

## ABSTRACT

LEONCHUK, OLENA. Evaluation of Investments In Science, Technology And Innovation: Applying Scientific & Technical Human Capital Framework For Assessment of Doctoral Students In Cooperative Research Centers. (Under the direction of Dr. Denis Gray).

This dissertation builds on an alternative framework for evaluation of science, technology and innovation (STI) outcomes – the scientific & technical (S&T) human capital which was developed by Bozeman, Dietz and Gaughan (2001). At its core, this framework looks beyond simple economic and publication metrics and instead focuses on scientists' social capital. The premise of the framework is that science does not happen in vacuum and that resources embedded in scientists' social networks are important and enduring outcomes of the scientific process that were not being captured by traditional metrics.

This dissertation examines social capital of science and engineering (S&E) graduate students, an underrepresented group of stakeholders in STI evaluations. S&E graduate students are unique for several reasons. In comparison with students in other disciplines, S&E graduate students have a greater proportion of international students; are widely employed by industry in numbers exceeded only by business graduates. And, most importantly, S&E graduates pursue education in fields that contribute the most to the US innovation capacity.

This dissertation introduces a multidimensional measure of social capital based on the network theory of social capital proposed by Nan Lin (1999). According to Lin, social capital consists of three components: *availability of resources* and *social embeddedness* in one's network and *mobilization* of these resources. In order to address these elements, the dissertation employs two studies that focus on different components of social capital. Study 1 looks at accessibility of resources in students' social networks and whether students would be likely to mobilize them by using a proxy measure of norms and values about collaborations. The study also addresses the effect of social capital on students' experiences and outcomes, specifically, on their satisfaction and perceived career preparedness. The researcher investigates the mechanisms that explain other students' outcomes by employing data from a matched sample of S&E doctoral students trained at the Industry/University Cooperative Research Centers, I/UCRCs (N=173), and doctoral students from the same universities and disciplines who were trained more traditionally (N=87). Two exploratory path models

demonstrate the important role of *availability* of network resources and *proxy for mobilizing* them on students' perceived career preparedness and satisfaction with their training.

Study 2 is a case study of one I/UCRC's whole social network. The researcher attempts to provide a better understanding of the *embeddedness* components of students' social capital in their I/UCRC network. The case study has significant limitations in that findings cannot be generalized to the population of I/UCRC students. Nevertheless, findings are interesting for the one I/UCRC. The students scored significantly higher on preparedness when they had higher out-degree centrality, indicator of how much they reach out to other center's personnel. Also, a visual representation of the whole I/UCRC social network could be used to understand better students' embeddedness.

Both studies show that social capital is a very hard concept to measure mainly because of its different dimensions. Nevertheless, they also show that social capital is a useful tool for comparing students' outcomes in different STI programs. A focus on students and social capital is one of the ways the S&T human capital model can be applied in evaluation of the STI programs. Such focus provides a considerable contrast to linear STI metrics that focus on long-term outcomes and often exclude students all together. It is important to provide information about the human side of science in its current state including students' graduate training, experiences and social networks. In addition, inclusion of students provides a view into the future - an opportunity to look at science of tomorrow as the same students will be part of the scientific elite networks in the near future.

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Evaluation Of Investments In Science, Technology And Innovation: Applying Scientific &  
Technical Human Capital Framework For Assessment of Doctoral Students In Cooperative  
Research Centers

by  
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## **BIOGRAPHY**

Olena Leonchuk was born in Kyiv, Ukraine. After receiving Division I athletic scholarship for the women's tennis varsity team from Virginia Commonwealth University she started her bachelor degree in 2006 in Richmond, VA. In 2010, she graduated with Bachelor of Science in International Relationships and minor General Business. After working in the Virginia Commonwealth University as part of clinical research since summer 2008, she was accepted into the Psychology in the Public Interest Program at North Carolina State University in 2011. Since fall 2011, she was working as a program manager and researcher for the National Science Foundation's Industry University Cooperative Research Centers Program Evaluation Project. Olena's interests include science, technology and innovation processes and evaluation, science & engineering workforce, social capital and networks and international students. Upon her graduation, she sees herself continuing her research on social capital and networks and evaluation of the STI outcomes with the goal of becoming an expert in these areas.

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## Literature Review

### **Problem Statement: Science, Technology and Innovation Investments**

In the last two decades, evaluation of governmental investments in science, technology and innovation (STI) has become more abundant and complex in response to the Government Performance and Results Act of 1993 that required all federal programs to be periodically evaluated (103<sup>rd</sup> Congress, 1993; Bozeman et al, 2001). STI investments have also broadened their scope to areas such as team-science (e.g. research centers, research and innovation hubs), entrepreneurial activity and industry-university and other partnerships (Gray et al, 2013). The overall focus has shifted beyond scientific and technical goals and towards the development of scientific careers and collaborations across various institutional and disciplinary boundaries.

Evaluation metrics of the STI programs, however, have not kept up with the volume and demands of these initiatives. Most remained focused on microeconomic models of cost and benefit analysis and the long-term outcomes such as intellectual property (IP) limited by distinct project or organizational boundaries (Bozeman et al, 2001). As a result, these metrics tend to leave the social context and short term impacts of scientific process out of the scope of the STI evaluation.

Another subset of metrics on STI evaluation, commonly known as bibliometrics, provides some information about the social side of science as it is based on scientists' publication record. However, it also has major limitations. While publication volume has increased and bibliometric data have become more easily accessible (Garfield, 2007), bibliometric techniques are still considered "too simple to capture the complexity and multiple dimensions of research output and impact" (Haustein & Larivière, 2015). Moreover, bibliometric data are inherently biased as they are significantly affected by journals' impact factor, publication practices and different disciplines (Leydesdorff, 2008).

This paper breaks new ground in two ways. First, it empirically tests an alternative approach to evaluation – Scientific & Technical Human Capital (S&T human capital). The approach is different from traditional evaluation schemes in its significant emphasis on the human side of knowledge creation. It not only takes into account human capital, "but also the sum total of researchers' tacit knowledge, craft knowledge, and know – how" (Bozeman, Dietz & Gaughan, 2001). In particular, it puts emphasis on social capital that brings human

capital and other resources together. Second, it applies this approach to doctoral students, a population that existing metrics and evaluation projects tend to neglect. In addition, the current paper not only presents empirical testing of a novel evaluation approach and focuses on students rather than existing scientists, but also compares students with different modes of graduate training: one that represents one of the more novel STI investments, Cooperative Research Centers (CRCs), and another that represents traditional departmental training. The paper also looks at the students specific outcome “perceived career preparedness” (also referred as preparedness) which has been introduced in the previous research (Leonchuk, 2015). Given the challenges in finding an objective outcome for students (e.g. publication performance) perceived career preparedness falls in between the continuum of subjective outcome measures such as satisfaction and more objective or “hard” outcomes that can only be measured for student alumni (e.g. job or internship acquisition).

Finally, the paper will place some focus on non-U.S. students. Existing metrics that do not capture the social dynamic of scientific process cannot fully capture the role of and outcomes for international doctoral students who account up to 56% in sciences and engineering (NSF, 2014). Higher numbers of international students have been associated with higher innovation activity in the US, but there has been little effort to investigate unique characteristics of and challenges international students face (Chellaraj et al., 2008).

### **Cooperative Research Centers**

Cooperative research centers are a novel type of STI instrument and organizational framework for the current study. CRCs also represent one of the most popular types of governmental investments as their structural composition allows for addressing multiple aspects of scientific process (Gray et al, 2013). The most comprehensive definition of a CRC is:

An organization or unit within a larger organization that performs research and also has an explicit mission (and related activities) to promote, directly or indirectly, cross-sector collaboration, knowledge and technology transfer, and ultimately innovation (Gray et al., 2013, p. 450).

Even though there are many different types of CRCs, they all are distinguishable in their ability to unite multiple sectors or disciplines and serve multiple stakeholders. Their complex and interactive structures enable them to have impacts on some of the newer more

social outcomes of STI including team work, collaboration, multidisciplinary, cross sector technology transfer, open innovation processes and triple helix (industry-university-government) interactions (Gray et al, 2013). However, while these benefits are frequently mentioned they are rarely measured in part because they do not fit neatly within existing econometric theories and frameworks.

The next section introduces a new theoretical framework for evaluating CRCs and other types of the STI investments that may overcome this limitation – Science & Technology Human Capital theory.

### **S&T Human Capital Framework**

In response to limitations of existing evaluation metrics, Bozeman, Dietz and Gaughan (2001) proposed Scientific & Technical Human Capital (S&T human capital) approach as a novel alternative to evaluation of STI programs and projects. It is different from traditional evaluation scheme in its significant emphasis on the human side of knowledge creation. In particular, it places emphasis on social capital that brings human capital and other resources together. Some aspects of this approach have been tested empirically, but primarily in the context of established scientists (Bozeman & Corley, 2004).

In addition to the general critiques of the existing metrics, authors (Bozeman, Dietz & Gaughan, 2001) challenge common assumption that “there is no variation ... in educational attainment, among scientists” (Allen & Katz, 1992, p.38). In sum, novelty of S&T human capital approach originates in its concentration on “scientists’ career trajectories and their sustained ability to contribute and enhance their capabilities”:

S&T human capital encompasses not only the individual human capital endowments ..., but also the sum total of researchers’ tacit knowledge, craft knowledge, and know-how.  
(Bozeman et al., 2001, p. 5)

This approach draws upon “recognition of the dynamic interplay between scientists’ human capital and their social networks” (Bozeman et. al, 2001; Bozeman & Rogers, 2002) following the footsteps of Coleman (1990) who defines social capital as a part of human capital (Human capital, 2014; Coleman, 1988). In his vision, social capital represents social channels through which human capital can be shared with other:

S&T human capital further includes the social capital that scientists continually draw upon in creating knowledge – for knowledge creation is neither a solitary nor singular event. In sum,

it is this expanded notion of human capital when paired with a productive social capital network that enables researchers to create and transform knowledge and ideas in ways that would not be possible without these resources (Bozeman et. al, 2001, p. 6).

