n = 2) for the option "other," those respondents who selected "other" were combined with the "government" sector. All the items and the full scale are presented in Appendix A: q.VI.b.

A summary of the outcome measures are presented in Table 4.

Table 4

Summary of Outcome Scales

Outcomes	%	M	SD	# of Items	Reliability
Satisfaction (Range 1 – 5)		3.68	0.72	10	0.90
Skills (Range 1 – 5)					
Perceived Soft Skills		3.84	0.61	4	0.80
Perceived Advanced Technical and Problem Solving Skills		3.83	0.66	6	0.88
Organizational Commitment (Range 1 – 5)		3.89	0.84	2	0.89
Competitive Advantage (Range 1 – 5)		3.81	.91	1	
Scholarly Achievements					
Publications		3.33	4.57	3	
Technical Report		.93	2.05	1	
Presentations		3.95	4.03	2	
Publications with Industry (Yes)*	39.9%			1	
Intellectual Property Events (Yes)	13.2%			5	
Career Goals					
Industry	53.7%			1	
Academia	29.5%			1	
Government/Other	3.7%			1	
Don’t Know Yet	13.2%			1	

Note: n = 190, * n = 178

Predictor Variables

As discussed earlier, centers undoubtedly differ on a variety of dimensions including the formal training mechanism they use and the extent to which they provide students with a training experience that is multidisciplinary, team-based, relevant to their current field, etc. Most of the predictor variables have been devised in order to assess the type of training experience a student receives within individual centers. Correlational analyses were used to examine variable relationships in order to ensure there were no problems of multi-collinearity among the outcome variables (see Appendix B: Table B7).

Experiences of a Graduate Student in a CRC

Technical Project Involvement: Some authors have suggested that center trained students receive better, more demanding technical training. Students were asked to specify their role with various aspects of their center project for the following six aspects: *design of the project, collecting and/or analyzing data, developing the methods for project implementation, reporting and communicating results, supervising others,* and *managing project implementation.* A five point Likert scale ranging from 1 = "not at all involved" to 5 = "extremely involved" was used to assess students' involvement with these activities (Appendix A: q.I.4a-f).

A factor analysis determined the items constituted one factor. "Supervising others" (q.4f) was removed from the factor since it reduced the factor's reliability. The five-item factor (q.4a-e) explained 46.92% of the variance in students' technical project involvement. The five items were summed and averaged for the technical project involvement measure (Cronbach's Alpha = .78). The measure's scale mean was 4.11 (S.D. = .74). The results of the factor analysis are presented in Table 5.

Table 5

Exploratory Factor Analysis Results for Technical Project Involvement

Item	Factor Loading 1	Communality
Overall design of the project	.63	.39
Developing the methods and procedures used in the project	.65	.42
Collecting and/or analyzing data	.64	.41
Reporting and communicating design, methods, and results	.86	.75
Managing the project	.61	.37
Eigenvalue	2.35	Total Variance
Variance Explained		46.92%

Formal Center Training Mechanisms: A few formal center training mechanisms have been mentioned in previous literature, such as whether or not a center offers seminars and/or internships (Ailes et al., 1997; Fitzsimmons et al., 1996). However, centers can offer a variety of different training mechanisms. In order to understand the extent to which exposure to different training mechanisms affects student outcomes, students were asked to report on the availability of the mechanism at their center and their personal involvement. First, students were asked to mark all of the formal training activities their center offers (a total of 10 activities). If the center offers the activity, a second question asked respondents to specify their level of involvement with that mechanism. For those centers that did not offer the activity, respondents were coded as "not at all involved." This ensured a full population for analyses. A five point Likert scale ranging from 1 = "not at all involved" to 5 = "extremely involved" was used to assess students involvement with that activity. An example of one of the mechanisms is: "Scientific/technical seminar series featuring student speakers" (q.III.h). All the items and the full scale are presented in Appendix A: q.III.a-j.

A factor analysis determined the items constituted two factors. The first factor included eight items; however, one of those items, "IAB meetings" (q.III.a), was removed from the factor since it reduced reliability. Thus, the first factor was a seven-item factor (q.III.b-e, g-i) and explained 19.61% of the variance in students' center training mechanisms. The variance explained is fairly low, which may be due to the scale being skewed since those centers that did not offer a training mechanism were coded as "not at all involved." The seven items were summed and averaged to create the formal training mechanism measure (Cronbach's Alpha = .68). The measure's scale mean was 2.18 (S.D. = .74).

The second factor that emerged, Unconventional Training Mechanisms, only includes two items (q.III.f, j), had poor reliability (Cronbach's Alpha = .63) and explained only 13.24% of the variance of students' center training mechanisms. This could be because there were only two items in this factor and few centers offered these items as training mechanisms. Therefore, this factor was not included as a predictor. The results of the factor analysis are presented in Table 6.

Table 6

Exploratory Factor Analysis Results for Center Training Mechanisms

Item	Factor Loading: Advanced Formal Center Training Mechanisms	Factor Loading: Unconventional Center Training Mechanisms	Communality
Co-op or Internship placements	.58	.05	.34
Regular meetings with your project team	.47	-.11	.23
Regular meetings with your entire center team	.42	.15	.20
New academic courses sponsored or developed by the center or center faculty	.58	-.03	.34
Educational interventions targeted at youth (K-12) and sponsored by the center	-.10	.76	.58
Scientific/technical seminar series featuring outside speakers (e.g., professors, industry participants)	.42	.23	.23
Scientific/technical seminar series featuring student speakers (e.g., brown bag, student presentations)	.43	.23	.24
Workshops on "soft skills" or non-technical topics (e.g., teamwork, communication, career development, leadership)	.31	.66	.53
Mentoring (formal mentor assignments)	.48	.22	.28
Eigenvalue	1.77	1.19	Total Variance
Variance Explained	19.61%	13.24%	32.85%

Center Experiences: A student's center experiences have yet to be fully understood since their informal activities and experiences have not been adequately researched. Since research question 1 asked, "What defines a student's center experience?," the results of the factor analyses and full psychometric properties are given in the results section.

Time involved in center: The respondent was asked to specify how long they have been involved with the center. The response choices were: *less than 6 months, 6-12 months, 1-2 years, 2-3 years, 4-5 years,* and *more than 5 years.* Respondents were removed from the study if they answered "less than 6 months" (Appendix A: q. B).

See Table 7 for a summary of the four predictor measures that were developed using factor analyses.

Table 7

Summary of Predictor Scales

	M	SD	# of Items	Reliability
Technical Project Involvement (Range 1-5)	4.11	0.74	5	0.78
Center Mechanisms (Range 1-5)				
Advanced Formal Center Training Mechanisms	2.18	0.74	7	0.68
Center Experiences (Range 1-4)				
Experiential Center Experiences	3.20	0.41	7	0.73
Multidisciplinary Center Experiences	2.98	0.58	4	0.76

Note: n = 190

Hours on Center Activities: Students were asked to specify, on average, how many hours per week they spend on center activities. The eight response choices range from “1-9 hours” to “70 hours or more” (Appendix A: q.I.1).

Size of project team: Students were asked to specify how many people are on their project team. The nine response choices ranged from “2” to “11 or more” (Appendix A: q.I.2). Due to the distribution of responses, those students who indicated they had six or more people on their project team were combined into one unit, resulting in five categories.

Project duration: Students specified how many months the project in which they most actively participate was expected to take. The six response choices ranged from “6 months or less” to “36 months or more.” The question also offered a “no time frame specified” option (Appendix A: q.I.3). Due to the distribution of responses, responses were coded into four categories: 18 months or less, 2 years, 3 or more years, and no time frame specified.

Thesis/Dissertation on center project: Students were asked if their thesis/dissertation is based on a center project (q.II.2). This was coded as a dichotomous variable: “yes” or “no.”

Number of academic departments on thesis/dissertation committee: A student’s committee is defined as those formal members who are responsible for approving and guiding a student’s thesis or dissertation. Students were asked to specify the number of academic departments represented on their thesis or dissertation committee (q.II.3). The scale ranged from “1” to “4” and included an option for those who did not have a committee yet. The number of academic departments on a student’s committee was coded into three categories: one department, two or more departments, and not having a committee yet.

Number of industry/government members on thesis/dissertation committee: Students were asked to specify the number of industry or government center members represented on their thesis or dissertation committee (q.II.4). The scale ranged from "0" to "4" and included an option for those who did not have a committee yet. Because of the lack of variability on this measure, the number of industry/government center members on a committee was treated as dichotomous variable. Those students who marked one or more members on their committee were coded as a "yes" and those students who marked "0" were coded as "no."

Visited Industry Site: To further understand students' interactions with industry or government members, respondents were also asked if they have ever visited an industry or government center member/sponsor site for center related purposes (excluding any internships/co-ops)? This question was dichotomous: "yes" or "no" (q.IV.2).

Interactions

Interactions with various center participants and stakeholders are perceived to be an important aspect of center training. Interactions with industry are assumed to be a primary benefit for students involved in CRCs (Ailes et al., 1997). The majority of industry members report contact with graduate students by phone, email, and in person (Ailes et al., 1997). However, research has shown graduate students desire even more involvement from industry (Fitzsimmons et al., 1996; Parker, 1997). In addition, students have expressed a desire for more contact with faculty (Scott, Schaad, & Brock, 1991). Interactions can be defined as the contact students have with various participants in a center via phone, email, and/or face-to-face. Respondents were asked the number of times, if any, they interacted with the following center participants: their advisor, their thesis or dissertation committee members, other center faculty (not advisor or committee), other center students, center director, center industry or government representatives, and faculty at other universities. Respondents chose the frequency that reflected the number of times they interact with each affiliate. The nine-point scale ranged from "daily" to "never" and included a "not applicable" response. All the items and the full scale are presented in Appendix A: q.IV.1.a-g).

For analyses purpose, respondents who answered "not applicable" were combined with those who responded "never." Thus, the interactions scale had eight categories. "Faculty at other universities" (q.IV.1.g) was not included as a predictor since it had limited variability.

Student Characteristics

In order to understand the extent to which student characteristics of the graduate student are associated with the outcomes, various characteristics of the individual student were collected. Data on the following characteristics were obtained.

Student status: The respondent was asked to specify if they were currently a center graduate student, used to be a graduate student involved in a center, or neither. Respondents were removed from the study if they indicated they were neither a current center graduate student nor a graduated center graduate student (Appendix A: q. A).

University: The graduate student was asked to specify the college or university they were currently attending (Appendix A: q. A2).

Academic department: The graduate student was asked to specify their academic department (Appendix A: q. A3). Academic departments were coded into seven categories: chemical engineering, chemistry, civil engineering, electrical engineering/electrical and computer engineering, materials science and engineering, industrial engineering/mechanical engineering, and other/management information.

Funding: Graduate students were asked if they are currently funded by the center. The response choices were: *yes, fully funded; yes, partially funded; no;* and *other (specify).* Respondents were removed from the study if they answered "no" (Appendix A: q. C).

Degree sought: Graduate students were asked what degree they were currently seeking. The response choices were: *master's degree—I do not plan to pursue a PhD, master's degree—I do plan to pursue a PhD, PhD,* and *other (specify)* (Appendix A: q.II.1). This question was coded to be dichotomous: those students who are planning on a master's degree only and those who are or plan on seeking a PhD.

Years as a graduate student: Participants were asked the number of years they have been a graduate student at their current university. A numerical response in years was given (Appendix A: q.XI.1).

GPA: The graduate students were asked their graduate student GPA. The response choices were: *2.49 or under, 2.5- 2.99, 3.0-3.19, 3.2-3.39, 3.4-3.59, 3.6-3.79, 3.8-3.99,* and *4.0* (Appendix A: q.XI.2).

Job experience: Graduate students were asked if they have worked or are working for a company/industry or government organization. More than one response could be selected. The response choices were: *never, I had an internship/Co-Op, I had a part-time job, I had a full-time job, I currently have a part-time job, and I currently have a full-time* *job* (Appendix A: q.XI.3). Internship/Co-Op was combined with the full-time job category and so job experience was coded to three categories: never, part-time job, and full-time job.

Demographics Characteristics

Gender: Graduate students were asked if they were male or female (Appendix A: q.XI.4).

Age: Graduate students were asked their age. The response choices were: *under 21 years old, 21-24, 25-28, 29-32, 33-36, 37-40,* and *over 40 years old* (Appendix A: q.XI.5).

Ethnicity/race: Graduate students were asked to specify their ethnicity/race. More than one ethnicity/race could be selected. The response choices were: *African American/Black, American Indian/Alaska Native, Asian American, European American/Caucasian/White, Hispanic/Latino, Native Hawaiian or other Pacific Islander,* and *other (Specify)* (Appendix A: q.XI.6). The response items of ethnicity/race were coded into three categories: African American/Black, European American/Caucasian/White, and Other (the rest of the categories were combined).

Citizenship: Graduate students were asked their citizenship status. If the student reported not being a U.S. citizen, multiple follow-up questions were asked. First, students were asked to specify their country of citizenship. Next, they were asked if they planned to become a U.S. citizen (*yes*, *no*, or *undecided*). Lastly, students who were not U.S. citizens were asked where they plan to seek employment after graduation (*U.S., my home country*, *don't know*, or *other*) (Appendix A: q.XI.7).

Center Characteristics

Similar to the demographic characteristics, the characteristics of the student's center may have an effect on the outcomes. The following center characteristics were obtained from the 2004-2005 Report of Center Structural Information (Gray, Schneider & Lloyd, 2006).

Center: The graduate student was asked to specify their center. There was a drop down menu listing all the centers (Appendix A: q. A1).

Single or multi university site: The number of universities involved with the center was coded as being single (one university) or multi (two or more universities involved).

Total center funding: The total center funding was coded in increments of hundred of thousands of dollars. Codes were assigned as follows: 1 = less than $100,000, 2=$100,000-$199,999, 3=$200,000-$299,999, 4=$300,000-$399,999, 5=$400,000-$499,999, 6=$500,000-$599,999, 7=$600,000-$699,999, and 8=$700,000 or more.

Age of the center: The age of the center refers to the number of years the center has existed.

Open-Ended Questions: There were three-open ended questions. The first question asked, "Are there any skills you wish the center had placed greater emphasis on?" The second question asked, "What are the strengths and/or weaknesses of being involved with the center?" The last open end question was, "How can your center improve educational components for graduate students?" (Appendix A: q.VII.2, XII.a-b).

RESULTS

Research Question 1: What defines a student's center experience?

A student's center experience can be defined by various elements of a center. First, descriptive statistics about a student's experience will be presented. This will include characteristics of their thesis/dissertation committees, center projects, center involvement, and their project team size. Then, results of the factor analyses for the center experience measure will be presented.

Although students' experiences varied in many areas, there were some common themes. Well over four-fifths (84.2%) of students indicated their thesis/dissertation was based on a center project. Furthermore, given that 61.1% of students reported having two more academic departments represented on their committees, most of the students' thesis/dissertation committees were multidisciplinary in nature. Also, about a quarter (24.2%) of students reported an industry member served on their thesis/dissertation committee.

The size of a student's project team and their time involvement with their center varied widely. About a fifth of the students had teams with six or more people on them, while nearly a quarter of students had just two (23.7%) or three (24.7%) people on their project teams. When examining how long students have been with their centers, roughly a quarter of students were involved with their center for 1-2 years (24.2%), 2-3 years (24.2%), and for 4-5 years (22.6%). Only 13.2% of students were involved in the center for 6-12 months; on the other hand, less than four-fifths (15.8%) of students had been involved with the center for more than 5 years. About a quarter (26.8%) of students indicated they spent 20-29 hours a week on center related activities, while 37.4% spent between 30 and 49 hours. Over a third (36.8%) of the students had visited an industry member's site for center related purposes.