This scientist-centric approach is also applicable to different levels of analysis: individual, project or product, program, scientific field and knowledge value collectives. Knowledge value collective is “a set of individuals connected by their uses of a particular body of information for a particular type of application. It is a loosely coupled collective of knowledge producers and users (e.g. scientists, manufacturers, lab technicians, students) pursuing a unifying knowledge goal (e.g. understanding physical properties of superconducting materials) but to diverse ends (e.g. curiosity, application, product development, skills development)” according to Bozeman, Dietz and Gaughan (2001). However, for the purpose of this study, the concept of social capital will be discussed at the individual level of analysis.

There has been much more theory-based development of S&T human capital framework than empirical testing. However, it has already inspired works on evaluating effects of scientists’ collaboration (Turpin et al, 2010) and effects of “brain circulation” (communication between diaspora and a native country’ scientists) on national policy (Patterson, 2005). In addition, as far back as 1991, Michel Callon talked about the importance of social networks of different “actors” in the process of scientific and technological innovations and proposed social network approach to measure interactions of different actors which he called techno-economic network (TEN):

Technology rarely flows in a predictable and unilinear manner within a relatively stable social and industrial context (Foray, 1991). ... Instead, the new sociology and economics of technology suggest that science and technology are a product of interaction between a large number of diverse actors. (p. 132)

Various advantages of S&T human capital approach over existing approaches to STI evaluation make it a promising candidate for empirical application. The next two sections introduce the origins of the term, social capital theory and lessons learned from empirical studies that looked at social capital of a similar population at individual level of analysis.

## Social Capital Theory and Measurement

Social capital finds its roots in theories of contagion. The theory's main assumption is that social networks are "contagious" with information, attitudes and beliefs from others in the same network (Burt, 1992; Contractor & Eisenberg, 1990; Carley & Kaufer, 1993).

Social capital is not called "capital" by accident. It is considered as a type of capital similar to human and financial capital. However, it is different from other forms of capital in that it "exists in the structure of relations" (Coleman, 1988, p.98) and because of this it cannot be "owned" in the same way as other types of capital (Robison, Schmid & Siles, 2000, p. 12).

In this paper, I focus on a person as the level of analysis because the definitions of social capital and its components vary significantly depending whether the focus is an individual or a group (Bozeman et al, 2001; Yang, 2007). For example, the term social capital as used in the World Bank's efforts to explain development of a community on a regional or national level of analysis (Dasgupta & Serageldin, 2000; Woolcock, 1998; Woolcock, & Narayan, 2000).

**Concept of social capital.** So, what is the definition of social capital? Table 1 in Appendix A borrowed from Adler and Kwon (2002) represents a collection of definitions of social capital by prominent scholars with the most cited highlighted in bold. The table is a fair representation of how sparse the understanding of SC is among scholars. In order to find common themes, I singled out nouns and their adjectives: "resources ... relationships", "social obligations" (Bourdieu, 1996, p. 248); "the sum of the resources ... a durable network" (Bourdieu & Wacquant, 1992, p. 119); "friends, colleagues, and more general contacts" (Burt, 1992, p. 9); "opportunities in network" (Burt, 1997, p. 355); "social structures" (Coleman, 1990, p. 302); "ability of people to work together" (Fukuyama, 1995, p. 10); "set of informal values or norms shared among members" (Fukuyama, 1997); "resources embedded in social structure" (Lin, 1999, p. 35). As these definitions demonstrate, social capital is interpreted very differently and that there is no particular noun that can represent the term.

Even though social capital is a widely used term, it is known to have lack of conceptual clarity (*what measures what?*), confusion about causality (*what leads to what?*) and measurement inconsistencies (Patulny & Svendsen, 2007; Portes & Landolt, 1996). Depending on the field of a study, researchers tend to choose a definition that suits their

goals (Robison et al. 2002). Robinson, Schmid and Siles' (2002) argue that majority of definitions of SC do not answer question "what SC is," but rather "where it resides", "what it does," and "where SC can be used to accomplish" something (Burt, 1992; Coleman, 1990; Narayan & Pritchett, 1997; Putnam, 1993; Woolcock, 1998). As community psychologists Perkins, Hughey and Speer noted: "The reason SC is ambiguous and controversial is that it has been defined differently to suit different ends, or left undefined" (2002).

Few scholars provide more clarity to the concept by going beyond conceptualizing social capital and applying it empirically in their works. These scholars are sociologists James Samuel Coleman and Nan Lin. Coleman made a significant contribution not only to the field of sociology but also education policies by focusing on adolescents. He advanced the term social capital as one of the most important forms of capital, along with human and physical, that helps a child to develop socially and cognitively (Coleman, 1988). Lin, on the other hand, took social capital to another level by proposing Network Theory of Social Capital (1999). His interest in social support lead him to provide a comprehensive overview of issues surrounding the concept and suggest different mechanisms of how to measure it (Lin, 1999; Lin, Fu & Hsung, 2001). Given Lin's expertise, I follow his lead in how to measure social capital.

**Measurement of social capital.** Nan Lin introduced network theory of social capital in 1999 (p. 35) claiming that "social capital, as a concept, is rooted in social networks and social relations, and must be measured relative to its root." Lin defines social capital as: "*resources embedded in a social structure which are accessed and/or mobilized in purposive actions*" (Lin, 1999, p. 35). By social structure he means the network of social connections. He explains that there are three major components embedded in social capital: "*resources* [emphasis by me] embedded in a social structure; *accessibility* of such social resources by individuals; and *use or mobilization* of such social resources by individuals in purposive actions." He specified three main elements of social capital: "the structural (embeddedness), opportunity (accessibility) and action-oriented (use)."

Lin emphasizes that social capital not only represents "social relations and networks," but also "resources" embedded in them (1999, p. 37). Thus, he separates how these components could be measured (Table 1). Embedded resources represent characteristics of the connections (contacts) and characteristics of the social network itself. For example, a



network could be a professional network which has a range of the resources that people in that network combined possess. Network locations, on the other hand, are measured using social network analyses and represent structural characteristics of the network and type of relationships people have in that network. While these techniques help to capture *resources* and *accessibility* components of social capital, they do not address *mobilization* of these network resources.

***Empirical studies on social capital.*** The empirical literature on human capital is too large and heterogeneous to summarize within the scope of this dissertation. For instance, studies have been done at the national, subnational (e.g., region), organizational and individual level of analysis. These studies look at many diverse contexts and target populations. Similar to the theoretical literature on social capital, the studies show little consensus on definition and measurement of social capital. Appendix B (including Table B.1) provides a brief summary of representative literatures. For instance, a majority of the studies look at social capital not as an outcome, but rather as predictor of outcomes such as: financial stability (Agarwal, Chomsisengphet & Liu, 2001; Dufhues et al., 2001) and general health (Furuta et al., 2012; Rojas & Carlson, 2006; Rose, 2000). Given the different context the term is used, it is often measured using information given in that situation. For example, the study that measures financial stability using individual's financial information from banks looks at marital status and homeownership status as indicators of social capital (Agarwal et al, 2001).

A subset of studies on social capital are inspired by Coleman's work in educational settings and assume social capital has a significant positive effect on students, particularly, students with low socioeconomic status (Coleman, 1988). These studies tend to focus on adolescents in middle school and high school and explore the link between social capital, student outcomes and overall well-being (Dika, 2003; Frank, Muller & Mueller, 2013; Patton & Johnson, 2010; Steinfield, Ellison & Lampe, 2008).

Table 1

*Social Capital as Assets in Networks*

Focus	Measurements	Indicators
Embedded resources	Network resources	Range of resources, best resources, variety or resources, composition (average resources), contact resources
	Contact statuses	Contacts' occupation, authority constraint
Network locations	Bridge to access to bridge	Structural hole, structural constraint
	Strength of tie	Network bridge, or intimacy , intensity, interaction & reciprocity

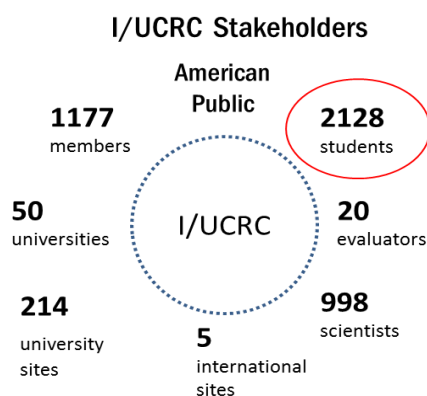
More relevant to my current research studies focus on populations that are similar to my interests. For example, a study on biological research scientists by McFadyen and Cannella (2004) measures social capital using publication data, more specifically, as a size of one's network in form of number of co-authors and strength of these relationships measured as past publication record with the same coauthors. McFadyen and Cannella found a positive significant relationship between their measure of social capital and new knowledge creation based on impact factor of journals the researchers published. Another study of scientists at the corporate settings (Gabbay & Zuckerman, 1998), looks at social capital as predictor of scientists being promoted to a more managerial position measured social capital based on Burt's social network structural properties such as density. Similarly, they found positive relationship between social capital and their outcome. While these studies show potential relevance of this dissertation's theoretical and empirical focus, none of these studies looks at social capital of the population of interest to this study - S&E students. Moreover, there are only few existing measures that can be used as a base or guidance for the social capital measure in the context of the current study.

**Summary.** Overall, Lin expands upon purely theoretical foundations of social capital by providing a reliable framework for conceptualizing social capital. Although he doesn't offer specific scales, he highlights the need to customize measures. Resources in the

professional network of a medical doctor, for instance, will be significantly different from resources embedded in the network of a tennis player.

### **I/UCRCs and Graduate Students**

**Industry-university cooperative research centers.** Understanding social capital creation in newer more collaborative settings needs to be anchored in a specific setting. Industry/University Cooperative Research Centers (I/UCRCs) are one of the longest operating examples of an CRC (over 35 years) and one of the most highly leveraged types of CRCs with only 11% of federal NSF funding (2013-2014 Structural Information Report). Team science, multidisciplinary and multi-institutional research and cross-sector partnership are some of the main components of the I/UCRCs (Gray, Boardman & Rivers, 2013). This strong collaborative element is the result of the government-mandated consortia structure that includes multiple universities, faculty, students, firms and industry scientists and that aims to meet the needs of I/UCRCs' multiple stakeholders (Figure 1). These and other distinct characteristics of I/UCRCs result in a strong track record of almost 60% graduating centers operating five years after NSF funding ends (Gray et al., 2011).<sup>1</sup>



*Figure 1.* The I/UCRC Stakeholders during 2014 Fiscal Year.

<sup>1</sup> Centers are called “graduated” when they successfully complete at least two 5-year phases of NSF funding while meeting all the requirements under the NSF I/UCRC solicitation.

The I/UCRC program has also incorporated a unique “improvement evaluation” strategy. Each I/UCRC has its own independent evaluator who performs a role not only as an observer but also as an advisor. In addition, structural and procedural data from all active centers are collected and analyzed annually at the national level.<sup>2</sup> This unique evaluation component of I/UCRCs has also produced an extensive volume of additional peer-reviewed research that looks at the different I/UCRC stakeholders and issues. The main findings demonstrate a variety of positive benefits and impacts of the I/UCRC for faculty (Coberly & Gray, 2010), industry (Gray & Steenhuis, 2003; Hayton, Sehili & Scarpello, 2010), universities (Steenhuis & Gray, 2006) and general economic impacts (Rivers & Gray, 2008) and, at the same time, lack of negative impact such as suppression of students’ academic freedom (Behrens & Gray, 2001).<sup>3</sup>

Nonetheless, there are gaps in the coverage. Only a modest amount of this research focuses on graduate student impacts. Withstanding the author’s recent research (Leonchuk, 2015), none of the assessments have focused on social capital outcomes. In the next section, I highlight what is known on these topics.

**Science & engineering students’ graduate training.** Although students are frequently cited as one of the I/UCRCs most important stakeholders and a valuable resource to other stakeholders like industry and university (Gray & Rivers, 2008; Gray, Sundstrom, Tornatzky & McGowen, 2011), they have not been the focus of a great deal of evaluative research. This may be due to the over emphasis on economic outcomes described at the beginning of the paper. Nevertheless, I/UCRC students receive a very valuable training experience that can result in positive long-term outcomes for not only for students but also for the organizations that eventually employ them.

I/UCRCs have many structural mechanisms that may have a big impact on social capital: each center has two annual meetings where projects are voted on and selected by industry while faculty and students present their project proposals or results of current projects. Besides these meetings, students and faculty often visit industry sites and communicate about the projects between the meetings. All these experiences are potentially

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<sup>2</sup> The centralized national data collection and processing have been done at North Carolina State University’s Department of Psychology under leadership of Dr. Denis Gray and his research team.

<sup>3</sup> The most recent presentation of the logic model of the IUCRC evaluation project that contains all the completed research on the IUCRCs and potential future research projects can be found at: [https://www.ncsu.edu/iucrc/Jan'15/Breakout%201-3\\_Logic%20Model\\_Behrens.pdf](https://www.ncsu.edu/iucrc/Jan'15/Breakout%201-3_Logic%20Model_Behrens.pdf)

very beneficial to center students as they have opportunities to work with different faculty and industry in the way that is not typical in traditional academic training. Below I summarize some of what is known about I/UCRC students and how this training experience affects them.

***Demographics.*** In order to understand S&E graduate students' training and their experiences at I/UCRCs, it is important to know the unique demographics of this population. First, only 23% of these students are female (National Science & Engineering Indicators, 2014). Second, foreign nations see the US educational system as an investment and have been providing steady and rising supply of international students that now accounts for the majority of all S&E graduate degrees in the US (57%). Finally, research in S&E has the most commercial value which has made these disciplines as the most lucrative for industry partnerships, both during the time students are in school (CRCs, co-ops, industry hubs etc.) and after their graduation as hires. Needless to say, S&E disciplines have second to highest rate of graduates being employed by industry after business schools (National Science & Engineering Indicators, 2014).

***CRC and I/UCRC students' training.*** A relatively modest amount of research has been conducted on students involved in I/UCRCs and similar CRCs. Table 2 provides a summary of all the studies found in the extant literature about students trained in CRCs, I/UCRCs and engineering research centers (ERCs), the type of CRCs that, in the contrast to I/UCRCs, are funded in full by the US government.

Main topics in the literature on CRC students include: students' satisfaction and perception of their graduate experiences of the cooperative work with industry (Ailes, Roessner, & Feller, 1997; Butcher & Jeffrey, 2007; Gemme & Gringas, 2004; Mendoza, 2007; Schneider, 2007; Scott, Schaad & Brock, 1993; Wallgren & Dahlgren, 2005); supervision and advising of their graduate career by a combination of faculty and industry (Ailes, Roessner, & Feller, 1997; Powles, 1993); effects of industry funding on academic freedom, productivity (publication and patenting), career ambitions and general experiences (Behrens & Gray, 2001; Gluck et al., 1987; Harman, 2002 & 2004); outcomes of the students' training with industry which include recruitment of students by industry (Ailes, Roessner, & Feller, 1997; Behrens & Gray, 2001; Beltramo et al., 2001; Lam, 2001; Scott & Schaad, 1992); labor prospects of these doctorate students (Moguerou, 2002); description of

early career of the former students (Cruz-Castro & Sanz-Menedez, 2005; Parker, 1997; Mangematin & Robin, 2003) and students' aspirations (Gemme & Gringas, 2004).

Ailes, Roessner and Feller's study (1997) with industrial members of the Engineering Research Centers (ERC) demonstrate that industry is involved with students in three different ways: mentoring students, sharing research projects with student and hiring students. The study done by Parker (1997) revealed that ERC alumni were significantly more likely to rate themselves higher on variety of skills. Scott, Schaad and Brock's (1991) study showed that I/UCRC students rated their exposure to industry research ( $p < .001$ ), participation in applied research ( $p < .001$ ) and establishment of contacts with industry and academic researchers ( $p < .001$ ) higher than students with more traditional graduate training. Behrens and Gray (2001) demonstrated that there is no support for the hypothesis that industry funding hinder students' outcomes and researchers and conclude that the outcomes of the I-U cooperation on graduate students are still not very well known. Mendoza's study (2007) showed that there is no instance of "exploitation" of "cheap labor" of students by industry. Finally, Schneider (2007) demonstrated that I/UCRC students were most likely to rate themselves as proficient at soft skills when they were more involved in the technical aspects of the projects and have more interaction with their committee and industry members. Also, the more experiential (hands-on) training students received, the more males and non-U.S. students were satisfied with their training.

The studies on CRC students demonstrate that students' interaction with other professionals is very rich. They are exposed to the team-like settings by working with industry and professionals from other disciplines. They also are involved with research projects that are more "real-world" and practical in nature than typical academic projects. Nevertheless, the CRC experiences and involvement differ for each student. For instance, students receive industry funding in different ways and at different levels (cooperatives or single-company funding, partial or full funding), have different frequency and depth of interaction with industry (defined by whether their thesis/dissertation is based on CRC research) and experience different levels of multidisciplinary.

Table 2

*Empirical Studies on CRC and I/UCRC Students*

Authors, Year	Design	CRC Involvement / Experiences	Outcomes
Ailes, Roessner, & Feller, 1997	Former ERC industry members	Mentoring by, collaboration with & hiring by industry.	40% of members hired ERC student. Not frequent communication of students with industry during training.
Scott & Schaad, 1992	Pilot. ERC alumni & their employers	Inconclusive as few employers knew ERC background of their hires.	
Parker, 1997	ERC alumni & their employers	Real-world experiences (31%); internships with industry (31%). ERC courses (23%), exposure to different disciplines (21%), equipment or facilities (19%), work in teams (16%), networking (12%), communication skills (7%)	NA
Scott, Schaad & Brock, 1991	I/UCRC vs. non-IUCRCs grad. Students	IUCRC students scored higher on: exposure to industry research, participation in applied research and establishment of contacts with industry and academic researchers.	I/UCRC more satisfied.
Behrens & Gray, 2001	I/UCRC students	Source of students' funding: industry (45%), government (34%), and other university funds or no funding (21%)	No negative consequences for students with industry funding. Lack of any funding made it hard to support thesis/dissertation research.
Mendoza, 2007	Case study with an I/UCRC's students	NA	No threats to academic values due to industry presence. Difficulty in communication with industry for international students
Schneider, 2007	I/UCRCs' and 1 ERC's students	Most had their thesis/dissertation based on center research and multidisciplinary committee for their research. Students were involved in the CRCs at different lengths of time. Two main types of experiences identified via EFA: experiential (hands-on) and multidisciplinary with industry and professionals from other disciplines.	Two main strengths of center training: general collaborations (19.0%) and interactions with industry (17.2%). Two main weaknesses: administration (12.1%) and time allocation/workload (10.3%). Male are more satisfied when have experiential experiences.
Leonchuk, 2015 <sup>4</sup>	Matched I/UCRC & non-I/UCRC students	Three types of experiences: cross-sector professional development, industry and multidisciplinary/group. Dosage of center involvement was determined by whether thesis/dissertation is based on center research.	IUCRC students are more satisfied, perceive themselves as more prepared and acquire more professional social capital. Some outcomes are mediated by citizenship status and dosage of center involvement.

<sup>4</sup> Measures and outcomes of this study will be discussed in more detail in the following section while this section mainly focuses on characteristics of students' training.