Center Experiences Measure

A rationally created experience scale was devised for this study based on hypothesized dimensions of graduate student experience in a center. Experiences were initially grouped into five factors: experiential learning, multi-disciplinary, teamwork, soft skills, and technical. Four items (two positively worded and two negatively) represented each factor (a total of 20 items). The items were presented in random order. A four point Likert scale ranging from 1 = "strongly disagree" to 4 = "strongly agree" was used to assess student involvement. An example of one of the experiences items is: "My involvement in the center includes…Opportunities to be a leader" (q.V.l). All the items and the full scale are presented in Appendix A: q.V.a-t.

An exploratory factor analysis was conducted on the twenty center experiences items. However, eight of the ten negatively worded items were removed after initial exploratory factor analysis showed they constituted a factor. However, the only commonality across the items appeared to be the fact that they were all negatively worded. According to literature, the loading of negative items on one factor is not an uncommon problem. Carmines & Zeller (1979) specify there may be a tendency for respondents to respond similarly to items worded in the same direction. "…[I]t is not unusual to find somewhat higher correlations among items which are worded the same direction than among items which differ in the direction of their wording" (Carmines & Zeller, p. 66). In some cases, attempts to negatively word items results in a scale that is an artifact of the wording (Carmines & Zeller, 1979; Spector, Katwyk, Brannick, & Chen, 1997).

Despite removing eight negatively worded items, two negatively worded items were kept (marked with an * below). These two items were kept since they loaded high on a substantive factor. The two items were reverse coded for analyses. The resulting scale used 12 of the 20 initial items. Although five factors were hypothesized, factor analysis suggested two factors: experiential center experiences and multidisciplinary center experiences.

Experiential Center Experiences: The experiential center experiences factor included seven items: *cutting-edge scientific problems, opportunities to be a leader, cooperation and collaboration, hands-on learning, an education that encourages listening and learning from others, applying concepts to actual problem,* and *working with people from diverse backgrounds* (q.V. b, c, e, f, h, j, l). An eighth item of the factor, "being exposed to scientific techniques that would otherwise not be available in my department" (q.V.i), was removed since it reduced the reliability of the experiential center experiences factor. The seven items explained 17.16% of the variance in students' center experiences. They were summed and averaged to create the experiential center experiences measure (Cronbach's Alpha = .73). The measure's scale mean was 3.2 (S.D. = .41).

Multidisciplinary Center Experiences: The multidisciplinary center experiences factor included four items: integrating/synthesizing information from different fields, working/interacting regularly with faculty from other disciplines, using knowledge and research from other disciplines*, and frequent interactions with students from other disciplines* (q.V.m-n, r-s). These four items explained 19.03% of the variance in students' center experiences. These items were summed and averaged to create the multidisciplinary center experiences measure (Cronbach's Alpha = .76). The measure's scale mean was 2.98 (S.D. = .58). The results of the factor analysis are presented in Table 8.

Table 8

Exploratory Factor Analysis Results for Center Experience

Item	Factor Loading		
	Multidisciplinary Center Experiences	Experiential Center Experiences	Communality
Working on scientific problems that are innovative and on the cutting edge	.19	.55	.34
Opportunities to be a leader	.21	.65	.46
Relying on the cooperation and collaboration of other principal investigators/scientists	.28	.43	.27
"Hands-on" learning/learning-by-doing approach	.13	.45	.22
Receiving an education that encourages me to listen, discuss, evaluate, and to learn from the ideas of others	.41	.48	.39
Showing how a particular concept can be applied to an actual problem or situation	.22	.41	.22
Integrating and synthesizing information from different fields in solving problems	.53	.23	.34
Working/interacting regularly with faculty from other disciplines	.69	.33	.58
Rarely using knowledge and research from other disciplines	.73	.10	.54
Infrequent interactions with students from other disciplines	.65	.18	.45
Working with people from diverse backgrounds (e.g., ethnicity, gender, nationality)	.04	.42	.18
Eigenvalue	2.09	1.89	Total Variance
Variance Explained	19.03%	17.16%	36.18%

Research Question 2: What formal center training mechanisms do center's offer?

The scale attempted to measure center training mechanisms at the center and individual level of analysis. Students were first asked, if their center offered a specific training mechanism (e.g., regular team meetings) and how involved they personally were in each mechanism. Unfortunately, there was a general lack of unanimity within centers about whether a training mechanism was offered. This seems to indicate that students were not always aware of center mechanisms and/or sometimes were unclear whether a training mechanism was offered by their department or their center. In order to resolve this discrepancy, a decision was made to code a mechanism as "offered" at the center-level of analysis when 50% of students within a center reported this was the case and "not offered" when less than 50% this was the case. At the individual level of analysis, all students who reported a mechanism was "not offered" were coded as "not involved" on the involvement measure. Further, those students who indicated they were involved, but their center was coded as not offering the mechanism were recoded as "not involved."

Table 9 reports the percentage of centers that offer a specific mechanism and the mean level of involvement students report in each mechanism (for all students and for just those who belonged to a center where the mechanism was offered). Centers were most likely to offer regular meetings with their project team (85.3% of centers) and center team (79.4%), IAB meetings (79.4%), and seminar series featuring outside speakers (79.4%). Only two of the thirty-four centers offered mentoring (5.9%) or K-12 educational interventions (5.9%). When examining student involvement in center mechanisms (1 = "not at all involved" to 5 = "extremely involved"), students reported being most involved in their regular project meetings (mean = 3.42). Also, students reported high involvement in regular meetings with their entire center team (mean = 2.54) and at their periodic center industrial advisory board (IAB) meetings (mean = 2.43).

Table 9

Summary of Center Training Mechanisms

Item	Percentage of centers who offer activity (n = 34)	Mean level of involvement (Range 1-5) (n =190)	Mean level of involvement if center has mechanism
Regular meetings with your project team	85.3	3.42	3.60 (n = 177)
Regular meetings with your entire center team	79.4	2.54	2.78 (n = 165)
Periodic center industrial advisory board (IAB) meetings	79.4	2.43	3.05 (n = 133)
Scientific/technical seminar series featuring outside speakers (e.g., professors, industry participants)	79.4	2.14	2.32 (n = 164)
Scientific/technical seminar series featuring student speakers (e.g., brown bag, student presentations)	64.7	2.25	2.88 (n = 126)
New academic courses sponsored or developed by the center or center faculty	26.5	1.38	2.30 (n = 56)
Co-op or Internship placements	29.4	1.30	1.84 (n = 68)
Workshops on “soft skills” or non-technical topics (e.g., teamwork, communication, career development, leadership)	14.7	1.23	2.63 (n = 27)
Mentoring (formal mentor assignments)	5.9	1.22	2.56 (n = 27)
Educational interventions targeted at youth (K-12) and sponsored by the center	5.9	1.18	2.30 (n = 27)

Analysis Strategy

Research questions 4-5 could be tested at either the individual or the center-level of analysis. That is, if centers (rather than individual faculty, committees or departments) exerted a significant influence on various student experiences, analyses could be performed using center-means rather than individual-level scores. In order to evaluate the appropriateness of this strategy, Intraclass Correlations (ICC) were evaluated for center experiences, technical project involvement, and formal training mechanisms. Since ICCs did not demonstrate sufficient between center variance, all analyses were performed using individual-level scores.

Statistical analyses for research questions three, four, and five followed a trimming approach by means of regression analyses (Lindblad, 2004). A statistical significance of $p < .10$ was utilized for exploratory purposes. First, bivariate regression analyses were run to determine all significant predictors of each of the outcome measures. Negative binomial regression was used to analyze the three scholarly achievement variables that were count data: publications, technical reports, and presentations. Logistic regression was used to analyze the categorical dependent variables: career goals, publications with industry, and intellectual property events. Next, the significant predictors were grouped by domain and tested using multiple regression analyses. The domains included: demographic characteristics, student characteristics, center characteristics, interactions, and center experiences. After running domain level regressions, all significant predictors for each outcome were combined for the full multivariate analysis. For the purpose of this study and analyses, standardized beta coefficients will be used as effect size parameters; however, it should be noted that some authors in this literature recommend using alternative effect size (Johnson, 2000).

Satisfaction

Appendix B shows the results of the bivariate regression analyses for graduate student satisfaction. Twelve of the thirty predictors tested were significant. Multiple regression was used to evaluate the significance of these predictors within variable domains (demographics, student characteristics, center characteristics, interactions and center experiences). The results for each domain are presented in Table 10. Nine of the twelve predictors were still significant at the domain level and were included in the full model. The predictors included in the center experience domain explained the most variance (34%) in student satisfaction.

Five of the nine predictors were still significant in the full model (see Table 11): gender (female reference) (B = -.15) (demographic), interactions with advisor (B = .20), interactions with industry members (B = .16), (interactions), technical project involvement (B = .12), and experiential (B = .27) and multidisciplinary center experiences (B = .22) (center experiences). Experiential center experiences and multidisciplinary center experiences were the largest predictors. The results of the full model suggest that after controlling for gender, center graduate students who report an experience that was more experiential and multidisciplinary in nature, were more involved in various aspects of technical project and interacted more with their advisor and industry members are more likely to be satisfied with the center. The amount of variance explained by the model significantly increased from 34% based on the center experience domain) to 44% in the full model (*F* (6, 180) = 5.52, *p* < .00). This was the largest amount of variance explained in any of the outcomes.

Table 10

Summary of Multiple Regression of Satisfaction on the Predictor Variables by Variable Domain

Variable	B	*B*	P
Demographic Characteristics			
Gender (0=Female, 1=Male)	-.29	-.18	.02
R^2	.03		
Student Characteristics			
Student Funded by Center (0 = No Funding, 1 = Some Funding, 2 = All of Funding)	.15	.16	.03
R^2	.03		
Center Characteristics			
Multi University Center (0=Single, 1=Multi)	-.27	-.18	.02
R^2	.03		
Interactions			
Advisor	.14	.25	.00
Committee	.01	.03	.71
Students	-.01	-.03	.67
Center Director	.06	.21	.01
Industry Members	.11	.20	.01
R^2	.22		
Center Experience			
Technical Project Involvement	.13	.13	.03
Advanced Technical Formal Training Mechanisms	.08	.08	.20
Experiential Center Experiences	.55	.31	.00
Multidisciplinary Center Experiences	.35	.28	.00
R^2	.34		

Note: n = 190

Table 11

Summary of Overall Multiple Regression of Satisfaction

Variable	B	*B*	P
Demographic Characteristics			
Gender (0 = Female, 1 = Male)	-.25	-.15	.01
Student Characteristics			
Student Funded by Center (0 = No Funding, 1 = Some Funding, 2 = All of Funding)	.06	.06	.30
Center Characteristics			
Multi University Center (0 = Single, 1 = Multi)	-.14	-.09	.13
Interactions			
Advisor	.11	.20	.00
Center Director	.01	.02	.74
Industry Members	.08	.16	.01
Center Experience			
Technical Project Involvement	.12	.12	.03
Experiential Center Experiences	.47	.27	.00
Multidisciplinary Center Experiences	.27	.22	.01
R^2	.44		

Note: n = 190

Perceived Soft Skills

Appendix B shows the results of the bivariate regression analyses for graduate students' perceived soft skills. Sixteen of the thirty predictors tested were significant. Multiple regression was used to evaluate the significance of these predictors within variable domains (demographics, student characteristics, interactions and center experiences). The results for each domain are presented in Table 12. Seven of the sixteen predictors were still significant at the domain level and were included in the full model. The predictors included in the center experience domain explained the most variance (22%) in perceived soft skills.

Five of the seven predictors were still significant in the full model (see Table 13): citizenship status (non-U.S. citizen reference) (B = .17) (demographic), number of years at the university (B = .23) (student characteristic), interactions with committee (B = .12) and with industry members (B = .15) (interactions) and technical project involvement (B = .28) (center experiences). Technical project involvement and number of years at university were the largest predictors. The results of the full model suggest that after controlling for the number of years at the university and citizenship status, center graduate students who were more involved in the technical aspects of projects and who had more interactions with their committee and with industry members were more likely to perceive themselves as more proficient in soft skills. The amount of variance explained by the model significantly increased from 22% (based on the center experience domain) to 26% in the full model (F (5, 182) = 5.35, p < .00).

Table 12

Summary of Multiple Regression of Perceived Soft Skills on the Predictor Variables by Variable Domain

Variable	B	*B*	P
Demographic Characteristics			
Citizenship Status (0 = Non-U.S., 1 = U.S.)	.24	.19	.01
R^2	.04		
Student Characteristics			
Number of Years at University	.12	.29	.00
GPA	.07	.12	.09
R^2	.10		
Interactions			
Advisor	.03	.05	.49
Committee	.04	.13	.09
Center Faculty	.01	.02	.78
Students	.01	.04	.67
Center Director	.01	.04	.63
Industry Members	.07	.14	.08
R^2	.08		
Center Experience			
Time Involved In Center	.09	.19	.01
Student Visited Industry Site (0 = No, 1 = Yes)	.13	.10	.16
Technical Project Involvement	.21	.24	.00
Advanced Technical Formal Training Mechanisms	.02	.03	.73
Experiential Center Experiences	.16	.10	.18
Multidisciplinary Center Experiences	.14	.12	.13
Number of Departments on Thesis/Dissertation Committee (One Department Reference)			
No Committee Yet vs. One Department	.35	.20	.02
Two or More Departments vs. One Department	.16	.10	.28
R^2	.22		

Note: n = 190

Table 13

Summary of Overall Multiple Regression of Perceived Soft Skills

Variable	B	*B*	P
Demographic Characteristics			
Citizenship Status (0 = Non-U.S., 1 = U.S.)	.22	.17	.01
Student Characteristics			
Number of Years at University	.10	.23	.01
GPA	.05	.08	.22
Interactions			
Committee	.04	.12	.07
Industry Members	.07	.15	.03
Center Experience			
Time Involved In Center	.01	.02	.79
Technical Project Involvement	.24	.28	.00
R^2	.26		

Note: n = 190

Perceived Advanced Technical and Problem Solving Skills

Appendix B shows the results of the bivariate regression analyses for graduate students' perceived advanced technical and problem solving skills. Fourteen of the thirty predictors tested were significant. Multiple regression was used to evaluate the significance of these predictors within variable domains (demographics, student characteristics, interactions and center experiences). The results for each domain are presented in Table 14. Eight of the sixteen predictors were still significant at the domain level and were included in the full model. The predictors included in the center experience domain explained the most variance (33%) in perceived advanced technical and problem solving.

Five of the eight predictors were still significant in the full model (see Table 15): number of years at the university (B = .17), (student characteristic), interactions with committee (B = .13) (interactions), technical project involvement (B = .23), multidisciplinary center experiences (B = .27), and one department on thesis/dissertation committee vs. no committee yet (B = .22) (center experiences). The variables in the center experiences domain were the largest predictors: multidisciplinary center experiences, technical project involvement, and one department on thesis/dissertation committee vs. no committee yet. The results of this model imply that after controlling for the number of years in graduate school at their current university, center graduate students who report an experience that was more multidisciplinary in nature, who were more involved in various technical aspects of the projects, who had a thesis/dissertation committee with one academic department, and who interacted more frequently with their committee members were more likely to perceive themselves as more proficient in advanced technical and problem solving skills. The amount of variance explained by the model significantly increased from 33% (based on the center experience domain) to 36% in the full model (*F* (4, 180) = 3.32, *p* = .01).