Most students rate their Industry-University experiences as very satisfactory and appreciate industry's involvement not only as the funding source, but also as a mechanism that helps them to finish their programs on time and to understand "real-world" problems. Moreover, there was no evidence found about negative effects of industry involvement on the students' outcomes such as academic freedom (Behrens & Gray, 2001). Therefore, industry seems to have a constant and positive presence in S&E academic fields.

In theory, CRC experience provides enormous opportunities to acquire rich and diverse social capital that, at the very least, can help students to secure a first job offer upon graduation. However we know little about the actual social capital outcomes or the *mechanisms* involved in these effects. For instance, up until recently, none of the studies looks at the social capital as one of the outcomes of the CRC training.

### **Recent Research**

Recently the author completed a study (Leonchuk, 2015) that helps shed some light on the issue of social capital in the context of graduate training of the S&E students. The goal of the study was to investigate how different types of graduate training affect social capital. It incorporated a quasi-experimental design with a matched sample of doctoral students in engineering and computer sciences trained at the NSF I/UCRCs ( $N_{IUCRC} = 173$ ) and doctoral students from the same universities who are not part of any research center ( $N_{Traditional\ Training} = 87$ ). The two groups were comparable in: gender (23% female), age, citizenship status (56% are international students who are not US citizens), GPA and time spent in graduate school.

Given the population of graduate students who are difficult to evaluate due to the limited professional activity than more established scientists the primary dependent variables included students' social capital, perceived career preparedness (hereafter referred to preparedness) and satisfaction with graduate training. Both measures, social capital and preparedness, had to be developed from scratch based on the existing literature on social capital and graduate students who are trained in CRC environment and feedback from the STI evaluation practitioners.

The findings showed a significant I/UCRC training effect on most components of social capital, satisfaction and preparedness. Some of the center effects, however, were significantly moderated by citizenship status (US vs. international). For example, Figure 2



demonstrates the results of two-way ANOVA of the between-subjects effects on the strength of industry network in form of availability of advice which was significantly predicted by the type of graduate training,  $F(1, 256) = 5.406, p = .021, \eta^2 = .021$ , citizenship status,  $F(1, 256) = 5.33, p = .022, \eta^2 = .020$ , and interaction of the two variables,  $F(1, 256) = 8.567, p = .004, \eta^2 = .032$ . This finding is, especially, interesting because the size of industry network was not affected by citizenship status. Thus, a mere availability of industry professionals in a student's network does not guarantee that students have the tools or personal characteristics to make these relationships meaningful. . Given that the size of international students' industry network was not affected by their training but its strength was suggests that international students may face challenges beyond language and cultural barriers as they try to achieve their professional development in the US context.

Figure 3 shows that I/UCRC training also had significant effect on students' satisfaction,  $F(1, 256) = 17.217, p < .001, \eta^2 = .063$ . All I/UCRC students were significantly satisfied with their training regardless of their citizenship status (Figure 3). Perceived career preparedness, on the other hand, was positively affected by the I/UCRC training ( $r = .343, p < .001$ ) but, it was not affected by citizenship status.

Besides citizenship status, another important moderator for I/UCRC students' outcomes is whether I/UCRC students' dissertation is based on the center research. When student's project is based on center research, he or she indicates stronger US academic network, stronger industry network and more positive values about collaborations.

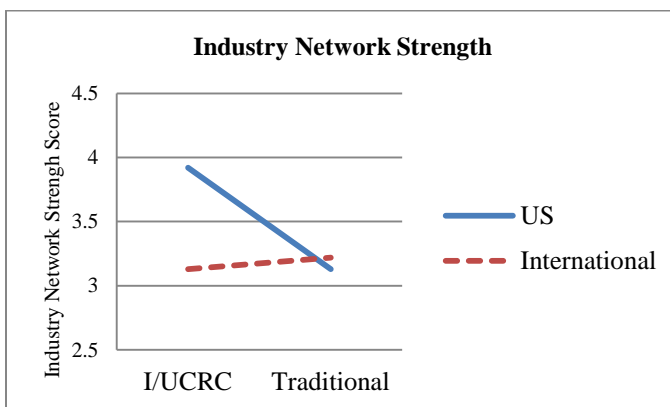
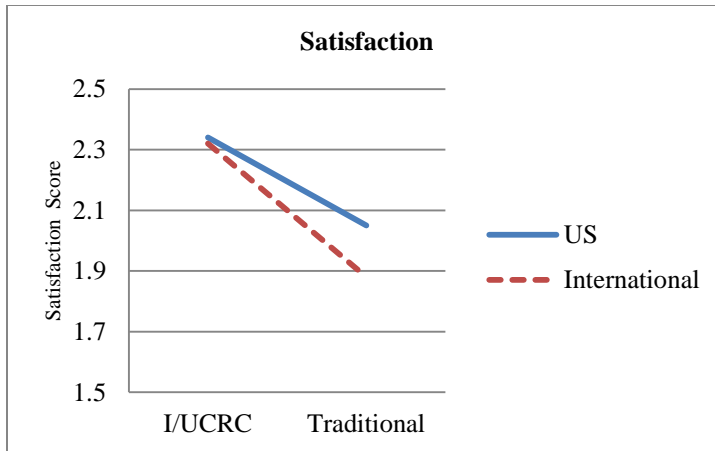


Figure 2. Type of Graduate Training Mean Difference of Industry Network Strength in form of Technical Advice and Input



*Figure 3.* Type of Graduate Training Mean Difference of Satisfaction

In addition, the study revealed an interesting pattern of international students' intentions to stay in the US or go back to their country of origins upon graduation. The results did not reach statistical significance (possibly due to a small sample size), but they demonstrated a pattern: more I/UCRC international students intended to stay in the US and more students trained in Traditional environment intended to go back home.

Overall, the study showed that the I/UCRC training has a significant positive effect on the students' outcomes, however, there are factors, particularly, citizenship status, that moderate these relationships. The results about industry network component of social capital showed that international students do not have the same access to the resources regardless of their center involvement (Leonchuk, 2015). This effect of citizenship status on the student outcomes showed that S&E doctoral students and international students should not be considered as a homogeneous group. However, it is not well understood how big the effect of citizenship status is on students' outcomes. Finally, conceptually, the study contributed to the literature on students by examining perceived career preparedness and social capital, which appear to be less subjective outcomes of graduate training than purely subjective measures like satisfaction.

**Limitations.** In spite of the new insights gained from the study, the study had some limitations and gaps. Most of the study analyses were bivariate in nature. Even though the study measured graduate training experiences for both groups of students, I/UCRC and Traditional, and extent of involvement with center for I/UCRC student, it did not investigate

*how* these training components interact with each other and whether they have direct or indirect effect on students' preparedness. For instance, the study does not provide information on whether variation in social capital and other outcomes can be attributed to students' unique demographics or characteristics of their training. Moreover, the study did not investigate whether social capital serves as a mediator of satisfaction and perceived career preparedness.

In other words, the study does not test these variables as part of the empirical model that could tell us more about *mechanisms* that help or hinder acquisition of social capital for some students (e.g. international students) and whether social capital impacts other important students' outcomes.

The other important limitation of the study was that it did not capture the students' *embeddedness* in their professional social network of an I/UCRC or department that Lin (1999) has stated as one of the three main components of social capital. In other words, it is unknown how students are positioned in their social network and whether they differ in how close their relationships are with other professionals.

**Next steps.** In the context of I/UCRC program and STI investments in general, graduate students' training and outcomes are often overshadowed by a focus on long-term outputs such as collaboration patterns of established scientists exhibited in publications and intellectual property. Nevertheless, graduate students have an immediate and long-term impact on the state of science and economy. Thus, more should be done to learn about their demographics and training outcomes.

Moreover, while NSF Science and Engineering Indicators and other sources regularly provide statistics about scientific workforce and international students' enrollment, they do not provide comprehensive information about students' graduate experiences and outcomes. Most sources, including empirical studies, do not provide information about *mechanisms* of how graduate training influences students' outcomes. Particularly, it is unknown how graduate training affect different components of social capital and what role these components play in students' graduate training.

Therefore, the following questions need to be answered: *Why does* the I/UCRC-type of training have such a strong impact on students' social capital, especially in the form of accessibility of resources and likelihood of mobilizing these resources? In the context of

social capital, *why do* international students not have the same availability to resources in their social network as the US students? And, finally, *how* are students positioned in their social network or how *embedded* are they in their social network that contains resources they need to succeed? The current two studies aim to answer these questions by looking at different components of social capital and exploring the mechanisms behind relationships that are already known about this population. These questions will be addressed in two studies described below.

### **Research Objectives**

This dissertation tests S&T human capital approach in the context of graduate students in S&E disciplines by looking at three elements of social capital proposed by Lin: *embeddedness* of resources in students' network, *accessibility* of these resources and indication of the extent to which these resources will be mobilized by students (Lin, 1999). The first study looks at social capital in terms of how accessible embedded resources are to graduate students and students' norms and values about professional collaborations as proxies for intentions to mobilize these resources. The second study aims to understand embeddedness of students in their social network with the goal of understanding students' structural positioning in their close professional social network.

In particular, the first study uses data from my previous research and aims to get a better understanding of direct and mediating effects of the two elements of social capital on other students' outcomes, satisfaction and perceived career preparedness. The second study looks at a case study of one I/UCRC. It aims to measure students' social embeddedness in the communication network of one I/UCRC. It looks to identify communication patterns and structural characteristics of students in relationships to other center personnel. The following two sections describe research questions and hypotheses, data collection procedures, measurement and main variables for each study.

## Study 1: Matched Groups Comparison of I/UCRC and Traditionally-Trained Students Method

**Questions and hypotheses.** Results from my previous research demonstrate that the I/UCRC program has a significant effect on several students' outcomes: social capital, preparedness and satisfaction. My hypotheses attempt to address the mechanisms for the processes that affect preparedness and general satisfaction with students' training on the whole sample ( $N=260$ ) and subsequently on the subsample of I/UCRC students only ( $N=173$ ). The analyses that test these hypotheses include two main steps: 1. preliminary analyses using correlations, univariate regressions and multiple regressions; 2. path analyses. The path models described in this section represent the *conceptual* models of relationships I will test in Analyses section.