Table 14

Summary of Multiple Regression of Perceived Advanced Technical and Problem Solving Skills on the Predictor Variables by Variable Domain

Variable	B	*B*	P
Demographic Characteristics			
Age	.13	.22	.00
R^2	.05		
Student Characteristics			
Number of Years at University	.14	.35	.00
Student Status (0=Graduated Student, 1 = Current Graduate Student)	-.22	-.11	.11
R^2	.14		
Interactions			
Advisor	.03	.06	.38
Committee	.06	.20	.01
Industry Members	.07	.15	.04
R^2	.09		
Center Experience			
Time Involved In Center	.09	.19	.01
Student Visited Industry Site (0 = No, 1 = Yes)	.10	.08	.24
Technical Project Involvement	.18	.21	.00
Advanced Technical Formal Training Mechanisms	-.01	-.01	.90
Experiential Center Experiences	.03	.02	.80
Multidisciplinary Center Experiences	.33	.32	.00
Industry Member on Thesis/Dissertation Committee (0 = No, 1 = Yes)	.09	.06	.36
Number of Departments on Thesis/Dissertation Committee (No Committee Yet Reference)			
One Department vs. No Committee Yet	.47	.28	.00
Two or More Departments vs. No Committee Yet	.24	.19	.03
R^2	.33		

Note: n = 190

Table 15

Summary of Overall Multiple Regression of Perceived Advanced Technical and Problem Solving Variables

Variable	B	*B*	P
Demographic Characteristics			
Age	.05	.08	.25
Student Characteristics			
Number of Years at University	.07	.17	.06
Interactions			
Committee	.04	.13	.05
Industry Members	.04	.08	.21
Center Experience			
Time Involved In Center	.03	.06	.48
Technical Project Involvement	.19	.23	.00
Multidisciplinary Center Experiences	.29	.27	.00
Number of Departments on Thesis/Dissertation Committee			
One Department vs. No Committee Yet	.37	.22	.01
Two or More Departments vs. No Committee Yet	.18	.14	.10
Two or More Departments vs. One Department	-.19	-.16	.08
R^2	.36		

Note: n = 190

Organizational Commitment

Appendix B shows the results of the bivariate regression analyses for graduate students' organizational commitment. Thirteen of the thirty predictors tested were significant. Multiple regression was used to evaluate the significance of these predictors within variable domains (demographic characteristics, student characteristics, center characteristics, interactions and center experiences). The results for each domain are presented in Table 16. Eight of the sixteen predictors were still significant at the domain level and were included in the full model. The predictors included in the center experience domain explained the most variance (34%) in organizational commitment.

Five of the eight predictors were still significant in the full model (see Table 17): ethnicity (Asian/Asian American vs. Caucasian ($\underline{B}$ = 24) non responders vs. Caucasian ($\underline{B}$ = 11) (demographic), interactions with center director ($\underline{B}$ = .13) (interactions), experiential ($\underline{B}$ = .35) and multidisciplinary center experiences ($\underline{B}$ = .19), and the number of departments on thesis/dissertation (one department vs. no committee yet ($\underline{B}$ = .19); two or more departments vs. no committee yet ($\underline{B}$ = .25)) (center experiences). The two largest predictors of organizational commitment were both in the center experiences domain: experiential center experiences and the number of departments on thesis/dissertation). The results of this model imply that after controlling for ethnicity, center graduate students who report an experience that was more experiential in nature, who had a thesis/dissertation committee, who agreed that their center offered more multidisciplinary experiences, and who interacted more with their center director had higher levels of organizational commitment to their center. The amount of variance explained by the model significantly increased from 34% (based on the center experience domain) to 40% in the full model (F (7, 178) = 2.78, p = .01). Organizational commitment's variance explained was the second largest among the outcomes.

Table 16

Summary of Multiple Regression of Organizational Commitment on the Predictor Variables by Variable Domain

Variable	B	B	P
Demographic Characteristics			
Ethnicity (Caucasian Reference)			
Asian/Asian American vs. Caucasian	.39	.20	.01
Other vs. Caucasian	.17	.07	.37
Not Available vs. Caucasian	.07	.04	.65
R^2	.04		
Student Characteristics			
Student Funded by Center (0 = No Funding, 1 = Some Funding, 2 = All of Funding)	.14	.13	.07
Number of Years at University	.07	.12	.09
R^2	.03		
Center Characteristics			
Multi University Center (0 = Single, 1 = Multi)	-.34	-.19	.01
R^2	.04		
Interactions			
Advisor	.02	.04	.61
Center Director	.10	.28	.00
Industry Members	.06	.09	.22
R^2	.11		
Center Experience			
Time Involved In Center	.03	.04	.58
Technical Project Involvement	.03	.03	.64
Advanced Technical Formal Training Mechanisms	.07	.07	.33
Experiential Center Experiences	.79	.39	.00
Multidisciplinary Center Experiences	.25	.17	.02
Number of Departments on Thesis/Dissertation Committee (No Committee Yet Reference)			
One Department vs. No Committee Yet	.42	.18	.02
Two or More Departments vs. No Committee Yet	.40	.23	.00
R^2	.34		

Note: n = 190

Table 17

Summary of Overall Multiple Regression of Organizational Commitment

Variable	B	*B*	P
Demographic Characteristics			
Ethnicity			
Asian/Asian American vs. Caucasian	.46	.24	.00
Other vs. Caucasian	.22	.09	.16
Not Available vs. Caucasian	.23	.11	.09
Other vs. Asian/Asian American	-.24	-.10	.16
Not Available vs. Asian/Asian American	-.23	-.11	.12
Student Characteristics			
Student Funded by Center (0 = No Funding, 1 = Some Funding, 2 = All of Funding)	.02	.02	.71
Number of Years at University	-.01	-.01	.89
Center Characteristics			
Multi University Center (0 = Single, 1 = Multi)	-.10	-.06	.35
Interactions			
Center Director	.05	.13	.05
Center Experience			
Experiential Center Experiences	.70	.35	.00
Multidisciplinary Center Experiences	.27	.19	.01
Number of Departments on Thesis/Dissertation Committee			
One Department vs. No Committee Yet	.43	.19	.01
Two or more departments vs. No Committee Yet	.42	.25	.00
Two or More Departments vs. One Department	-.01	-.00	.96
R^2	.40		

Note: n = 190

<u>Competitive Advantage</u>

Appendix B shows the results of the bivariate regression analyses for graduate students' competitive advantage. Nine of the thirty predictors tested were significant. Multiple regression was used to evaluate the significance of these predictors within variable domains (student characteristics, center characteristics, interactions and center experiences). The results for each domain are presented in Table 18. Three of the nine predictors were still significant at the domain level and were included in the full model. The predictors included in the center experience domain explained the most variance (22%) in competitive advantage.

Two of the three predictors were still significant in the full model (see Table 19): total center funding ($\underline{B}$ = -.16) (center characteristics) and experiential center experiences (center experiences). The largest predictor was experiential center experiences ($\underline{B}$ = .43). Surprisingly, the less total center funding a student's center had, the more likely they were to feel they had a competitive advantage. The results of this model imply that after controlling for total center funding, center graduate students who report an experience that was more experiential in nature were more likely to perceive themselves as having a competitive advantage when compared to other students seeking similar jobs or education following graduation. The amount of variance explained by the model increased from 22% (based on the center experience domain) to 23% in the full model (F (2, 186) = 3.39, p = .04). Although the explained variance in the final model only increased by one percent, this was a significant increase from the center experience domain.

Table 18

Summary of Multiple Regression of Competitive Advantage on the Predictor Variables by Variable Domain

Variable	B	*B*	P
Student Characteristics			
Academic Department (Chemical Engineering Reference)			
Chemistry vs. Chemical Engineering	-.14	-.04	.60
Civil Engineering vs. Chemical Engineering	.60	.15	.06
Electrical Engineering vs. Chemical Engineering	.01	.01	.95
Materials Science vs. Chemical Engineering	.63	.17	.03
Industrial Mechanical Engineering vs. Chemical Engineering	.31	.15	.12
Management Information/Other vs. Chemical Engineering	.48	.18	.04
R^2	.07		
Center Characteristics			
Multi University Center (0 = Single, 1 = Multi)	-.17	-.09	.25
Total Center Funding	-.07	-.15	.05
R^2	.04		
Interactions			
Faculty	.05	.11	.17
Center Director	.06	.15	.05
Industry Members	.07	.10	.18
R^2	.07		
Center Experience			
Advanced Technical Formal Training Mechanisms	.09	.07	.30
Experiential Center Experiences	.80	.36	.00
Multidisciplinary Center Experiences	.19	.12	.12
R^2	.22		

Note: n = 190

Table 19

Summary of Overall Multiple Regression of Competitive Advantage

Variable	B	*B*	P
Center Characteristics			
Total Center Funding	-.07	-.16	.02
Interactions			
Center Director	.01	.03	.66
Center Experience			
Experiential Center Experiences	.95	.43	.00
R^2	.23		

Note: n = 190

<u>Publications</u>

Appendix B shows the results of the negative binomial regression analyses for the number of graduate students' publications. Fourteen of the thirty predictors tested were significant. Multiple negative binomial regression was used to evaluate the significance of these predictors within variable domains (demographic characteristics, student characteristics, center characteristics, interactions and center experiences). The results for each domain are presented in Table 20. Eleven of the fourteen predictors were still significant at the domain level and were included in the full model. The predictors included in the center experience domain explained the most variance (6%) in the number of publications.

Seven of the eleven predictors were still significant in the full model (see Table 21): citizenship status (non-U.S. citizen reference) (Odds Ratio = .64) (demographics), student status (graduated center student reference) (Odds Ratio = .50), highest degree expected to complete (master's degree reference) (Odds Ratio = 2.11), academic department (chemistry vs. chemical engineering (Odds Ratio = .41) and management information/other vs. chemical engineering (Odds Ratio = 1.66)) (student characteristics), interactions with committee (interactions) (Odds Ratio = 1.16), time involved in center (Odds Ratio = 1.30), and advanced technical formal training mechanisms (Odds Ratio = 1.29) (center experiences). Highest degree expected to complete, academic department, time involved in center, and advanced technical formal training mechanisms were the largest predictors. The results of this model imply that after controlling for highest degree expected to complete, academic department citizenship status, and whether or not the respondent is a current or graduated center student, those students who spent more time on center related work and projects, who were more involved in advanced formal training mechanisms, and who interacted more frequently with their committee members were more likely to produce more publications. The amount of variance explained by the model increased from 6% (based on the center experience domain) to 11% in the full model.

Technical Reports

Appendix B shows the results of the negative binomial regression analyses for graduate students' production of technical reports. Eleven of the thirty predictors tested were significant. Multiple negative binomial regression was used to evaluate the significance of these predictors within variable domains (student characteristics, interactions, and center experiences). The results for each domain are presented in Table 20. Five of the eleven predictors were still significant at the domain level and were included in the full model. The predictors included in the center experience domain explained the most variance (3%) in production of technical reports.

Two of the five predictors were still significant in the full model (see Table 21): GPA (Odds Ratio = .77) (student characteristic) and interactions with committee (Odds Ratio = 1.15) (interactions). Interestingly, the lower a student's GPA, the more likely they were to produce technical reports. The results of this model imply that after controlling for GPA, those students who interacted more frequently with their committee members are 1.15 times more likely to have produced technical reports. The amount of variance explained by the model increased from 3% (based on the center experience domain) to 5% in the full model.

Table 20

Summary of Negative Binomial Regression of Publications, Technical Reports, and Presentations on the Predictor Variables by Variable Domain

Variable	Publications		Technical Reports		Presentations	
	Coefficient	Odds Ratio	Coefficient	Odds Ratio	Coefficient	Odds Ratio
Demographic Characteristics						
Citizenship Status (0 = Non-U.S., 1 = U.S.)	-.40	.67**				
Age	.28	1.32**				
Psuedo R^2	.01					
X^2	12.91, 2, p = .002					
Student Characteristics						
Number of Years at University	.25	1.28***	.20	1.22*	.19	1.21***
GPA	.12	1.12	-.26	.77*	-.34	.71
Student Status (0=Graduated Student, 1 = Current Graduate Student)	-.71	.49**	.88	2.40		
Highest Degree Expected to Complete (0 = Masters, 1 = PhD)	.67	1.96*				
Job Experience (0 = No, 1 = Co-op/Internship, 2 = Part-time, 3 = Full-time)			.16	1.17		
Academic Department (Chemical Engineering Reference)						
Chemistry vs. Chemical Engineering	-1.11	.33**				
Civil Engineering vs. Chemical Engineering	.52	1.68				
Electrical Engineering vs. Chemical Engineering	.20	1.21				
Materials Science vs. Chemical Engineering	-.13	.88				
Industrial Mechanical Engineering vs. Chemical Engineering	.47	1.60*				
Management Information/Other vs. Chemical Engineering	.37	1.44				
Psuedo R^2	.06		.02		.02	
X^2	52.58, 10, p < .001		11.86, 4, p = .02		17.69, 2, p < .001	
Center Characteristics						
Multi University Center (0 = Single, 1 = Multi)	-.38	.69*				
Psuedo R^2	.004					
X^2	3.65, 1, p = .06					
Interactions						
Advisor					.11	1.12**
Committee	.11	1.12**	.19	1.21**		
Center Director			.07	1.07		
Industry Members			.15	1.16		
Psuedo R^2	.01		.02		.01	
X^2	6.16, 1, p = 001		10.08, 3, p = .02		4.45, 1, p = .04	
Center Experience						
Time Involved In Center	.36	1.43***	.23	1.26*	.27	1.30***
Hours Spent on Center Activities	.04	1.04			-.01	.99
Technical Project Involvement					.32	1.38***
Advanced Technical Formal Training Mechanisms	.31	1.36**	.25	1.28	.05	1.06
Experiential Center Experiences				1.15		
Multidisciplinary Center Experiences	-.02	.98			.14	1.15
Number of Departments on Thesis/Dissertation Committee (No Committee Yet Reference)						
One Department vs. No Committee Yet	.47	1.60				
Two or More Departments vs. No Committee Yet	.64	1.90**				
Project Duration (18 months or Less Reference)						
No time specified vs. 18 months or Less			.29	1.34	.41	1.50**
More than 18 months to 2 years vs. 18 months or Less			-.94	.39*	-.15	.86
3 or more years vs. 18 months or Less			-.04	.96	-.01	.99
Psuedo R^2	.06		.03		.05	
X^2	51.04, 6, p < .001		15.04, 6, p = .02		46.30, 8, p < .001	

Note: n = 190; *p<.10, **p<.05, ***p<.01

Table 21

Summary of Negative Binomial of Publications, Technical Reports, and Presentations

Variable	Publications		Technical Reports		Presentations	
	Coefficient	Odds Ratio	Coefficient	Odds Ratio	Coefficient	Odds Ratio
Demographic Characteristics						
Citizenship Status (0 = Non-U.S., 1 = U.S.)	-.45	.64**				
Age	.12	1.23				
Student Characteristics						
Number of Years at University	.08	1.08	.14	1.16	.09	1.09
GPA			-.27	.77*		
Student Status (0=Graduated Student, 1 = Current Graduate Student)	-.69	.50**				
Highest Degree Expected to Complete (0 = Masters, 1 = PhD)	.75	2.11**				
Academic Department (Chemical Engineering Reference)						
Chemistry vs. Chemical Engineering	-.89	.41**				
Civil Engineering vs. Chemical Engineering	.40	1.50				
Electrical Engineering vs. Chemical Engineering	.38	1.46				
Materials Science vs. Chemical Engineering	-.06	.95				
Industrial Mechanical Engineering vs. Chemical Engineering	.42	1.52				
Management Information/Other vs. Chemical Engineering	.51	1.66*				
Center Characteristics						
Multi University Center (0 = Single, 1 = Multi)	.21	1.23				
Interactions						
Advisor					.11	1.11**
Committee	.15	1.16***	.14	1.15*		
Center Experience						
Time Involved In Center	.26	1.30***	.16	1.17	.21	1.23***
Technical Project Involvement					.29	1.38***
Advanced Technical Formal Training Mechanisms	.26	1.29**				
Number of Departments on Thesis/Dissertation Committee (No Committee Yet Reference)						
One Department vs. No Committee Yet	.10	1.11				
Two or More Departments vs. No Committee Yet	.35	1.43				
Project Duration (18 months or Less Reference)						
No time specified vs. 18 months or Less			.53	.170	.31	.76
More than 18 months to 2 years vs. 18 months or Less			-.71	.49	-.27	.89
3 or more years vs. 18 months or Less			.07	1.07	-.12	1.36
Psuedo R^2	.11		.05		.05	
X^2	98.59, 17, $p < .001$		22.08, 7, $p = .003$		50.24, 7, $p < .001$	

Note: n = 190; *p<.10, **p<.05, ***p<.01

Presentations

Appendix B shows the results of the negative binomial regression analyses for graduate students' number of presentations. Nine of the thirty predictors tested were significant. Multiple negative binomial regression was used to evaluate the significance of these predictors within variable domains (student characteristics, interactions, and center experiences). The results for each domain are presented in Table 20. Five of the nine predictors were still significant at the domain level and were included in the full model. The predictors included in the center experience domain explained the most variance (5%) in the number of student presentations.

Three of the five predictors were still significant in the full model (see Table 21): interactions with advisor (Odds Ratio = 1.11) (interactions), time involved in center (Odds Ratio = 1.23), and technical project involvement (Odds Ratio = 1.38) (center experiences). The center experiences variables, technical project involvement and time involved in center, were the largest predictors of presentations. The results of this model imply those students who were more involved in various technical aspects of center projects, who were a part of the center longer, and who interacted more with their advisor were more likely to give presentations. The amount of variance explained by the model remained at 5% from the center experience domain base to the full model.

Career Goals

Appendix B shows the results of the bivariate regression analyses for students' career goals. The predictor, highest degree the student was planning on receiving, was so strongly correlated with career goals that it would not run as a predictor (no students seeking a master's degree planned on going into academia); therefore, highest degree sought was excluded from the regression analyses. Six of the thirty predictors tested were significant. Logistic regression was used to evaluate the significance of these predictors within variable domains (demographics, student characteristics, and center characteristics). The results for each domain are presented in Table 22. Three of the six predictors were still significant at the domain level and were included in the full model. The predictors included in the student characteristics domain reduced the error in predicting the log odds by 11% in students' career goals.

All three predictors remained significant in the full model (see Table 23): student funded by center (no center funding reference), job experience (student characteristics), and center age (center characteristics). The strongest overall predictor of whether or not the student wanted a career in academia or industry was whether or not the student received center funding. The more funding support a student received the less likely they were to plan a career in academia (odds reduced by .52). However, those students who had more job experience were .44 times more likely to go into careers in academia than industry. The error in predicting the logs odd increased from 11% (based on the student characteristics domain) to 16% in the full model. This was a significant change (X^2 = 10.92, 3, p = .01) (see Appendix B: Table B8 for more detailed results).

Table 22

Summary of Logistic Regression of Career Goals on the Predictor Variables by Variable Domain

Variable	X^2	df	Academia vs. Industry (Industry Reference) Coefficient	Odds Ratio
Demographic Characteristics				
Gender (0=Female, 1=Male)	6.10	3	-.22	.81
Citizenship Status (0 = Non-U.S., 1 = U.S.)	2.49	3	.09	1.10
Ethnicity	7.56	9		
Caucasian			.46	1.59
Asian/Asian American			-.51	.60
Other			.63	1.89
Nagelkerke R^2	.15			
Student Characteristics				
Student Funded by Center (0 = No Funding, 1 = Some Funding, 2 = All of Funding)	11.78***	3	-.74	.48***
Job Experience (0 = No, 1 = Co-op/Internship, 2 = Part-time, 3 = Full-time)	7.66*	3	.37	1.45**
Nagelkerke R^2	.11			
Center Characteristics				
Center Age	10.48**	3	.00	1.0
Nagelkerke R^2	.06			

Note: n = 190; *p<.10, **p<.05, ***p<.01

Table 23

Summary of Logistic Regression of Career Goals

			Academia vs. Industry (Industry Reference)	
Variable	X^2	df	Coefficient	Odds Ratio
Student Characteristics				
Student Funded by Center (0 = No Funding, 1 = Some Funding, 2 = All of Funding)	11.98***	3	-.74	.48***
Job Experience (0 = No, 1 = Co-op/Internship, 2 = Part-time, 3 = Full-time)	7.95**	3	.37	1.44**
Center Characteristics				
Center Age	10.92**	3	-.01	.99
Nagelkerke R^2	.16			

Note: n = 190; *p<.10, **p<.05, ***p<.01

Publications with Industry

Appendix B shows the results of the bivariate regression analyses for whether or not graduate students published with industry as co-authors. Ten of the thirty predictors tested were significant. Logistic regression was used to evaluate the significance of these predictors within variable domains (demographics, student characteristics, center characteristics, and center experiences). The results for each domain are presented in Table 24. Seven of the ten predictors were still significant at the domain level and were included in the full model. The predictors included in the center experience domain reduced the error in predicting the log odds by 16% in whether or not students had published with industry.

Two of the seven predictors were still significant in the full model (see Table 25): student visited industry site (Odds Ratio = 2.19) and advanced technical formal training mechanisms (Odds Ratio = 1.60) (center experiences). The greater of the two predictors was whether or not the student had visited an industry site. Students were more than twice as likely to publish with industry if they had visited an industry site. The results of this model imply that the students who visited an industry site and who were more involved in advanced technical formal training mechanisms were more likely to publish with industry members as co-authors. The error in predicting the logs odd increased from 16% (based on the center experience domain) to 19% in the full model. This was not a significant increase ($X^2 = 6.07, 3, p > .05$).

Table 24

Summary of Logistic Regression of Publications with Industry and Intellectual Property Events on the Predictor Variables by Variable Domain

Variable	Publication with Industry		Intellectual Property Events	
	Coefficient	Odds Ratio	Coefficient	Odds Ratio
Demographic Characteristics				
Age	.27	1.32*		
Citizenship Status (0 = Non-U.S., 1 = U.S.)	-.34	.71		
Ethnicity (Caucasian Reference)				
Asian/Asian American vs. Caucasian	-.41	.66		
Other vs. Caucasian	.45	1.57		
Not Available vs. Caucasian	-.08	1.08		
Nagelkerke R^2	.10			
Student Characteristics				
Number of Years at University	.29	1.34***	.44	1.55***
Student Status (0=Graduated Student, 1 = Current Graduate Student)	-.90	.41*		
Student Funded by Center (0 = No Funding, 1 = Some Funding, 2 = All of Funding)			.80	2.22**
Academic Department (Chemical Engineering Reference)				
Chemistry vs. Chemical Engineering			19.42	.00
Civil Engineering vs. Chemical Engineering			18.95	.00
Electrical Engineering vs. Chemical Engineering			19.74	.00
Materials Science vs. Chemical Engineering			19.74	.00
Industrial Mechanical Engineering vs. Chemical Engineering			19.15	.00
Management Information/Other vs. Chemical Engineering			20.74	.00
Nagelkerke R^2	.08		.27	
Center Characteristics				
Center Age	.07	1.07**		
Nagelkerke R^2	.04			
Interactions				
Industry Members			.25	1.29*
Nagelkerke R^2			.03	
Center Experience				
Hours on Center Activities			.18	1.20
Time Involved In Center	.28	1.33*	.16	1.17
Student Visited Industry Site (0 = No, 1 = Yes)	.76	2.13**	1.58	4.80***
Advanced Technical Formal Training Mechanisms	.48	1.61**	.12	1.13
Number of Departments on Thesis/Dissertation Committee (One Department Reference)				
No Committee Yet vs. One Department	.41	1.51	-.62	.54
Two or More Departments vs. One Department	.57	1.77	1.23	3.08
Nagelkerke R^2	.16		.25	
	n = 178		n = 190	

Note: *p<.10, **p<.05, ***p<.01

Table 25

Summary of Logistic Regression of Publications with Industry and Intellectual Property Events

Variable	Publication with Industry		Intellectual Property Events	
	Coefficient	Odds Ratio	Coefficient	Odds Ratio
Demographic Characteristics				
Age	.08	1.10		
Student Characteristics				
Number of Years at University	.16	1.17	.34	1.41*
Student Status (0=Graduated Student, 1 = Current Graduate Student)	-.92	.40		
Student Funded by Center (0 = No Funding, 1 = Some Funding, 2 = All of Funding)			.65	1.91*
Center Characteristics				
Center Age	.05	1.05		
Interactions				
Industry Members			.08	1.09
Center Experience				
Time Involved In Center	.15	1.61		
Student Visited Industry Site (0 = No, 1 = Yes)	.78	2.19**	1.57	4.79***
Advanced Technical Formal Training Mechanisms	.47	1.60**		
Nagelkerke R^2	.19		.23	
	n = 178		n = 190	

Note: **p*<.10, ***p*<.05, ****p*<.01

Intellectual Property Events

Appendix B shows the results of the bivariate regression analyses for whether or not center students produced an intellectual property event. Nine of the thirty predictors tested were significant. Logistic regression was used to evaluate the significance of these predictors within variable domains (student characteristics, interactions, and center experiences). The results for each domain are presented in Table 24. Four of the nine predictors were still significant at the domain level and were included in the full model. The predictors included in the student characteristics domain reduced the error in predicting the log odds by 27% in whether or not students had published with industry.

Three of the four predictors were still significant in the full model (see Table 25): number of years at the university (Odds Ratio = 1.41), student funded by center (no center funding reference) (Odds Ratio = 1.91) (student characteristics), and student visited industry site (Odds Ratio = 4.79) (center experiences). The strongest predictor of intellectual property events was whether or not the student had visited an industry site (not visited reference). The results of this model imply that after controlling for student funding and the number of years at their university, those students who visited an industry site were 4.79 times more likely to produce an intellectual property event than those that did not visit an industry site. The error in predicting the logs odd significantly decreased from 27% (based on the student characteristics domain) to 23% in the full model ($X^2 = 12.41, 2, p = .01$). This indicates the student characteristic domain model is a better model for predicting intellectual property events than the full model.

Exploratory Analyses

Moderation of Competitive Advantage and Satisfaction

Citizenship status (non-U.S. citizen reference), gender (female reference), and job experience were tested in order to determine if they significantly moderated the relationship between satisfaction and the model's significant predictors: gender, interactions with their advisor, interactions with industry members, technical project involvement, experiential center experiences, and multidisciplinary center experiences. Also, citizenship status, gender, and job experience were tested to see if they moderated any of the relationships between competitive advantage and the outcome's significant predictors: total center funding and experiential center experiences.

The variables were tested as moderators by running the multivariate model for the outcome with only the significant predictors. The moderator variable and the interaction term between the moderating variable and the predictor being tested were also included. There were no significant moderator effects for competitive advantage.

Job experience was not a significant moderator of satisfaction; however, both citizenship status and gender moderated the relationship between satisfaction and experiential center experiences ($\underline{B} = -.89$, $p = .05$ and $\underline{B} = 1.02$, $p = .02$ respectively).

The interactions for citizenship status and gender are graphed in Figure 2 and 3. As Figure 2 demonstrates, at low levels of experiential training, U.S. students were significantly more satisfied than their non-U.S. peers. However, as experiential training increased this difference disappears. In fact, at the highest levels of experiential training, non-U.S. citizens had higher levels of satisfaction than U.S. citizens. Thus, while satisfaction increased for both groups with increasing experiential training, the slope for non-U.S. citizens appears to be greater.

A similar interaction pattern is revealed for the interaction of gender and experiential center experience on satisfaction. At low levels of experiential center experience, female students were more satisfied than males (Figure 3). However, as experiential center experiences increased, this difference disappears. As a consequence, it appears experiential training had a greater impact on the satisfaction of male students than female students. It was only at the highest levels of experiential training that men reached and surpassed female student satisfaction.

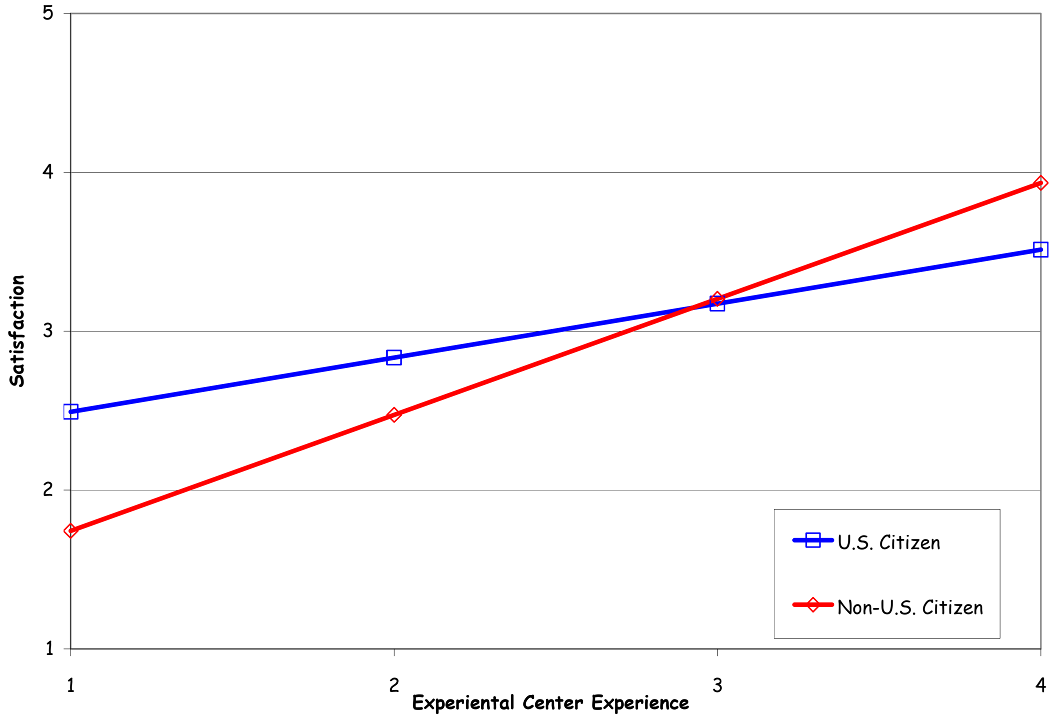

Figure 2: Relationship of Satisfaction and Experiential Center Experiences for Citizenship for the Average Student

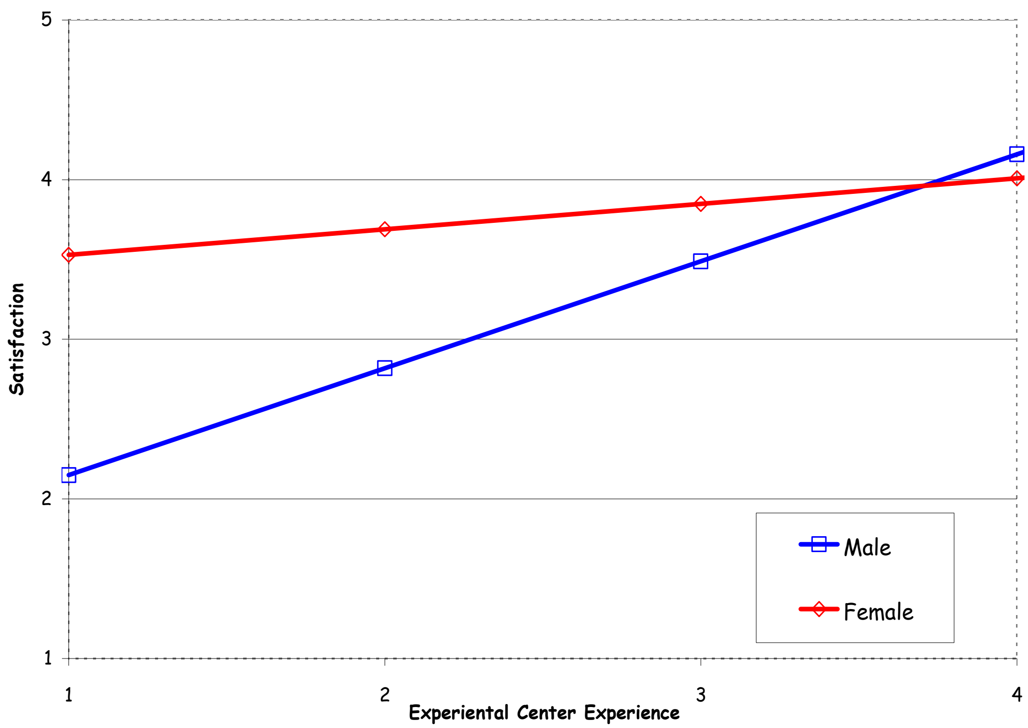

Figure 3: Relationship of Satisfaction and Experiential Center Experiences for Gender for the Average Student

Comparison of Samples

Since two types of centers were included in the sample, multivariate regressions were performed to determine if the I/UCRC students (n=167) were significantly different from the STC students (n=23). Results showed only three changes to the final models when only looking at I/UCRC students. Two of the three alterations that were significant predictors in the full population became non-significant predictors without the students in the STC. The discrepancies were as follows: interactions with center director became a non-significant predictor of organizational commitment (p = .32); and if a student visited industry for center related purposes became a non-significant predictor of publications with industry (p = .12). On the other hand, whether or not the student was a current center student (graduated center student reference) became a significant predictor of whether or not a student had published with an industry member as co-author (Odds Ratio = .27, p = .04).