The first two hypotheses are tested on the whole sample of I/UCRC ( $N = 173$ ) and Traditionally-trained ( $N = 87$ ) students. Figure 4 contains path Model A that display hypothesized relationships that will be tested for  $H_1$  and  $H_2$ . Variables that are marked with asterisk are grouping variables: students are *nested* in different categories of these variables.

There are three types of experiences S&E students are exposed to during their graduate training: cross-sector professional development, experiences with industry and team/multidisciplinary (Leonchuk, 2015). These experiences are the proxies for the I/UCRC training. Nevertheless, it is unknown whether these experiences differ for students trained at different settings and whether these experiences *mediate* the effect of graduate training on preparedness and satisfaction with graduate training:

**H<sub>1</sub>:** The effect of graduate training on preparedness and satisfaction will be significantly *mediated* by:

- a. Industry Experiences
- b. Cross-sector Professional Development Experiences
- c. Multidisciplinary/Team Experiences

My previous research (Leonchuk, 2015) shows that access to one's industry network, as measured by the size of the network and strength of its connections, and norms and values (that represent the proxy for action-oriented aspect of social capital) significantly differ for

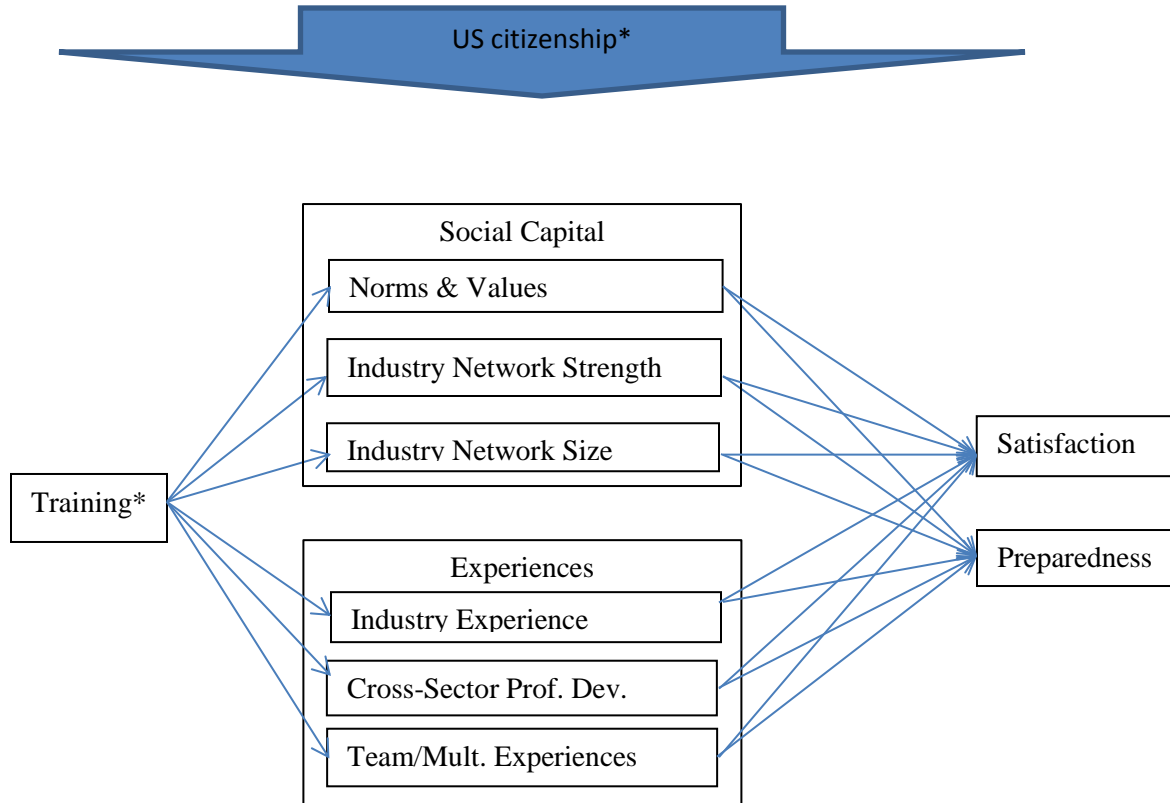


Figure 4. Path Model A (N=260)

\*Grouping variables.

traditionally-trained students (Lin, 1999). Thus, these components of social capital are also tested as mediators of the effect of training on preparedness and satisfaction.

**H<sub>2</sub>:** The effect of graduate training on preparedness and satisfaction will be significantly *mediated* by:

- a. Industry Network's Size
- b. Industry Network's Strength
- c. Norms and Values

In addition, although there is insufficient basis for testing a hypothesis, I will examine an additional research question. My previous findings indicated that US citizenship status moderates the effect of graduate training on industry network strength. Thus, I would like to investigate if there is any effect of this variable on the hypothesized relationships in Model A:

**RQ<sub>1</sub>:** Does citizenship of the participants moderate the relationships in Model A?

My next set of hypotheses focuses on the *mechanisms* involved in I/UCRC training and therefore only apply to those students ( $N=170$ ). My previous research and empirical literature demonstrate that individual I/UCRCs differ in the extent to which they follow “best practices” (fidelity to consortium model). Also, students differ in their dosage of the center involvement and on the exposure to different I/UCRC experiences which are also referred as I/UCRC proxies. Dosage of the center involvement includes three variables: a) focus of the research project; b) duration of time at I/UCRC; c) percentage of time spent on I/UCRC activities. Three I/UCRC proxies include: a) industry experience; b) cross-sector professional development experience; c) multidisciplinary/team experience. Thus, the next hypotheses and research question investigate to what extent the effects on preparedness and satisfaction is mediated by the three social capital components (Model B in Figure 5).

The following hypothesis investigates whether an I/UCRC’s fidelity affects students’ preparedness and satisfaction and whether social capital components mediate its effects.

**H<sub>3</sub>:** Industry network size will mediate the effect of the following predictors on preparedness and satisfaction:

- a. Center fidelity
- b. Dosage of the I/UCRC involvement
- c. I/UCRC proxies

**H<sub>4</sub>:** Industry network strength will mediate the effect of the following predictors on preparedness and satisfaction:

- a. Center fidelity
- b. Dosage of the I/UCRC involvement
- c. I/UCRC proxies

**H<sub>5</sub>:** Norms & values will mediate the effect of the following predictors on preparedness and satisfaction:

- a. Center fidelity
- b. Dosage of the I/UCRC involvement
- c. I/UCRC proxies

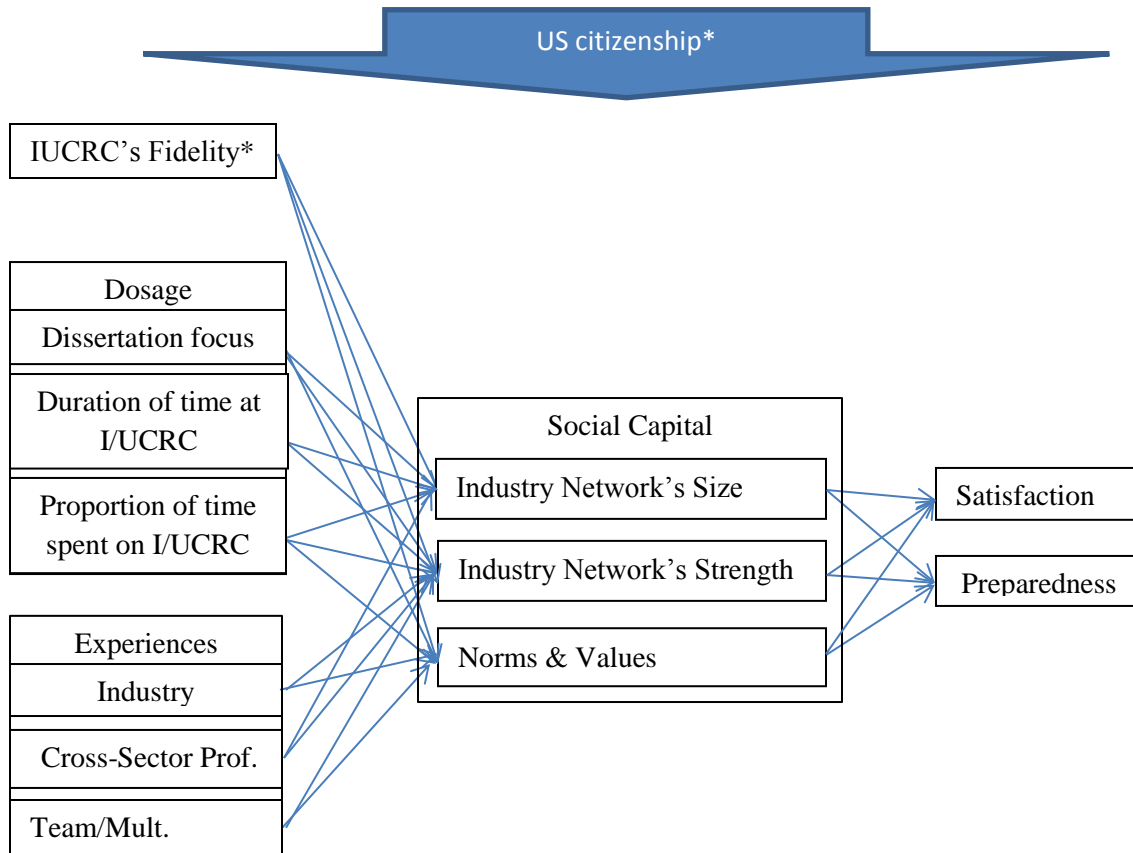


Figure 5. Path Model B (N=173)

\*Grouping variables.

Similarly, a research question about the moderating role of US citizenship in the relationships in the model B will be tested:

**RQ<sub>2</sub>:** Does citizenship of the participants moderate the relationships in Model B?

**Population, procedures and methods.** The population for the study was graduate students in S&E in US research intensive universities. The study compared students trained at I/UCRCs and those who were trained at departments with the most traditional experiences that do not include collaboration with centers. First, data were collected using Qualtrics web survey from the I/UCRC students. Then, I attempted to find a matched sample of students who did not receive center-based training (Traditional Training). Before the data were collected, power analysis (G\*Power software) was used to identify the adequate sample size. A priori power analyses for MANOVA special effects and interactions were chosen to perform this task as the study has multiple IVs, multiple DVs, and some variation within



groups. A total of 190 participants was needed to have 80% power for detecting a small size effect when employing the traditional .05 criterion of statistical significance. Thus, the original goal of this study was to contact at least 100 students in each of two groups which would make the total sample of 200.

*I/UCRC students.* At the time of data collection, the I/UCRC program had 66 active centers and 181 university sites that accounted for 1,690 (PhD = 1,071, MS = 619) graduate students. All centers were asked to provide their current graduate students' emails. Total of 1,019 email addresses were received from 81 (about half) of the university sites.<sup>5</sup> Link to the survey was sent to all 1,019 identified students with study's description, encouragement from NSF program directors and opportunity to win one of two \$50 Amazon gift cards. Table 3 provides responses to the questionnaire, amount of missing data and responses that did not qualify for the study and, thus, were excluded from the analysis. A total of 612 I/UCRC students started the survey, 233 fully completed it. Qualified responses belong to 176 students pursuing PhD, 19

Table 3

*Response Rate*

Response Categories	I/UCRC	Traditional
Sent to	1,019	1,399
Started	612	398
No to consent	5	5
Early Drop-outs	23	24
Not qualified (academic standing)	56	21
Drop-outs	16	NA
Not qualified (center involvement)	61	194
Not qualified (1-3 months in grad. school)	11	6
Partially Missing	207	53
Final	233	95
Outliers*	3	0
Final PhD	176	87

\* Three outliers were excluded from the analysis. Two were extreme outliers for the Norms & Values scale scoring extremely low on all 8 questions. One outlier was a 78 y. o. man.

<sup>5</sup> The data on the total number of the graduate I/UCRC students is taken from the 2012-2013 Structural Report.

pursuing only Masters' and 38 Masters' students who were planning to go to finish with a PhD.

***Traditional-trained students.*** Creating the traditional training students group included the following steps. First, an attempt was made to match the sample to graduate standing, discipline (department) and university. Student contacts were downloaded from the websites of the universities most sample I/UCRC students belong to. I tried to match the disciplines to the I/UCRC group as closely as possible, however, not all the universities and disciplines had their students' emails available. Therefore, preference was given to universities with online information about enrolled graduate students. Students' emails were collected using I-Python Notebook program.

Traditionally-trained students were asked the following screening question: "Choose the answer that best describes the research project you are engaged in to satisfy your degree requirement" (Appendix C, Q4). Only students who chose one of the following answers were included: (1) My Master's/PhD research project is an individual project that is being supervised by my main academic advisor(s) and dissertation committee (74%); and (2) My Master's/PhD research project is part of a larger team-based project but is still supervised by my main advisor(s) and dissertation committee (26%). The survey was sent to 1,399 students. Out of 398 students who started the survey, 194 (49%) were involved in some kind of CRC and were excluded from the sample. The rest of the excluded responses were early drop-outs and students who did not qualify due to being an undergraduate student ( $N=21$ ). Excluding the non-qualified and non-respondent students, the final sample was 95 (PhD = 87, MS<sub>only</sub> = 3, MS<sub>plus PhD</sub> = 5). PhDs accounted for 76% of the I/UCRC sample and majority (92%) of the Traditionally-trained students were PhDs. Since the number of MS students in both samples was relatively small, all analyses were performed with PhD students ( $N_{IUCRC} = 173$ ,  $N_{Traditional} = 87$ ). Two different types of training, I/UCRC and Traditional, were the main independent variable for the study.

***Demographics.*** The two groups were representative of the US national population of the S&E graduate students and were also comparable in demographics and other relevant characteristics (National Engineering Indicators, 2014). The mean for age in both groups was 28 years old. GPA was 3.8 for I/UCRC students and 3.7 for Traditional Training students. Time spent in graduate school averaged three years. Percentage of women in S&E graduate

disciplines at the national level is low and ranges from 23 to 33% depending on the discipline (National Engineering Indicators, 2014). The same is true for our two groups: I/UCRC group was 23.7% ( $N = 41$ ) female and the traditional training group was 21.8% ( $N = 19$ ).

Similarly, both groups were comparable in citizenship status (US citizen/permanent resident as “1” or international as “2”) where international student account for 56.1% ( $N = 97$ ) in I/UCRC group and 56.3% ( $N = 49$ ) in non-traditional training group.

The data were collected from research intensive universities most of which have at least one I/UCRC. There were five main groups that students represented in terms of discipline (Table 4). The samples for the two training groups, however, were not matched well on the type of disciplines. For example, the sample had more I/UCRC students studying mechanical and electrical engineering while the traditional training group was more numerous in computer science. Also, I/UCRC students significantly outnumbered traditional students in “Other” category which may indicate that they were a more diverse group. This was the only difference between the two groups that was significant according to Chi-Square analyses of the discipline variable with graduate training,  $X^2 = 63.823$ ,  $p < .001$ . Thus, discipline will be used as the main covariate in the final analyses in order to identify whether the type of discipline rather the type of training has an actual effect on students’ outcome.

Table 4

*Descriptive Summary of Most Common Disciplines*

	Training		Total
	Traditional	I/UCRC	
Computer Science & Engineering	39	17	56
	45%	10%	22%
Electrical Engineering	17	46	63
	20%	27%	24%
Material Science & Engineering	21	22	43
	24%	13%	17%
Mechanical Engineering	2	44	46
	2%	25%	18%
Other	8	44	52
	10%	25%	20%
Total	87	173	260

**Instruments and measures.** The survey went through multiple revisions and feedback from researchers familiar with the subject matter helped to insure validity of the measures. With the following few exceptions all respondents answered the same set of questions. Traditional training students did not answer questions related to I/UCRC involvement (Appendix C, Q5-9). Second, the wording of the survey was slightly modified for the Traditional students so that there was no reference to the I/UCRC program. For example, the italicized portion of question that measured students' preparedness level was dropped for traditionally-trained students: "In comparison with other students at your department *who are/were not involved with I/UCRC*, indicate to what extent do you agree or disagree with the following statements." The following sections describe variables that were used in this study.

**Dependent variable.** Perceived career preparedness was a rationally created scale developed for the study (Appendix C, Q11). Students were asked their degree of agreement or disagreement with statements about their preparedness for their future careers described in Table 5. Principal component analyses (PCA) showed that all four items loaded on a single factor and explained 61% of the variance. Reliability analysis of demonstrated the scale had acceptable internal consistency (Coefficient alpha = .761).

Table 5

*Descriptive Summary of the Perceived Career Preparedness*

Variable	Mean	SD	Skew	Skew SE
My training has better prepared me to the demands of future employment.	4.12	.759	-.790	.151
I feel that I have expanded more my network of academic professionals who can give me advice and assistance in the future.	4.03	.871	-.808	.151
I feel that I have expanded more my network of industry professionals who can give me advice and assistance in the future.	3.85	1.043	-.737	.151
I think I have more necessary skills to make a valuable contribution to an organization that is going to hire me.	4.20	.758	-.880	.151

The second outcome variable was students' satisfaction with their graduate training based on a single Likert type question (Appendix C, Q33, mean = 4.16, SD = .81). Since the distribution was skewed towards positive values of satisfaction, the number of the students who choose responses dissatisfied ( $N = 3$ ) and mostly dissatisfied ( $N = 6$ ) was very small. Thus, the variable was recoded into three-item scale where neutral, mostly dissatisfied and dissatisfied were combined. Recoded satisfaction had mean = 2.20 and SD = .69 (Table 6).

Table 6

*Descriptive Summary of the Recoded Satisfaction Variable*

	Frequency	Valid Percent	Cumulative Percent
Neutral/Mostly Dissatisfied/Dissatisfied	40	15.4	15.4
Mostly Satisfied	127	48.8	64.2
Satisfied	93	35.8	100.0
Total	260	100.0	

**Predictor Variables.** Measures of social capital depend heavily on the context of the population and the goals of the study (Gaag & Snijders, 2003). This study focuses exclusively on individual professional social capital of the young scientists in S&E fields.

The first component of social capital is a measure of accessibility of resources embedded in students' network (Lin, 1999). It is measured as the actual social network of students, particularly, size as the number of social connections and strength of these network connections. Network size is measured by asking students about the number of professionals they know from 14 specified categories (Appendix C, Q15). There was no maximum value given for the number students can provide for a given category, so most categories had extreme outliers. Extreme outliers for each of the original categories were recoded into the closest value on the distribution of that category (Shadish, Cook & Campbell, 2002). For instance, when an extreme outlier with a value of 50 for category of "Faculty from other disciplines/departments from your university" was identified using P-P-plot, it was recoded into the highest value on the distribution which was 30. The original 14 categories were combined into three final categories that represented the main types of groups students had connections to during their training: *US academics*, *international academics* and *industry*.

Strength of connections was measured using Likert-type scale items that measured the availability of “technical advice or input” and “introduction to another researcher” from five original categories of professionals (Appendix C, Q16 & 17). The same three final network categories were used in the final analyses for the two different types of strength of students’ networks: *US academics*, *international academics* and *industry*.