Similarly, the eleven outcome models were rerun to determine if the current center graduate students (n = 170) significantly differed from those center students who had recently graduated (n = 20). Again, final regression models were very similar to the models that included only current center graduate students. There were only two discrepancies between all the models. After removing those students who had recently graduated, interactions with committee members became a non-significant predictor of perceived soft skills (p = .11) and job experience became a non-significant predictor of career goals (p = .18).

Open-Ended Analysis

There were three open-ended questions addressing skills, benefits/limitations, and suggestions for improvements. All responses were grouped into common themes per question. All identifying information was removed. Table 26 shows a summary of the content analysis. The responses to the open-ended questions are in Appendix C.

The first open-ended question asked: *Are there any skills you wish the Center had placed greater emphasis on?* Thirty students answered the question (15.8%) and gave a total of 40 comments. These comments were grouped into eight themes: technical (26.7%), communication (20.0%), soft skills (20.0%), leadership (16.7%), software & equipment (13.3%), collaboration (13.3%), employment (10.0%), and other (13.3%). The three largest themes were technical skills, communication skills, and soft skills. Respondents provided specific technical skills, such as “Measurement techniques, short tutorials” or “Patent searches,” that they wished were emphasized more by their center. The communication theme comments revealed a desire for greater emphasis on general communication and presentation skills (“More involvement of students in public speaking”). Under the soft skills theme, students’ comments indicated they wished the center had emphasized skills such as “Multidisciplinary problem solving” and “Social skills.”

The second open-ended question asked: *What are the strengths and/or weaknesses of being involved with the Center?* Fifty-eight students answered the question and gave a total of 97 comments. The question was broken into two parts: strengths and weaknesses.

There were 68 comments that were considered strengths of the center or benefits. These comments were grouped into ten themes: general collaboration (19.0%), interactions with industry (17.2%), research projects (15.5%), funding/financial support (12.1%), operations/administration (10.3%), access to resources (8.6%), job opportunities (8.6%), interactions with faculty (6.9%), soft skills (6.9%), and other (12.1%). Collaboration and interactions with industry were the two themes that had the most comments categorized as center strengths. Collaboration comments ranged from general "Interaction with different researchers" to "Opportunities for collaboration." Most of the comments under the theme interactions with industry expressed the value they received from having industry interactions: "The largest benefit of the center is being able to work with industrial partners. This interaction helps you to understand how the industrial world is run and how research fits into it. I believe this is an invaluable asset to any student within the center."

There were 29 comments that were considered weaknesses of the center or limitations. These comments were grouped into seven themes: operations/administration (12.1%), time allocation/workload (10.3%), consequences of working with industry (6.9%), collaboration (5.2%), employment (5.2%), meetings/conferences (5.2%), and other (5.2%). For comments on center weaknesses, the themes with the largest number of comments were operations/administration ("Little cohesiveness in the dissemination of center information from the director on down to the lower levels") and time allocation/workload ("The pay is poor for the hours put in (especially when compared to other graduate assistantships").

The third open-ended question asked: *How can your center improve educational components for graduate students?* Thirty-nine students answered the question and gave a total of 49 comments. These comments were grouped into seven themes: courses/curriculum (28.2%), seminars/meetings (25.6%), training & involvement (23.1%), interactions (17.9%), personnel (7.7%), employment opportunities (5.1%), and other (3.7%). The themes with the greatest number of comments were courses/curriculum and seminars/meetings. Comments in the courses/curriculum theme were suggestions to add center courses or changes to the current curriculum ("Providing courses or seminars which are related to the center research would be beneficial"). Similarly, the comments in the seminars/meetings theme centered on adding more center meetings/seminars ("Other than the center meetings (bi annual), there should be an interim meeting for the faculty where ideas, explanations, etc. are shared and discussed"), types of meetings/seminars ("Hold meetings or presentations from well-known centers, universities or colleges in the world"), and specific topics for meetings/seminars (Include more seminars on career planning").

Table 26

Overview of the Open-Ended Analysis

Question	n	% of respondents	% of total sample (n =190)
qVIII.11. Are there any skills you wish the center had placed greater emphasis on?			
Total Student Sample	190		
Students who answered the question	30		15.8%
Total number of comments	40		
Themes			
Technical	8	26.7%	4.2%
Communication	6	20.0%	3.2%
Soft Skills	6	20.0%	3.2%
Leadership	5	16.7%	2.6%
Software & Equipment	4	13.3%	2.1%
Collaboration	4	13.3%	2.1%
Employment	3	10.0%	1.6%
Other	4	13.3%	2.1%
qXII.1 What are the strengths and/or weaknesses of being involved with the center?			
Total Student Sample	190		
Students who answered the question	58		30.5%
Total number of comments	97		
Themes			
Strengths	*68*		
Collaboration	11	19.0%	5.8%
Interactions with Industry	10	17.2%	5.3%
Research Projects	9	15.5%	4.7%
Funding/Financial Support	7	12.1%	3.7%
Operations/Administration	6	10.3%	3.2%
Access to Resources	5	8.6%	2.6%
Job Opportunities	5	8.6%	2.6%
Interactions with Faculty	4	6.9%	2.1%
Soft Skills	4	6.9%	2.1%
Other	7	12.1%	3.7%
Weaknesses	*29*		
Operations/Administration	7	12.1%	3.7%
Time Allocation/Workload	6	10.3%	3.2%
Consequences of Working with Industry	4	6.9%	2.1%
Collaboration	3	5.2%	1.6%
Employment	3	5.2%	1.6%
Meetings & Conferences	3	5.2%	1.6%
Other	3	5.2%	1.6%
q.XII.2 How can your center improve educational components for graduate students?			
Total Student Sample	190		
Students who answered the question	39		20.5%
Total number of comments	49		
Themes			
Courses/Curriculum	11	28.2%	5.8%
Seminars/Meetings	10	25.6%	5.3%
Training & Involvement	9	23.1%	4.7%
Interactions	7	17.9%	3.7%
Personnel	3	7.7%	1.6%
Employment Opportunities	2	5.1%	1.1%
Other	7	17.9%	3.7%

Note: Appendix C contains all comments

DISCUSSION

The quality and availability of engineering education is an increasingly important component in the efforts to keep the nation globally competitive with challenging foreign talent. There is a performance gap between the skills entry-level engineers have and the skills industry wants them to have (DeLange, 1996; Tong, 2003). Specifically, engineering employers are seeking employees who are not only competent in technical skills, but who also have soft-skills (e.g., teamwork, communication, creativity) and understand industrial needs and problems. This performance gap has triggered calls for engineering educational reform, generally focusing on the need for more extensive use of active and collaborative learning methods (Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001). Cooperative Research Centers (CRC) are a widely used mechanism for providing this type of training experience to graduate students.

Graduate students who participate in CRCs are assumed to have educational advantages; however, there are gaps in research when determining if this is the case. Further, it is assumed graduate students in centers are receiving an experiential education, career and internship opportunities, teamwork skills, multidisciplinary experiences, and interactions with industry. The experiences of and advantages to graduate students are for the most part speculative assumptions.

Policy makers and university administrators tend to agree that graduate students trained in CRCs receive significant educational advantages. However, the research support for this assumption is both vague and methodologically weak. While generally positive, virtually all of the research on this topic involves retrospective ratings by CRC alumni and not current graduate students (Fitzsimmons, Grad, & Lal, 1996; Parker, 1997;

Scott, Schaad, & Brock, 1991). Further, most studies simply report descriptive statistics that demonstrate “positive” ratings by alumni and/or alumni supervisors. Studies with appropriate comparison groups are essentially non-existent. Finally, all of the studies to date have examined program level effects and have failed to evaluate the extent to which individual centers and specific center mechanisms (e.g., multidisciplinary) might produce a more-or-less effective educational experience. Consequently, researchers are missing opportunities to understand how and to what extent CRCs work and to enhance educational outcomes.

There is a need to understand individual center’s educational practices to see what mechanisms are influencing student outcomes. The training experience provided by individual centers varies and those differences have the potential to affect student outcomes. This study was the first of its kind to explore benefits, experiences, and satisfaction of current graduate students in cooperative research centers. Also, it attempted to identify key center mechanisms needed to achieve those educational benefits and identify to what extent differences are attributable to center-level factors, project team-level factors, advisor/committee-level factors, and individual differences.

Center Experience and Testing for Center-Level Effects

A student’s center experience was found to vary by individual, but consisted of a few commonalities. The majority of students’ thesis or dissertation projects were based on a center project. Furthermore, nearly two-thirds of students had two or more academic departments represented on their committees. These findings demonstrate that students’ center experiences overlap with their department experiences. Since the majority of students have multiple academic departments on their committees, this also indicates their exposure to an education that is multidisciplinary. Industry involvement was also found to be an element of a student's center experience. Industry members served on about a quarter of students' thesis/dissertation committees while over a third of students visited an industry site.

Five dimensions were theorized to represent center experiences: experiential learning, multi-disciplinary, teamwork, soft skills, and technical; however, only two major factors emerged: multidisciplinary and experiential center experiences. Thus, these appear to be critical dimensions of a student's center experience. However, since this was an exploratory measure, these two factors may or may not be an accurate representation of the number of different factors in a student's center experiences. First, almost half of the twenty items were negatively worded and were excluded from the measure. Further, IUCRCs may not be representative of the kind of training experiences students at other kinds of centers receive.

One of the study's assumptions was that students within a center would have very similar experiences. However, the data did not support this assumption. Based on ICC analyses, there was not enough within center variance to justify center level analyses. Although, there are several common denominators to a students center experience, there was a lot of variability. As the center mechanisms scale showed, students did not even agree on what mechanisms their center offered. These differences could be due to the fact that students within a center have different faculty advisors, committees and sometimes come from different academic departments and universities. This would mean the center experience is not as homogeneous as some of the previous literature assumes. The small student sizes for many of the centers also hindered the ability to get accurate center level data. Consequently, data could not be examined at the center level for this study.

Major Results

Major Results: Predicting Subjective Outcomes

In general, the predictor variables explained a lot of the variance in students' subjective outcomes. Between half and a third of the variance was explained in satisfaction (44%), organizational commitment (40%), and advanced technical and problem solving skills (36%). This high level of variance explained is due to the large effect sizes of many of the center experience predictors, which include variables such as experiential and multidisciplinary center experiences, technical project involvement, advanced formal training mechanisms, visiting an industry site, number of departments on the thesis/dissertation committee, and years involved with the center.

Experiential and multidisciplinary center experiences emerged as the strongest predictors. Experiential center experiences was the largest predictor for half of the subjective outcomes: satisfaction, organizational commitment, and competitive advantage. Despite there being only two predictors for competitive advantage, almost a quarter of the variance was still explained due to the large effect size experiential center experience had on perceived competitive advantage. Multidisciplinary center experiences was also a significant predictor for satisfaction and organizational commitment and was the largest predictor for perceived advanced technical and problem solving skills. These results imply multiple benefits may occur for the student if their center offers experiences that are "hands on" or that integrate multiple academic disciplines.

Another significant predictor was the level of involvement students had in various technical aspects of center projects. Surprisingly, a technical experience, technical project involvement, was the largest significant predictor in students' perceived soft skills. This counter intuitive finding suggests students who are more involved in technical aspects of their center projects will benefit in their perceived proficiency in soft skills. It was also the second largest predictor in students' perceived advanced technical and problem solving skills. Additionally, technical project involvement significantly predicted student satisfaction.

Interactions with various personnel were also intriguing and significant predictors in subjective outcomes. Past studies indicated the number one suggestion for improvements to center education was more involvement with industry (Abt 1996, 1997). This suggestion for improvement seems to be a valid one that will produce multiple benefits. The more students interacted with industry members the more likely they were to be satisfied in their center and the more likely they were to report perceived proficiency in soft skills. Also, interactions with the center director predicted higher levels of organizational commitment to their center and interactions with their advisor predicted higher levels of satisfaction.

It should come as no surprise that the types of interactions most students have with advisors and committees also make a difference. For instance, another significant predictor was students' interactions with their thesis/dissertation committee. The more students interacted with their committee, the more likely they were to perceive themselves proficient in both advanced technical and problem solving skills and soft skills.

These results imply the more involved students are with various center personnel, particularly industry members, thesis/dissertation committees, center directors, and their advisor, the more likely students are to perceive themselves as benefiting in various outcomes, including their commitment to their center, their perceived skills, and their overall satisfaction with the center.

Despite explaining only sixteen percent of the variance in what career sector students wanted to pursue, two interesting predictors emerged to explain students' choices between academia and industry. Those students funded by the center were roughly fifty percent more likely to go into industry than academia. This is not surprising as it might be expected that students funded by the center are more involved with industry research projects and have more frequent industry interactions. Also, students with more job experience were nearly one and a half times more likely to go into academia than industry. This could possibly be due to many students returning after participating in the workforce and wanting a career change.

Major Results: Predicting Objective Outcomes

Not surprisingly, the predictors explained less variance overall in the objective outcomes. The most variance explained occurred in whether or not the student had an intellectual property event (24%) and whether or not they had a publication with an industry member as a co-author (19%). The largest predictor for both of these outcomes was whether or not the student had visited an industry site. Students who had visited an industry site were 4.79 times more likely to have an intellectual property event and 2.19 times more likely to have published with industry. These strong effect sizes suggest there are benefits to having center students visit an industry site. However, these results should be interpreted with caution since it is not certain whether visiting an industry site causes students to publish with industry or produce an intellectual property event or, just the opposite, producing a publication with an industry member or an IP event causes students to visit an industry site.

The other objective measures: publications, technical reports, and presentations were the outcomes that had the least variance explained. Although 11% of the variance was explained in how many publications students achieved, only 5% of the variance was explained in how many technical reports and presentations students produced. How frequently students interacted with their thesis/dissertation committee predicted both the number of publications and technical reports. Again, the causal direction of this relationship is uncertain.

Given the interest in center impacts, it is noteworthy that student involvement in advanced formal center training mechanisms increases the likelihood of student publishing. Students who were more involved in various mechanisms in their center were 1.6 times more likely to publish with industry and 1.29 times more likely to publish. The mechanisms included in this factor were scientific seminars, center and project meetings, internships, and academic courses.

Some of the findings involving demographic characteristics are also important to note. Asian/Asian American students reported more commitment to their center than Caucasian students. Determining if different cultures impact students' organizational commitment may be an area to explore in the future. Further, U.S. citizens and students who had been at the university longer were more likely to be proficient in soft skills. This finding may be expected due to potential communication difficulties that occur for non-

U.S. citizens entering the U.S. and the adaptation difficulties of incoming graduate students. Despite this discrepancy in soft skills, non-U.S. citizens were roughly fifty percent more likely to publish than U.S. citizens. These relationships may be of interest to examine and/or to be used as control variables in future studies.

The exploratory analyses that examined moderation of satisfaction revealed two significant findings. Satisfaction increased for both U.S. citizens and non-U.S. citizens with increasing experiential training; however, the slope for non-U.S. citizens appears to be greater. When gender was examined, experiential training had a greater impact on the satisfaction of male students than on female students, although it was found that it was only at the highest levels of experiential training that men had greater satisfaction than women. These findings suggest non-U.S. citizens and males will experience greater increases in their center satisfaction when exposed to center experiences that are experiential than would U.S. citizens or females.

The open-ended analysis provided specific suggestions and feedback; however, even though there were several common themes, the greatest number of comments on one theme was only attributable to less than six percent of the respondents. Despite only a third of students providing open-ended comments, the small percentage of comments within a theme demonstrates the wide range of feedback students provided. Most common were observations on strengths and weaknesses of the center, finding that students' perceived center strengths as collaboration opportunities and more specifically, interaction with industry. Center limitations included operations/administration and time allocation workload. Suggestions for improvements to their center education included comments on their courses/curriculum, but also on their informal education, such as suggestions for seminars/meetings.

Limitations

This study had several limitations that are worth mentioning. Although the design of the survey was more advanced than past studies, the study would have benefited from a comparison group. Comparing center students to non-center students in their respective departments would have suggested the results are due to center effects and not departmental experiences. The measures were created for the purposes of the study and the measures could have had better psychometric properties. For instance, the negative items in the center experiences measure had to be excluded and the center mechanisms factors had low reliability.

The response rate for the study was disappointing. An inflated population size may be one reason the response rate was low. The email lists provided for the study contained numerous students who did not meet the requirements for the study. Those potential participants who emailed the researchers that they had either graduated or were not involved in the center were removed from the total population; however, it is assumed there were many more students or graduated students who did not respond to indicate they should not be included in the study. This seemed to inflate the total population size, and probably lowered the overall response rate.

Future Directions

Although this study is exploratory, these predictions provide a strong basis for causal research in the future. Potential research should also examine the relative influence of centers, departments, teams, committees and individual faculty advisors. This research would better help identify key mechanisms to enhance center students' educational outcomes. Part of doing this would require developing more objective measures of center training mechanisms and center experiences, and measures of experiences at different levels of analysis. Other measures of this research could also be advanced, including the measure for interactions with various center personnel.

Some of the findings of the study provide new angles on which to base research of center students. Most importantly, research should further examine the link between center mechanisms and student outcomes such as satisfaction, skills, center commitment, and scholarly achievements. The strong predictive factors this study identified, such as experiential and multidisciplinary center experiences, technical project involvement, and advanced formal training mechanisms, may provide educational benefits to students. This signifies centers should focus their research efforts on further understanding this relationship in order to reveal what experiences and mechanisms are particularly beneficial. This will help all CRCs implement educational "best practices" in order to maximize the educational benefits to all center students. Once identified, future center focuses could also determine how to best implement these positive educational practices into the centers.

In addition to unique center mechanisms and experiences being beneficial to center students, results confirmed basic educational mechanisms, like interactions with advisors and committees, also add to a student's education. The value these traditional educational mechanisms add to students' outcomes along side unique center mechanisms, such as interactions with industry members.

In addition, it would be of interest to research the effect of visiting an industry site, interactions with industry, and various other center mechanisms has on scholarly achievements. It is unclear if a visit to an industry site is causing an increase in scholarly achievements or whether scholarly achievements are causing more visits with industry members. Next, a better understanding of the relationship technical project involvement has with perceived soft skills would help to identify what centers should do to enhance students' soft skills. This would consequently help students' competitive advantage in seeking employment. As past research has pointed out, interactions with industry are viewed as advantageous. This study's results imply frequent interactions with industry members predict higher levels of perceived soft skills and satisfaction. It would be interesting to learn more about students' relationship with industry members to determine how these interactions benefit students. Lastly, some of the demographic characteristics may be of interest. First, the relationship ethnicity has with organizational commitment and citizenship has with publications could be explored. Also, the two significant interaction effects, how the relationship between satisfaction and experiential education varied by gender and citizenship, provides a foundation for exploring how experiences and center mechanisms may have different impacts on different populations.

Conclusion

There is still a need for continued research on students' center education. Centers are a critical mechanism for efforts to reform graduate education in science and engineering and deserve more serious and rigorous examination. From a practical standpoint, centers would benefit from more real time feedback from graduate students on an ongoing basis. This evaluation would provide greater understanding of which center components may assist in an enhanced education/training experience for graduate students. It is hoped that centers will consider using some components of the questionnaire to assess student outcomes on an ongoing basis in order to improve current center education.

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APPENDICES

APPENDIX A

COOPERATIVE RESEARCH CENTERS
Program Evaluation Project

Graduate Student Questionnaire

Your data will be completely anonymous. By taking this survey, you are giving us consent to use your data in our analyses.

	Yes	Yes-- I used to be, but I have graduated	No
A. Are you currently, or have you ever been, a graduate student working for a Cooperative Research Center (e.g. I/UCRC or STC)?	☐	☐	☐

If you answered "No" to Question #1 above, you do not need to fill out or submit the survey. We appreciate your time.

If you answered "Yes" to Question #1 above, please continue. If you have graduated, please fill out the survey with the most recently completed semester in mind.

A1. ***PLEASE INDICATE YOUR CENTER***	[dropdown]
A2. Please enter the college or university you are currently attending:	[text field]
A3. Please enter your academic department:	[text field]

	Less than 6 months	Between 6 and 12 months	Between 1 and 2 Years	Between 2 and 3 Years	Between 3 and 4 Years	4 or more Years
B. How long have you been involved with the Center?	☐	☐	☐	☐	☐	☐

	Yes-All of my funding	Yes-Some of my funding	No	Other
C. Are you currently funded by the Center or a Center project?	☐	☐	☐	☐ Please Specify:

I. Center Projects
We would like to learn more information about your Center projects.

	9 hours or less	10-19 hours	20-29 hours	30-39 hours	40-49 hours	50-59 hours	60-69 hours	70 or more hours
1. On average, how many hours per week do you spend on Center activities (e.g. time on Center projects, thesis research if on Center project, etc.)?	☐	☐	☐	☐	☐	☐	☐	☐

Please answer the following questions (Q.2-Q.4) thinking of the **Center research project in which you most actively participate.**

	2	3	4	5	6	7	8	9	10	11 or more
2. Including yourself and the principal investigator/primary scientist, how many people are on your project team?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

	6 months or less	12 months	18 months	24 months	36 months or more	No time frame specified
3. From start to finish, approximately how many months is this project expected to take?	☐	☐	☐	☐	☐	☐

4. How much involvement do you have in the following aspects of your Center project?

	Not at all Involved	**Slightly Involved**	**Moderately Involved**	**Very Involved**	**Extremely Involved**
a. Overall design of the project	☐	☐	☐	☐	☐
b. Developing the methods and procedures used in the project	☐	☐	☐	☐	☐
c. Collecting and/or analyzing data	☐	☐	☐	☐	☐
d. Reporting and communicating design, methods, & results	☐	☐	☐	☐	☐
e. Managing the project	☐	☐	☐	☐	☐
f. Supervising others	☐	☐	☐	☐	☐

II. Degree & Thesis/Dissertation Project
We would like to learn more information about your thesis/dissertation project.

	Master's degree— I do not plan to pursue a PhD	**Master's degree— I do plan to pursue a PhD**	**PhD**	**Other**
1. What is the degree you are **currently** pursuing?	☐	☐	☐	☐ Please Specify:

	Yes, it is	**Yes, it will be**	**No, it is not or will not be based on a Center project**	**I Don't Know Yet**
2. Is your current or planned thesis or dissertation based on a Center project?	☐	☐	☐	☐

	0	**1**	**2**	**3**	**4**	**I don't have a committee yet**
3. How many different academic departments are represented on your thesis or dissertation committee?	☐	☐	☐	☐	☐	☐
4. How many industry or government Center members/participants, if any, are on your thesis or dissertation committee?	☐	☐	☐	☐	☐	☐

III. Formal Center Training Activities

We would like to know what types of formal training activities your Center offers. **In Column A** below, please check the training activities offered by your Center. **If your Center offers that activity,** indicate your level of involvement **in Column B**.

	COLUMN A	COLUMN B				
Formal Center Training Activities	**Check All that Apply**	**Not at all Involved**	**Slightly Involved**	**Moderately Involved**	**Very Involved**	**Extremely Involved**
a. Periodic Center industrial advisory board (IAB) meetings	☐	○	○	○	○	○
b. Co-op or Internship placements	☐	○	○	○	○	○
c. Regular meetings with your project team	☐	○	○	○	○	○
d. Regular meetings with your entire Center team	☐	○	○	○	○	○
e. New academic courses sponsored or developed by the Center or Center faculty	☐	○	○	○	○	○
f. Educational interventions targeted at youth (K-12) and sponsored by the Center	☐	○	○	○	○	○
g. Scientific/technical seminar series featuring outside speakers (e.g., professors, industry participants)	☐	○	○	○	○	○
h. Scientific/technical seminar series featuring student speakers (e.g., brown bag, student presentations)	☐	○	○	○	○	○

i. Workshops on "soft skills" or non-technical topics (e.g., teamwork, communication, career development, leadership)	☐	○	○	○	○	○
j. Mentoring (formal mentor assignments)	☐	○	○	○	○	○
k. Other formal meetings/activities	Please Specify:	○	○	○	○	○

IV. Interactions

1. Thinking of your most recently completed semester, **approximately** how many times did you discuss

Center-related projects and activities (via phone, email, or face-to-face interactions) with…?

	Daily	**Bi-Weekly**	**Weekly**	**Bi-Monthly**	**Monthly**	**A Few Times a Sem-ester**	**Once a Sem-ester**	**Never**	**Not Applic-able**
a. Your advisor	○	○	○	○	○	○	○	○	○
b. Your thesis or dissertation committee members (cumulatively)	○	○	○	○	○	○	○	○	○
c. Other Center faculty (not advisor or committee)	○	○	○	○	○	○	○	○	○
d. Center students	○	○	○	○	○	○	○	○	○
e. Center director	○	○	○	○	○	○	○	○	○
f. Center industry or government representatives	○	○	○	○	○	○	○	○	○
g. Faculty at other universities	○	○	○	○	○	○	○	○	○

	Yes	No
2. Have you ever visited the site of an industry or government Center member/participant for Center related purposes (excluding any internships/co-ops)?	☐	☐

V. Center Experience
For the following items, please indicate the extent to which you agree or disagree that the following statements accurately reflect your Center experiences.

"My involvement in the Center includes… "	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
a. An education that rarely requires me to take responsibility for my learning	☐	☐	☐	☐
b. Working with people from diverse backgrounds (e.g., ethnicity, gender, nationality)	☐	☐	☐	☐
c. Working on scientific problems that are innovative and on the cutting edge	☐	☐	☐	☐
d. Rarely being knowledgeable about the work occurring on other Center projects	☐	☐	☐	☐
e. Relying on the cooperation and collaboration of other principal investigators/scientists	☐	☐	☐	☐
f. "Hands-on" learning/learning-by-doing approach	☐	☐	☐	☐
g. Few opportunities to use my creativity when solving research problems	☐	☐	☐	☐
h. Receiving an education that encourages me to listen, discuss, evaluate, and to learn from the ideas of others	☐	☐	☐	☐
i. Being exposed to scientific techniques and expertise that are not usually available in my department	☐	☐	☐	☐
"My involvement in the Center includes… "	**Strongly Disagree**	**Somewhat Disagree**	**Agree**	**Strongly Agree**
j. Showing how a particular concept can be applied to an actual problem or situational.	☐	☐	☐	☐
k. Rarely applying advanced computer skills	☐	☐	☐	☐
l. Opportunities to be a leader	☐	☐	☐	☐
m. Integrating and synthesizing information from different fields in solving problems	☐	☐	☐	☐
n. Working/interacting regularly with faculty from other disciplines	☐	☐	☐	☐

o. Working alone on projects	◻	◻	◻	◻
p. Not working regularly with state-of-the art equipment and resources	◻	◻	◻	◻
q. Experiences that are rarely applicable to "real-world" situations and problems	◻	◻	◻	◻
r. Rarely using knowledge and research from other disciplines	◻	◻	◻	◻
s. Infrequent interactions with students from other disciplines	◻	◻	◻	◻
t. Few opportunities to develop my verbal and written communication skills	◻	◻	◻	◻

VI. Career Goals
We are interested in learning more about your personal interests and career goals.

	Industry	**University**	**Government**	**Other**	**Didn't/Don't Know**
a. Upon entry into graduate school, where did you expect your first job **would be** after graduation?	◻	◻	◻	◻	◻
b. Upon completing your highest degree, where do you expect your first job **will be**?	◻	◻	◻	◻	◻

VII. Scholarly Achievement
We would like to know the kind and quantity of publications, presentations, and intellectual property events that have resulted from your Center projects. **Please enter the number of scholarly achievements produced for each type of scholarly achievement.**

	Specify the Number	
1) ***Publications*** ***<u>(include those in press)</u>***	a. Refereed Journals:	0
	b. Refereed Proceedings:	0
	c. Not Refereed Proceedings:	0
	d. Invited Articles (e.g. reviews, articles, book)	0
	e. Technical Reports:	0
	f. Were any of these publications with Center industry participants as co-authors?	☐ **Yes** ☐ **No**
2) *Presentations* at national or international scientific or professional meetings (include poster presentations)	Total Number:	0
3) *Presentations* made at other scientific or professional meetings that were not national or international (include poster presentations)	Total Number:	0
4) ***Intellectual property events***	a. Invention Disclosures:	0
	b. Patent Applications:	0
	c. Copyrights:	0
	d. Patents Granted/Derived:	0
	e. Licensing Agreements:	0

VIII. Skills

1. We are interested in your self-assessment of your skills in various areas.
For the following questions, please rate your proficiency in the following skills.

"Your ability to…"	Beginner	Novice	Somewhat Proficient	Proficient	Expert
a. Use and understand your area's computer, technical, and/or laboratory equipment	☐	☐	☐	☐	☐
b. Effectively solve technical problems	☐	☐	☐	☐	☐
c. Understand problems using a systems approach	☐	☐	☐	☐	☐
d. Communicate your ideas (via writing and/or oral presentations)	☐	☐	☐	☐	☐
e. Take charge in a situation and lead your team	☐	☐	☐	☐	☐
f. Understand the implications of research for application and commercialization	☐	☐	☐	☐	☐
g. Collaborate well with others	☐	☐	☐	☐	☐
h. Solve problems within time and money constraints	☐	☐	☐	☐	☐
i. Understand the depth and breadth of your technical area	☐	☐	☐	☐	☐
j. Apply the knowledge from different disciplines in an integrated fashion to solve research problems	☐	☐	☐	☐	☐

2. Are there any skills you wish the Center had placed greater emphasis on?

IX. Organization
Pertaining to your involvement in the Center, please rate your level of agreement or disagreement according to the statements below:

	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
a. My Center experiences will give me a competitive edge over other students seeking similar jobs or education following graduation	☐	☐	☐	☐	☐
b. The Center inspires the very best in me in doing research	☐	☐	☐	☐	☐
c. I am proud to tell others I am a part of my Center	☐	☐	☐	☐	☐

X. Satisfaction with Center Experiences
We are interested in how satisfied you are with different aspects of your Center training and experience. For the following items, please indicate **how satisfied you are with the following Center features:**

	Not Satisfied	Slightly Satisfied	Somewhat Satisfied	Very Satisfied	Extremely Satisfied
a. Center management/administrative operations					
b. Degree of autonomy/independence on thesis/dissertation projects (such as the freedom to discuss research, control over research)					
c. Opportunities to interact with and learn about industry and other outside non-academic researchers					
d. Frequency and quality of interactions with Center personnel (such as access to and relationships with faculty, peers, advisors, directors)					
e. Financial support (such as your amount of funding, stipend, tuition, health benefits)					
f. Amount and quality of supervision and support I receive from advisors, faculty, mentors, and peers (such as feedback, recognition, guidance, availability, input)					
g. Opportunities to learn and practice soft skills (such as presentations, communication, leadership)					
h. Workload (such as the amount of time spent on Center projects, amount of time spent on Center activities, length of projects)					
i. Quality and access to facilities and equipment (such as the sophistication, availability)					
j. Relevance of the research to my career goals					

Now, thinking of your experiences as a whole. Please rate your level of satisfaction with the Center.