The three variables indicating the size of the three types of network connections had large negative skewedness. I tried to correct for skewedness, but it resulted in variables changing their skewedness in the opposite direction (from negative to positive). Thus, I decided to keep the variables as they were. Exploratory factor analysis and reliability analyses were conducted using these variables to determine if they can be converted in a scale or multiple scales. However, the analyses were not successful in combining these individual measures into a scale(s). Thus, these nine variables (three types of networks (industry, US academics and international academics) and their corresponding measures of size (#1) and strength in form of availability of advice (#2) and introduction (#3) were used individually in the analyses as components of bridging social capital. Table 7 provides descriptive information about student’s average bridging social network and its nine measures.

Previous analyses (Leonchuk, 2015) indicated that only industry network’s size and strength were significantly affected by the I/UCRC training. Thus, the current study will focus on the following network measures: *size* of industry network and *strength* of industry connections where strength is a combined measure that contains two items, availability of advice and availability of introduction, with corresponding loadings .907 and .907 on a single factor with  $\alpha = .785$  and 82% of variance explained.

Table 7

*An Average Student's Social Network Availability*

Network Type	Size	Strength*	
		Advice	Introduction
Industry	13	3.38	3.49
US academics	58	7.83	7.95
International academics	11	3.18	3.35

\*Two strength items were measured as Likert-type item with five response options.

The second component of social capital examined in this study focuses on norms and values about collaboration with different types of professionals (Leonchuk, 2015). This scale represents a proxy for whether the resources in the students' network will be mobilized or final third component of individual social capital (Lin, 1999). Given resources embedded in students' social network connections, positive norms and values about working with other people provide a proxy for whether students will actually capitalize on them. This approach represents a more accurate representation of whether students' network resources will be mobilized as their norms and values are more stable than their plans and intentions which tend to be more affected by other events and opportunities students may face upon graduations. Unfortunately, few scholars have attempted to address these constructs empirically and none have for scientists or students. As a consequence, I rationally developed a set of items that attempted to tap into the actual willingness of students to use the resources embedded in their network connections. There are total 8 items measured on the Likert-type five response options range from *Strongly Agree* to *Strongly Disagree*. Table 8 lists the items' descriptive statistics. PCA demonstrates one-factor solution and that the Norms and Values scale is reliable ( $\text{Alpha} = .820$ ).

Both groups were asked to provide self-report ratings on the extent to which the training they received involved different types of experiences (Appendix B, Q10). PCA with Varimax rotation was performed with the ten variables (Table 9).<sup>6</sup> Based on these analyses, three subscales were created: multidisciplinary and team-based (5 items,  $\text{alpha} = .795$ ); cross-sector professional development experiences factor (3 items,  $\text{alpha} = .718$ ); industry factor (2 items,  $\text{alpha} = .619$ ).

I measured to what extent students are involved with their centers, or *dosage* of the center involvement. It reflects three dimensions of the center involvement: a) whether student's dissertation was based on I/UCRC research; b) duration of time at I/UCRC; and c)

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<sup>6</sup> One item was removed due to its difference from other variables in its low mean ( $M = 2.53$ ,  $SD = 1.61$ ) and meaning: *Working or interacting with researchers who are not located in the US*.

Table 8

*Descriptive Summary of the Norms and Values Scale Items*

	Mean	SD	Skew	Skew SE
1. I believe that science benefits from involvement of different sectors such as private businesses, government and academia.	4.37	.689	-.857	.151
2. Sometimes, it may be challenging to work with people who come from different cultures, but the end results of such work are worth it.	4.06	.850	-.727	.151
3. I view collaborations between industry and academia as positive despite differences in the ways they operate and things they value.	4.44	.663	-.931	.151
4. I like working with researchers from different disciplines as I can use their knowledge in my area of work.	4.32	.709	-.735	.151
5. I believe that any contemporary scientist must have strong communication skills in order to be able to solve today's problems.	4.48	.722	-1.392	.151
6. Despite extra time and resources spent on communication, I still think that working in teams is important for building innovation capacity.	4.39	.680	-.814	.151
7. Despite the challenges associated with bringing professionals from different disciplines to work together, I still think that such collaborations are important for science.	4.48	.630	-.892	.151
8. I believe that a problem-solving approach can contribute to science as much as development of theory.	4.52	.642	-1.188	.151

Table 9

*Rotated Component Matrix of the Graduate Training Experiences*

	Component		
	Multidisc./Team	Cross-sector Prof. Dev.	Industry
1. Working or interacting with researchers from other disciplines.	.730	.399	-.076
2. Working or interacting with researchers from industry.	.261	.080	.747
3. Working or interacting in teams of researchers.	.675	.194	.410
4. Presenting research findings to researchers and other professionals from different sectors and disciplines.	.427	.642	.037
5. Working or interacting with researchers from other universities.	.685	.080	.221
6. Working in settings where there is a high level of interdependency between team members.	.653	.084	.462
7. Being exposed to scientific techniques and expertise that are not usually available in my department.	.549	.458	.118
8. Learning how a particular concept can be applied to an actual problem or "a real world" situation.	.088	.401	.772
9. Integrating and synthesizing information from different fields in order to solve problems.	.327	.735	.245
10. Opportunities to develop my written and communication skills.	.001	.803	.242

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 10 iterations.



percentage of time allocated to I/UCRC activities. Response options for the first variable are provided in Table 10. Since this measure had limited variability, it was collapsed into a dichotomous variable. Categories 1, 2, and 5 were recoded into “Project is based on IUCRC project” (coded 2) and categories 3 and 4 into “Project isn’t based on IUCRC project” (coded 1). Duration of time at I/UCRC and percentage of time spent on I/UCRC activities are both continuous variables. All three dosage indicators were treated as individual variables.

Table 10

*Is your current, planned or finished dissertation based on I/UCRC research project?*

	Frequency	Percent	Valid Percent	Cumulative Percent
1. Yes, it is.	58	22.3	33.5	33.5
2. Yes, it will be.	67	25.8	38.7	72.3
3. No, it is not/will not be based on IUCRC project.	22	8.5	12.7	85.0
4. I don't know yet.	21	8.1	12.1	97.1
5. Yes, it was.	5	1.9	2.9	100.0
Total	173	66.5	100.0	
Non-CRC students	87	33.5		
	260	100.0		

I/UCRCs differ in their fidelity to consortium model encouraged by the NSF. In 2014, each I/UCRC was rated by their on-site evaluator who attends all meetings and monitors operations on the extent to which the center meets the NSF standards on three characteristics: a) what is the decision making process within an I/UCRC; b) how research projects are being selected; c) how the results of the research projects are being disseminated. The score of these three variables combined represents the Fidelity score where 15% of centers do not meet any of the fidelity standards, 18% met one standard, 26% met two standards and 41% of centers met all three fidelity standards. Ultimately this variable was dichotomized as follows: 1 – for none or at least one standard not being met (59%) and 2 – for all three standards being met (41%). In summary, Table 11 includes the main variables that will be used in the current study.

**Research Analysis Strategy.** Because there is so little prior empirical work on the topic of social capital of S&E students in the context of STI, I took a model building strategy to test the hypotheses and answer research questions. There were two main steps in this approach. The first involved preliminary analyses of the relationships between main variables and second – building of the path model informed by information from the first step. The goal of the preliminary analysis was to help to select the variables for the model. The first step involved examining the bivariate correlations and univariate regression of each variable with the outcome. Variables that did not have significant bivariate relationship with the outcome were eliminated from the next steps in the model building exercise. Multivariate relations were tested using multiple regression analyses. The first regression includes the outcome and all the variables, predictors and mediators, that would have passed bivariate relationships tested with correlations and univariate regressions. The goal of this regression was to see which variables were the strongest predictors of the outcome when other variables are taken into account as well.

The next step involved a set of multiple regressions ran separately with the outcome, the main predictor and each of the other predictor variables that were identified as the strongest predictors in the previous regression analysis. These regressions helped to identify which of the predictors might be considered as mediators in the path model. They also informed the model building process by comparing the direct effect of the main predictor (in form of  $R^2$ ) with the indirect effect of the main predictor when a mediator was taken into account. They also showed the changes in regression coefficient for the main predictor. For instance, if the regression coefficient (beta) was smaller with a mediator, it may have suggested that there is partial mediation. If regression coefficient became nonsignificant, it would have suggested full mediation (Baron & Kenny, 1986). Those mediators that changed regression coefficient to non-significant or smaller and increased  $R^2$  were considered to be used first in the path model.

Table 11

*Study 1 Main Variables*

Type	Name	Descriptor	Grouping	Measurement Kind
DV <sub>1</sub>	Perceived Career Preparedness	Four items, Alpha = .761	No	Continuous (scale)
DV <sub>2</sub>	Satisfaction	A single Likert type item	No	Continuous
IV <sub>1</sub>	Graduate Training	IUCRC vs. Traditional	Yes	Dichotomous/Categorical
IV <sub>2</sub>	US citizenship	Dichotomous	Yes	Dichotomous/Categorical
<b>Center-level predictors</b>				
IV <sub>3</sub>	I/UCRC	A single item	Yes	Categorical
IV <sub>4</sub>	I/UCRC Fidelity	3 items combined into one	Yes	Dichotomous/Categorical
<b>Dosage of the I/UCRC involvement</b>				
IV <sub>5</sub>	Project focus	A single item	No	Dichotomous/Categorical
IV <sub>6</sub>	Time spent on I/UCRC activities	A single item	No	Continuous
IV <sub>7</sub>	Duration of time at I/UCRC	A single item	No	Continuous
<b>Proxies for I/UCRC training</b>				
IV <sub>8</sub>	Industry Experience	2 items, Alpha = .619	No	Continuous (scale)
IV <sub>9</sub>	Cross-sector Prof. Dev. Experience	3 items, Alpha = .718	No	Continuous (scale)
IV <sub>10</sub>	Team/Multidisc. Experience	5 items, Alpha = .795	No	Continuous (scale)
<b>Social Capital</b>				
IV <sub>11</sub>	Industry Network's Size	A single item	No	Continuous
IV <sub>12</sub>	Industry Network's Strength	2 items, Alpha = .785	No	Continuous (scale)
IV <sub>13</sub>	Norms & Values about collaborations	Eight items, Alpha = .820	No	Continuous (scale)
<b>Covariate</b>				
IV <sub>14</sub>	Discipline	A single item with five response options	No	Categorical

The next major step in model building is the building the actual path model. I will use SPSS AMOS software to do this step. The main goal of the model building is to build a path model that meets the following characteristics. First, the model should have non-significant Chi-Square. Second, it should have good fit indices which correspond to having CFI that is

larger than 0.95 (Hu & Bentler, 1999; Hooper et al, 2008) and RMSEA that is smaller than 0.07 (Steiger, 2007, Hooper et al, 2008). This final model should have large variance explained in the outcome ( $R^2$ ) and all standardized regression weights of this model should be significant.