	Not Satisfied	Slightly Satisfied	Somewhat Satisfied	Very Satisfied	Extremely Satisfied
k. Overall Center experience					

XI. Demographics
Please fill out the following demographic information so we are able to learn a little about your background.

1. How many years have you been a graduate student at your university? ____ Years

2. What is your approximate graduate school grade point average (A = 4.0)	4.0 3.8-3.99 3.6-3.79 3.4-3.59 3.2-3.39 3.0-3.19 2.5- 2.99 2.49 or under

3. Have you ever worked for a company/industry or government organization (outside of your university)? *(Check all that apply)*	Never Yes, I had an internship/Co-Op Yes, I had a part-time job Yes, I had a full time job Yes, I currently have a part-time job Yes, I currently have a full time job

4. Please specify your gender	Male Female

5. Please specify your age	○ Under 21 years old ○ 21-24 ○ 25-28 ○ 29-32 ○ 33-36 ○ 37-40 ○ Over 40 years old

6. Please specify your ethnicity/race *(check all that apply)*	☐ African American/Black ☐ American Indian/Alaska Native ☐ Asian American ☐ European American/Caucasian/White ☐ Hispanic/Latino ☐ Native Hawaiian or Other Pacific Islander ☐ Other (Specify) _____ ☐ I do not want to specify my ethnicity/race

7. Are you a U.S. citizen?

○ Yes- SKIP TO SECTION XII

○ No-ANSWER Q.A and B BELOW

a. Do you plan to become a U.S. Citizen? ○ Yes ○ No ○ Undecided

b. Where do you plan to seek employment after graduation? ○ U.S. ○ My Home Country ○ Don't Know ○ Other (Please Specify): _____

XII. Open Ends
We are interested in any comments you would like to share with us about your Center involvement.
Your opinions and suggestions will help to see what the strengths and weaknesses are of an education in a Center environment.

a. What are the benefits and/or limitations of being involved with the Center?

b. How can your Center improve educational components for graduate students?

PLEASE CHECK HERE TO INDICATE YOU HAVE FINISHED COMPLETING THE SURVEY: ☐

THANK YOU FOR FILLING OUT THE QUESTIONNAIRE!

If you have a firewall or privacy block features installed on your computer, you may need to disable them in order to submit the survey.

Submit Reset

Questions/Concerns about the questionnaire, please contact iucrc@ncsu.edu

APPENDIX B

Table B1

Descriptive Statistics of Student Characteristics

Item	%	M	SD
Number of Years at University		3.2	1.48
Student Status			
Current Center Graduate Student	89.5%		
Recently Graduated Center Student	10.5%		
Academic Department			
Chemical Engineering	20.0%		
Chemistry	8.9%		
Civil Engineering	5.3%		
Electrical Engineering/Electrical and computer Eng.	22.1%		
Materials Science & Engineering	6.8%		
Industrial Engineering/Mechanical Engineering	24.2%		
Other/Mgt. Information	12.6%		
Student Funded by Center			
Not funded	17.9%		
Some funding from Center	28.9%		
All funding from Center	53.2%		
Highest Degree Expected to Complete			
Master’s Degree	13.2%		
Doctoral Degree	86.8%		
Job Experience			
Never	34.2%		
Co-Op/Internship	31.6%		
Part-time	7.9%		
Full-time	26.3%		

Note: n = 190

Table B2

Descriptive Statistics of Center Characteristics

Item	M	SD
Total Funding	3.07	1.98
Center Age (years)	8.15	5.18

Note: n = 190

Table B3

Descriptive Statistics of Interactions

Item	Never/ N/A	Once a Semester	Several Times a Semester	Monthly	Bi-Monthly	Weekly	Bi-Weekly	Daily
Interactions								
Advisor		1.6	4.7	5.3	5.3	45.8	23.2	14.2
Committee	30.5	15.3	22.1	6.8	5.8	11.6	5.8	2.1
Center Faculty	36.8	17.9	17.9	8.4	4.2	9.5	3.2	2.1
Students	10.0	5.8	13.2	5.8	5.3	18.9	8.9	32.1
Center Director	30.0	8.9	13.2	8.4	5.3	17.9	10.0	6.3
Industry Members	40.5	30.5	16.3	6.3	2.6	2.1	1.1	.5

Note: n = 190

Table B4

Descriptive Statistics of Experiences of Center Graduate Students

Item	%
Visited Industry Site (Yes)	36.8%
Industry on Committee (Yes)	24.2%
Academic Departments on Committee	
No committee yet	23.2%
One academic department	15.8%
Two or more departments	61.1%
Project Duration	
18 months or less	23.7%
2 years	26.3%
3 or more years	27.4%
No time specified	22.6%
Thesis on Center Project (Yes)	84.2%

Note: n = 190

Table B5

Summary of Bivariate Regressions of Predictor Variables on Continuous Dependent Variables (Standard Coefficients)

	Satisf.	Soft Skills	Adv. Tech. and Problem Solving Skills	Org. Commit.	Com. Adv.	Pubs	Tech Reports	Present
Demographic Characteristics								
Age	-0.03	0.07	0.22***	0.04	0.05	0.19**	0.03	0.05
Gender	-0.18**	-0.08	0.03	-0.02	-0.10	0.09	0.09	0.08
Ethnicity	-0.08	-0.12	0.04	-0.01	-0.02	0.03	0.07	-0.03
Citizenship Status	0.00	0.19**	-0.06	-0.11	-0.12	-0.15**	-0.11	-0.09
Student Characteristics								
Number of Years at University	0.08	0.29***	0.35***	0.13*	0.02	0.30***	0.16**	0.26***
Student Status	0.03	-0.11	-0.12*	-0.03	-0.04	-0.21***	0.11	-0.13*
Academic Department	0.00	0.06	0.06	0.16**	0.18**	0.18**	0.00	-0.01
Student Funded by Center	0.16**	0.06	0.07	0.13*	0.11	0.03	-0.02	-0.05
Highest Degree Expected to Complete	0.11	-0.11	0.06	-0.03	-0.05	0.13*	0.08	0.10
Job Experience	-0.06	0.03	0.06	0.06	0.09	0.08	0.14*	0.05
GPA	0.01	0.12*	0.10	0.10	0.10	0.16**	-0.16**	0.01
Center Characteristics								
Multi University Center	-0.18**	-0.01	-0.01	-0.19**	-0.12*	-0.14*	0.00	0.01
Total Funding	-0.08	-0.04	-0.05	-0.10	-0.17**	-0.08	-0.01	-0.05
Center Age	-0.03	0.07	0.01	-0.05	-0.07	0.04	0.07	-0.02
Interactions								
Advisor	0.35***	0.13*	0.14*	0.14*	0.02	0.04	0.07	0.15**
Committee	0.17**	0.20**	0.25***	0.08	0.08	0.17**	0.21***	0.08
Center Faculty	0.06	0.13*	0.03	0.11	0.18**	0.04	0.02	-0.05
Students	0.17**	0.13*	-0.05	0.12	0.06	-0.07	0.07	0.04
Center Director	0.33***	0.15**	0.08	0.32***	0.21***	0.11	0.13*	0.05
Industry Members	0.31***	0.21***	0.22***	0.18**	0.18**	0.05	0.12*	0.07
Center Experience								
Time involved in Center	0.06	0.25***	0.30***	0.15**	0.04	0.36***	0.15**	0.31***
Hour on Center Activities	-0.02	0.11	0.11	-0.01	-0.13*	0.13*	-0.09	0.13*
Visited Industry Site	0.07	0.15**	0.14*	0.04	0.06	0.11	0.08	0.05
Industry on Committee	0.08	0.07	0.19**	0.10	0.09	0.10	0.12	0.09
Academic Departments on Committee	-0.06	-0.25***	-0.32***	-0.16**	-0.08	-0.11	-0.02	-0.03
Project Duration	-0.01	0.04	0.00	0.09	0.07	0.10	0.12	0.12
Technical Project Involvement	0.20**	0.31***	0.30***	0.14*	0.04	0.08	0.04	0.20**
Advanced Technical Formal Training Mechanisms	0.29***	0.13*	0.13*	0.22***	0.21***	0.23***	0.18**	0.12
Experiential Center Experiences	0.50***	0.21***	0.22***	0.51***	0.44***	0.07	0.13*	0.09
Multidisciplinary Center Experiences	0.48***	0.19**	0.33***	0.40***	0.33***	0.11	0.08	0.12

Note: n = 190; *= $p<.10$, **= $p<.05$, ***= $p<.01$

Table B6

<u>Summary of Bivariate Regressions of Predictor Variables on Categorical Dependent Variables (Standard Coefficients)</u>

	Publications with Industry				Intellectual Property Events				Career Goals	
	B	Odds Ratio	X^2	df	B	Odds Ratio	X^2	df	X^2	df
<u>Demographic Characteristics</u>										
Age	.31	1.37	4.22**	1	.10	1.11	.24	1	13.69	15
Gender	.07	1.07	.04	1	.62	1.85	1.28	1	10.36**	3
Ethnicity			.79	2			1.24	2	18.98**	9
Citizenship Status	-.79	.45	6.53	1	-.39	.67	.82	1	13.07***	3
<u>Student Characteristics</u>										
Number of Years at University	.29	1.33	7.59***	1	.38	1.46	7.52***	1	30.52	36
Student Status	-.85	.43	2.74	1	-.57	.56	.82	1	1.89	3
Academic Department			5.90	6			15.79**	6	22.83	18
Student Funded by Center	-.88	.42	2.58	1	.80	2.22	5.97**	1	10.89**	3
Highest Degree Expected to Complete	.12	1.12	.07	1	.12	1.23	.04	1	21.98***	3
Job Experience	-.00	1.0	.00	1	.27	1.31	2.27	1	9.46	9
GPA	.14	1.15	.87	1	.32	1.38	2.20	1	11.39	15
Center Characteristics										
Multi University Center	-.14	.87	.17	1	.22	1.25	.23	1	3.31	3
Total Funding	.06	1.06	.61	1	.04	1.04	.13	1	14.32**	6
Center Age	.07	1.07	5.75**	1	.04	1.04	1.03	1	52.01*	39
<u>Interactions</u>										
Advisor	.02	1.02	.03	1	.03	1.03	.04	1	19.33	21
Committee	.09	1.09	1.24	1	.11	1.12	1.15	1	17.71	21
Center Faculty	.03	1.03	.17	1	-.02	.99	.02	1	17.60	21
Students	-.09	.92	1.99	1	.07	1.07	.52	1	23.67	21
Center Director	.02	1.02	.06	1	.05	1.05	.30	1	22.85	21
Industry Members	.18	1.20	2.43	1	.25	1.28	3.05*	1	12.01	21
<u>Center Experience</u>										
Time involved in Center	.36	1.44	8.72***	1			5.74**	1	12.45	12
Hour on Center Activities	.08	1.08	.68	1	.26	1.29	3.99**	1	22.52	21
Visited Industry Site	.91	2.47	8.01***	1	1.71	5.59	14.79***	1	1.50	3
Industry on Committee	-.43	.65	1.48	1	-.67	.51	2.02	1	1.04	3
Academic Departments on Committee			6.33**	2			10.24***	2	2.68	6
Project Duration			3.23	3			5.31	3	9.43	9
Team Size	.05	1.05	.21	1	-.05	.95	.11	1	14.99	12
Technical Project Involvement	.27	1.25	1.16	1	.54	1.17	2.64	1	1.23	3
Advanced Technical Formal Training Mechanisms	.53	1.70	.65**	1	.52	1.69	3.65*	1	.09	3
Experiential Center Experiences	.12	1.22	.10	1	.51	1.66	.87	1	1.47	3
Multidisciplinary Center Experiences	.25	1.29	.93	1	.31	1.37	.70	1	5.40	3

Note: *= p<.10, **=p<.05, ***=p<.01

Table B7

Summary of Correlations for Outcome Variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Satisfaction	1.00									
2. Perceived Soft Skills	0.29***	1.00								
3. Perceived Advanced Technical and Problem Solving Skills	0.34***	0.65***	1.00							
4. Organizational Commitment	0.51***	0.26***	0.29***	1.00						
5. Competitive Advantage	0.39***	0.20***	0.25***	0.72***	1.00					
6. Publications	0.13*	0.29***	0.36***	0.13*	0.14*	1.00				
7. Technical Reports	0.09	0.19**	0.28***	0.07	0.12	0.19**	1.00			
8. Presentations	0.16**	0.31***	0.37***	0.14*	0.18**	0.43***	0.22***	1.00		
9. Career Goals	0.10	-0.02	-0.11	0.04	0.03	0.04	-0.08	0.00	1.00	
10. Publications with Industry	0.06	0.08	0.26***	0.15**	0.21**	0.30***	0.13*	0.16**	-0.13*	1.00
11. Intellectual Property Events	0.12	0.14*	0.16**	0.09	0.05	0.12	0.19**	0.13*	-0.03	0.18**

Note: n = 190 except Publications with Industry = n = 178; *p<.10, **p<.05, ***p<.01

Table B8

Summary of Logistic Regression of Career Goals

			Don't Know Yet vs. Industry (Industry Reference)		Government/Other vs. Academia (Academia Reference)		Don't Know Yet vs. Academia (Academia Reference)		Don't Know Yet vs. Government/Other (Government/Other Reference)	
Variable	X^2	df	Coefficient	Odds Ratio	Coefficient	Odds Ratio	Coefficient	Odds Ratio	Coefficient	Odds Ratio
Student Characteristics										
Student Funded by Center (0 = No Funding, 1 = Some Funding, 2 = All of Funding)	10.67**	3	-.05	.95	.15	1.16	.69	1.98**	.54	1.71
Job Experience (0 = No, 1 = Co-op/Internship, 2 = Part-time, 3 = Full-time)	6.85*	3	-.11	.89	-.34	.71	-.48	.62**	-.13	.88
Center Characteristics										
Center Age	10.15**	3	.10	1.10**	-.23	.79	.11	1.11**	.34	1.40*
Nagelkerke R^2	.25									

Note: n = 190; *p<.10, **p<.05, ***p<.01

APPENDIX C

Open End Codes

<u>qVIII.11 Are there any skills you wish the Center had placed greater emphasis on?</u>

- Technical (8)
  - Material characterization techniques such as SEM, TEM
  - Sensor technology
  - Application of risk assessment to include mathematical computations
  - More applicable class[work] on setting up controlled experiments for purposes of statistical analysis
  - Measurement techniques, short tutorials
  - Design
  - Patent searches
  - Combine the knowledge of the research area and interest [in order] to design and develop a systematic device or object to realize certain functions important for industrial applications
- Communication (6)
  - Communication skill is the most important one. As an international student, I believe there are some cultural and language related obstacles between me and my supervisors. The university should offer a mandatory (otherwise [every]body ignores, including me) course to enhance the communication skills and make sure that everybody is on the same page in terms of overall strategy of the research.
  - Chance to train [in] communication and provide opportunity to go to conference[s]
  - Communication skills: how to effectively communicate ideas, group discussions on how to properly present results and discuss ideas
  - Presentation [of] verbal and oral skills, there's a tendency to "hide" those with lesser skills because of what the industry advisors prefer to see.
  - More involvement of students in public speaking
  - Ability of scientists to communicate information to the general public
- Soft Skills (6)
  - Importance of scientists being involved in their community, K-12 outreach
  - More personal development skills as managers of teams
  - Social skills
  - Soft skills development
  - Mentoring
  - Multidisciplinary problem solving
- Leadership (5)
  - Leadership
  - Leadership skills
  - Leadership, just to name one.
  - Leadership
  - Skills for graduate students to become leaders in the future

- Software & Equipment (4)
    - Software design and programming math programming
    - Software: CoventorWare, CFD-ACE, Unigraphics, AutoCAD, Mathematica, MATLAB, PIC-C Hardware: PSI-AFM, ZEISS-Confocal microscope, ION milling, RIE, M2000 laser machine, mask aligner (MA6), CNC-MACHINING CENTER
    - Experience with state of the art equipment
    - Training on the proper use of equipment and laboratory safety
- Collaboration (4)
    - Networking opportunities with other students
    - Opportunities to collaborate with existing and new members
    - Provide further contacts and training in the area I am working in
    - Industry contact
- Employment (3)
    - Job opportunities
    - Mentoring from advisors/industry contacts as we go through the process of looking for jobs
    - Internships & Co-ops
- Other (4)
    - Work Ethic
    - Funding stability
    - Grant proposal writing
    - Apply the knowledge from different disciplines in an integrated fashion to solve research problems

<u>qXII.1 What are the strengths and/or weaknesses of being involved with the Center?</u>

Strengths

- Collaboration (11)
  - Good way to interact with members of other related disciplines
  - Interaction with different researchers
  - Interact with different scientists
  - The interaction with other students in my discipline who represent the future leaders in the field is also a motivating and rewarding opportunity
  - Opportunities for collaboration
  - [My center] does a pretty good job all around. I understand that they are primarily a support organization, and they do that for me, but in addition they offer a unique opportunity to interact with other students and depts.
  - Close environment with peers of other or similar projects in which ideas can be exchanged.
  - Opportunity to develop professional relationships with future employers and research peers
  - Opportunity to meet different types of people and expand my knowledge base
  - Chance to learn from a lot of people
  - I think one of the greatest benefits is being exposed to the fundamental problems that industry and government deal with. In order to do quality research, the problem must be understood. It is difficult to gain this understanding while in academia unless you have exposure from industry/gov or have worked in the field. IUCRC provides the means to obtain this understanding to academic researchers whether they have had previous work experience in a field or not.
- Interactions with Industry (10)
  - Industry involvement
  - I found interacting with industrial partners to be very beneficial. At first, only my professors were communicating regularly, i.e. weekly or monthly, with industrial representatives, but I eventually asked to be included in teleconference calls for two reasons: to no longer get second-hand information concerning the project AND to learn from the industrial partners by listing to them talk to my professor and other industrial representatives. I found that direct contact was VERY helpful in understanding the scope and direction of my project, i.e., implications of research and possible commercialization, AND when it came time to interview for an industrial position.
  - Meet many companies
  - Exposure to industrial training is good
  - Opportunities to interact with and learn about industry and other outside non-academic researchers
  - Company interaction and networking
  - The largest benefit of the center is being able to work with industrial partners. This interaction helps you to understand how the industrial

world is run and how research fits into it. I believe this is an invaluable asset to any student within the center.
  - The main benefit is the network formed between people in academia and people in industry.
  - The benefits include having contact with persons from industry, including becoming more aware of the mindset of research in an industrial setting, as well as "showing off" what I can do with a scientific problem.
  - The contacts with industry and multi-disciplinary teams keep me interested in several aspects of research.
- Research Projects (9)
  - The opportunity to be involved in cutting-edge research
  - I gained exposure to many different research projects
  - We get exposed to cutting edge technologies
  - Exposed to high quality research
  - Opportunity to access cutting-edge research problems
  - Real-world application for research studies
  - Exposure to innovative projects and innovative students
  - The main benefit of being involved with the Center is that I get to hear about a variety of research projects from a number of institutions.
  - Be exposed to a lot of research projects
- Funding/Financial Support (7)
  - I mostly took a job there to get my tuition paid (big benefit). It had little to do with my ultimate career goals, but in the end I learned a great deal of valuable information.
  - Great opportunities to get funding to conduct research.
  - Opportunities for funding
  - You are provided financial support while working on your degree
  - It's a benefit for my advisor not to worry about how he'll pay my stipend!
  - Funded project while it is part of the dissertation
  - School is paid for

- Operations/Administration (6)
  - [My center] is well-managed. Any dissatisfaction I have [is] with my own performance.
  - IAB meetings, while a pain, tend to be very useful in meeting people and starting collaborations.
  - I appreciate the semi-annual meetings where I can present the research I have been working on and improve my presentation skills.
  - The website directory and event calendar is handy
  - Last few decades, [my center] is one of the most attractive benefits, which provides excellent facilities and fabrication technologies in [my area].
  - The benefits are numerous and the ones that are especially helpful to me is the professional manner of the administration and secretaries who are in contact with the students. We are treated respectfully and our opinions are considered.
- Access to Resources (5)
  - The benefits are the access to all resources
  - I think the biggest benefit of the center is access. Access to equipment, people and other resources.
  - Access to industrially funded projects thought programs such as the Affiliates program.
  - Access to group equipment that one PI could not have otherwise. However, student ownership of equipment is key; otherwise that equipment gets abused and/or damaged.
  - The most important benefit in my opinion would be the opportunity to work with cutting edge technology and greatly knowledgeable researchers in the field. This probably can help with a student's motivation as well as his/her career.
- Job Opportunities (5)
  - I hope a benefit is that I can apply for a government job and be seriously considered, possibly above the rest of the applicants.
  - Access to national companies for job opportunities summer, internship, or full time upon graduation.
  - Networking
  - Good connections
  - Great resume builder (being involved with a NSF program)

- Interactions with Faculty (4)
  - Benefits include interaction with principal investigators, research personnel, and staff workers
  - You work around highly respected professors and researchers
  - I think that the positive experience I have had with my center comes from my positive experience with my advisor, who is also the director. There were several instances in my research where decisions were made based on feedback from center industry members. It gave me confidence that my work would be practical.
  - The opportunity to work with the most respected and well-recognized professors in my particular field of research is extremely rewarding educational experience
- Soft Skills (4)
  - Multidisciplinary education
  - Opportunities for presentation practice
  - Opportunities to learn and practice soft skills (such as presentations, communication, leadership)
  - The opportunity to present
- Other (7)
  - The Center inspires the very best in me in doing research
  - My involvement with the Center is one of the reasons I have persevered to complete my PhD while under some difficult circumstances.
  - I don't see any limitations in our center. Its simply the best I've ever seen. It has been extremely supportive and helped me immensely both in my career and personal front.
  - Keep up the good work
  - Great experience and chance to do something a bit different
  - I see it as a window to acquire the best of education by exposure to diversity and an approach of looking at the current emerging problems with different perspective[s].
  - I also feel that IUCRC's encourage the much needed open discussion to foster solutions to difficult problems. It gathers experts that can provide direction to a "knee-deep" student researcher while still providing some autonomy for the student to work.

Weaknesses

- Operations/Administration (7)
    - Management is in bad order
    - There are a lot of politics involved with being a part of the center.
    - Little cohesiveness in the dissemination of Center information from the director on down to the lower levels
    - Due to the amount of work being conducted at our research facility it can often be difficult to schedule testing and laboratory work and to obtain access to the facilities. However, all members involved do their best to coordinate the maximum possible amount of research.
    - The technologies are no [longer] unique. The center has to change its strategy and provide unique and interesting benefits, such as nanofabrication facility or X-ray lithography.
    - Lack of cohesiveness in the center... each part gets along and does well but the machine itself is disjoint[ed].
    - I should mention that this center is relatively new, created a little over 5 years ago. Many of the issues that I have may be due to the growing pains that the center is undergoing. Nonetheless, there is a major lack of mentoring and guidance for some groups within the center.
- Time Allocation/Workload (6)
    - I have been over-involved in the administrative tasks regarding the operation of the Center, I feel. Thus, more of my time seemed to be spent doing busy work rather than doing actual research and learning.
    - The pay is poor for the hours put in (especially when compared to other graduate assistantships)
    - My work with the center is not related to my research at all making it hard to put the 20+ hours in each week
    - The center project is not part of the dissertation, you still have some benefits (experience, networking, etc.) but the dissertation project is not funded plus it require[s] more time to work for the different projects (dissertation + center project).
    - The workload was at times quite uneven which sometimes made it hard to balance with my schoolwork.
    - Not enough deadlines, a problem in all o[f] graduate school. A lot of work gets done the week before the industrial affiliates meeting (once a semester) though.

- Consequences of Working with Industry (4)
    - Confidentiality of the material and lack of response from some of the companies
    - The extent of involvement of the companies needs to be made clear to the graduate students working on the projects , credit should be given to the graduate student for working on a particular project , by way of publication or patent in time so that a graduate student has living proof of his work before he graduates.
    - Since several industries (members) work together on a single theme within the center (in general, theme represents the broad focus of the center) and some of them compete against each other out of the center, the student working with these industries ends up with incomplete access to all information that he/she might want. In other words, the student might work on a project without completely appreciating the ultimate purpose that the sponsoring-industrial member might have. One way to solve this would be for the industrial member to sign some form of non-disclosure agreement with the student and/ faculty member involved in their project and be completely transparent in terms of end-objectives, motivations etc.
    - The limitation I see with being involved in the Center is that in order to present or publish any of my work, I need to get clearance and I am not able to present all of the work that I have spent so much time on.
- Collaboration (4)
    - There are not enough chance to interact with industry, students and professor from other universities
    - Not enough chance to exchange ideas with other faculty members within center and outside of center
    - A major limitation is that a number of the PIs are from a government agency and lack experience in academia. They are not knowledgeable of the University guidelines and courses, which in turns means that any guidance they give within these areas is generally random or not beneficial.
    - There needs to be [a] forum where, graduate students from different centers could share their experiences, not research information, but common problems or positives, so that each student is allowed to evaluate for himself, how others in a similar environment are shaping up. The job market being fierce, you need to be able to evaluate your weaknesses and work on them to be at or above par from the rest of the gang.
- Employment (3)
    - Not too many intern opportunities
    - Job opportunities
    - One huge limitation is placement opportunities through the center

- Meetings & Conferences (3)
    - I sometimes think that the necessity of report outs for the center takes too much time and hinders research. Most researchers would agree that Industry Advisory Board meetings result in a lot of reporting and very little time with industry and even less feedback from them. It would be better if there was merely an abstract available to industry and then a poster session. If industry wants more they could ask for it but there's no reason to do reporting that often feels like no one is looking at.
    - Not enough chance to attend national and international conferences
    - Equals too many group meetings and oral presentations...should be reduced to one meeting every two weeks instead of every week - collaboration is not always possible nor always a benefit because as graduate students we are interested in graduat[ion] in a timely fashion.
- Other (3)
    - Few [limitations]
    - Limitations would be the ability to learn more about experimental designs to get the skills to do independent research
    - Technical direction is somewhat weak. There is not a thorough understanding of experimental design, and how [research is] implemented.

q.XII.2 How can your Center improve educational components for graduate students?

- Courses/Curriculum (11)
  - Instead of full semester length classes, have 2 week long mini-classes
  - A center must be able to offer core courses in the areas that it considers itself to be generally focused on - usually it leaves the task of course offering to the respective constituent departments and that sometimes fails to meet all student requirements
  - Provide classes
  - Set up a class that teaches … risk assessment
  - Improve the way statistics is taught [in] the department
  - Encourage [taking] courses from other departments except core courses prescribed
  - Offer more graduate classes covering design
  - Build a more structured plan for specializing in the fields that are offered through the department and center
  - Relate practical world knowledge to academic curriculum
  - Providing courses or seminars which are related to the Center research would be beneficial
  - I believe that students completing degrees need a great amount of aid in the areas of personal development, managerial styles etc. For the past several years I have spent my time tackling the technical aspects of the work, however as graduation grows closer, my skills to lead, teach, and become an effective professor need improvement. Perhaps courses in development or mentoring from advisors/ industry contacts would be an aid in helping students to accomplish their goals to become researchers or professors. (We have got the technical, help us with the rest!)

- Seminars/Meetings (10)
    - Include more seminars on career planning
    - Other than the center meetings (bi annual), there should be an interim meeting for the faculty where ideas, explanations, etc. are shared and discussed
    - Holding seminar series on the specific topics would be a great help. Without the help of a well-organized center, it is difficult to organize the seminar[s] provided by experts and others
    - Have inter-departmental seminars (student presentations)
    - Give lectures about looking for a job.
    - By holding monthly meetings regarding lab safety, proper use of lab equipment, laboratory rules and experiments on-going
    - Hold meetings or presentations from well-known centers, universities or colleges in the world
    - The technical fellows from the participating industries can give lectures/seminars to the graduate student community on a regular basis. They can share their experiences as to how the industrial setting compares to that of an academic place from a research and development standpoint
    - It is not enough to just provide resources to a student. Science, more than anything else, is a discussion of ideas to explain the phenomenon we experience in the world around us and that means there should be a far better level of communication. Individual and group meetings should occur on a regular basis within each lab group, and to a lesser degree, internal Center meetings should take place to update the present and future goals of the Center and to help maintain a level of cohesiveness and awareness. From a student standpoint, the center needs to put more effort into mentoring and guidance to allow a foundation to be created from which the student will be able to grow as researchers. I certainly don't mean that the students need to be hand held through their entire degree, but there should be a sincere effort to give each student an equal opportunity to succeed.
    - Having site visits at member industry locations

- Training & Involvement (9)
    - More tutorials and fundamentals of the field/measurement techniques for new students
    - Provide more opportunities for training grad students on the state of the art equipment
    - Give graduate student more freedom to do research and provide them with necessary equipment
    - More training sessions are needed
    - Help students to understand the depth and breadth of their technical area
    - Greater emphasis on soft skills would be a plus
    - Provide students with experience in cutting edge-actual research, communication/writing skills, job opportunities, and industrial exposure
    - I think the biggest drawback to graduate students is not being integrally involved in the project definition. It seems that students join a center to do research on a project that has already been determined. This stems from the fact that needed projects are really determined by industry/government needs prior to the students joining or beyond their ability to influence. Research is done where there is funding. Yes, focus and scope of projects change, however, I feel that it is not an ideal situation for a graduate student to miss out on the creative/inventive stage at the very onset of the project definition. I feel that this is one area in which I lack. I don't see a ready solution to this problem since it is often the case that the student is not even a part of the center when the need for a new research project is identified. However, it may be that the current students play a more integral part in the definition of new research areas for succeeding students and so forth.
    - Perhaps more emphasis on graduate students being involved in meetings
- Interactions (7)
    - Increase faculty communication with students
    - Better interaction with faculty and director. There seems to be a big separation between faculty and students and this leads to break down in communication
    - More interaction among the faculty members and students
    - More interactions with industry
    - More involvement with industrial representatives, even if it's just sitting in on conference calls
    - Send students more frequently to companies where their research could eventually be implemented
    - Continue regular [center] lunches, and promote them to the rest of the [center personnel]. They are valuable for networking, learning, and feedback

- Personnel (3)
  - More undergraduate students to do the experiments
  - Increase the number of faculty working in the center and or department. By doing so, more graduate classes could be offered and advisors would have more time to spend on projects.
  - Need some full time persons in charge of management, sales, and equipment and material consumption.
- Employment Opportunities (2)
  - Make companies come and interview students every semester.
  - Need to focus on industries[,] making some form of internship in their [R&D centers] mandatory for all or some graduate students they are interested in, so as to smooth the transition from being a student to a employee.
- Other (7)
  - I don't feel it is the Center's job to teach me. The only thing that matters is that there is a common thread to all projects and that we communicate with one another from time to time.
  - Be able to work with people in the same area of expertise
  - More student talks with food
  - Improve collaboration with the engineering resources of the university
  - Makes you think.
  - Increase funding for research activities
  - The center should have some say on the graduate policy of the department. For example, students that work for the center can/should participate in an internship as part of their curriculum or academic requirements.