## Results

The key outcome variables in Study 1 were preparedness ( $M = 16.20$ ,  $SD = 2.64$ ) and satisfaction ( $M = 2.20$ ,  $SD = .69$ ). The original distribution of satisfaction that was measured as one Likert type item was:  $M = 4.16$  and  $SD = .81$ . The variable was recoded due to its skewed distribution where only few students reported as being dissatisfied ( $N = 3$ ) and mostly dissatisfied ( $N = 6$ ) with their graduate training. Measure of preparedness, on the other hand, had to be developed rationally based on what is known about students and their training. For a rationally created measure, it represented a relatively reliable scale ( $\alpha = .767$ ) that explained 61% of variance. The four variables were measured as a Likert type scale on the level of agreement with statements about career preparedness perceived of students. Particularly, the questions were asked in the context of students comparing themselves to their peers on how prepared they are to the demands of future employment, whether their training helped to expand social networks of academic and industry professionals and whether they have all necessary skills for future employment. Distribution of preparedness score did not differ for the two groups, US and international. Both groups had a slight negative skew,  $S_{US} = -.56$ ,  $S_{nonUS} = -.40$ , the same minimum and maximum values and similar means,  $Mean_{US} = 16.3$  and  $Mean_{nonUS} = 16.1$ , and medians,  $Median_{US} = 16.3$  and  $Median_{nonUS} = 16.0$ .

As described in the section above, the study takes the model building approach to path analyses. First a series of relational analyses will be examined to qualify variables for inclusion and I will attempt to build a good fitting path model. All tables with the results of preliminary analyses are included in Appendix C.

**Explaining the effect of the training on preparedness.** Hypotheses 1 and 2 specified variables that would have a mediating or direct effect on the outcomes. Particularly, they looked at whether the effect of graduate training on preparedness and satisfaction is mediated by industry, cross-sector professional development and multidisciplinary/team

experiences ( $H_{1a-c}$ ) and social capital components ( $H_{2a-c}$ ). Question 1 looked at whether US citizenships moderated any of the relationships.

Previous analyses on the differences between two groups, I/UCRC and traditionally-trained students, showed that the groups were significantly different only on one aspect - disciplines they represent. Thus, it was very important to identify whether students' discipline rather than the type of training has the effect on the study's main outcome. Thus, I recoded the original categorical discipline variable into four dummy variables listed in table 12 and ran multiple regression analysis with these variables and preparedness as the outcome. The results were not significant. As a consequence discipline variable was not used as a covariate when testing specific hypotheses.

Table 12

*Results of Regression Analyses with Discipline Dummy Variables*

Model	Unstandardized Coefficients		Standardized Coefficients		<i>p</i>
	B	Std. Error	Beta	t	
Intercept	16.00	.36		43.93	.000
Computer Science	-.46	.51	-.07	-.92	.360
Electrical Engineering	.56	.49	.09	1.13	.260
Material Science Engineering	.12	.54	.02	.22	.830
Mechanical Engineering	.80	.53	.12	1.51	.132

a. Dependent Variable: Perceived career preparedness

Table B1, B2 and B3 in Appendix C demonstrate the results of preliminary analyses. Table B1 includes results of two-tailed Pearson's correlations of all the main variables. It demonstrates that the two study outcomes, preparedness and satisfaction, had a strong and significant correlation ( $r = .543, p < .001$ ). Also, other than industry network size and industry network strength, satisfaction had a significant moderate correlation with other predictors. Thus, there are strong dependencies between predictors and outcomes and between the two outcomes. In addition, logically satisfaction can be considered as the last subsequent outcome in this study on students as any positive effect on more concrete outcome such as preparedness will have positive effect on satisfaction. Given these

relationships and logic that views satisfaction as the final student outcome that is being affected by preparedness more than any predictor, the decision was made to focus on preparedness as the main outcome of study 1 and look at how it consequently affects satisfaction. Given this strategy, the subsequent analyses included univariate and multivariate regressions with preparedness as dependent variable. The correlation table B1 informed the relationships of the predictor variables to satisfaction.

The results from all three tables showed that the strongest predictors of preparedness besides type of graduate training were: industry network strength and industry experience. This means that these variables were good candidates to test for a strong direct or indirect effect on preparedness. Table B4 summarizes results of whether the variables screened in bivariate analyses were potential mediators of the effect of training on preparedness. The results of this set of multiple regressions show that all potential mediators in the table are significant partial mediators of preparedness and that the most promising mediator was industry experience.

Before moving on to the final step in model building process, Table B1 results show few patterns that may help to understand better relationships between variables. It shows that industry network strength had the smallest significant correlation with preparedness ( $r = .233$ ) and with the main predictor graduate training ( $r = .128$ ). The highest significant correlations were for preparedness and satisfaction and preparedness and industry experience.

The first model was the simplest model of the effect of the training on preparedness and its strongest mediator. The model depicted in figure 6 which used industry experience as a mediator had a good fit,  $X^2 (df=0) = .00$ ,  $p < .001$ , CFI = 1.00, RMSEA = .04 and explains 26% of variance in preparedness.

In the final model industry network strength was added as a mediator of industry experience on preparedness. It changed the relationships of other variables as it became a strong mediator of the effect of training on industry network strength and it illuminated direct effect of training on industry network strength (Figure 7). Satisfaction was added to the model as well as the final outcome. This model explained more variance in preparedness (28%) and 32% of variance in satisfaction and demonstrated good fit of  $X^2 (df=3) = 4.433$ ,  $p = .218$ , CFI = .99, RMSEA = .04.

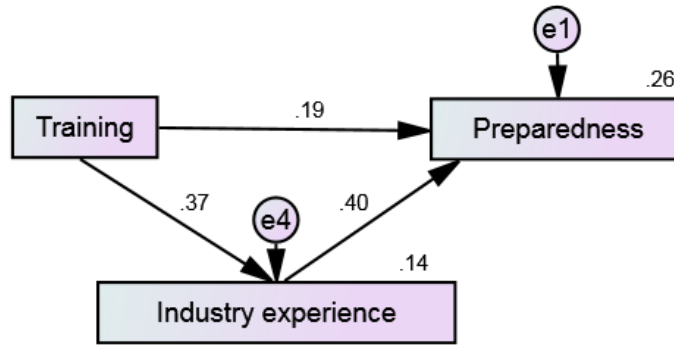


Figure 6. Simple Path Model A on a full Sample of Students

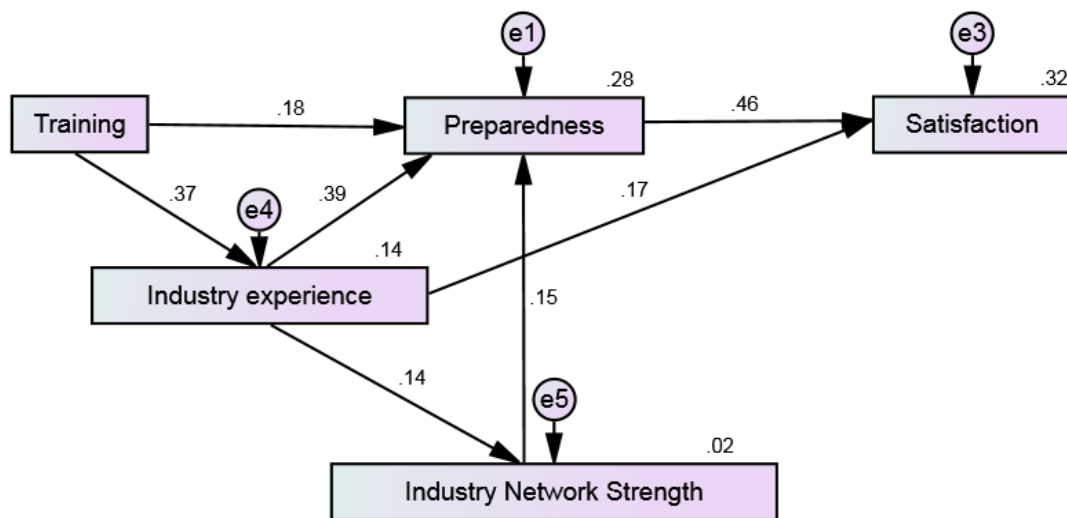


Figure 7. Final Model A on a full Sample of Students

The results only demonstrate support for H1a that industry experience will be a significant mediator of the effect of training on preparedness. H<sub>1b&c</sub> and H<sub>2a,b,c</sub>, were not supported. Cross-sector professional development experience, multidisciplinary/team experience and social capital components (industry network size, strength and norms and values about collaborations) did not mediate the effect of training on the outcome. However, industry network strength was the second level mediator of the effect of industry experience on preparedness. Thus, H<sub>2b</sub> was partially supported.

In order to answer RQ<sub>1</sub> on whether US citizenship moderated relationships in the final Model A, I compared two models by citizenship status. These analyses were done with

multi-group feature in AMOS. The model had a good fit  $X^2 (df = 6) = 13.77, p = .032$ , CFI = .97, RMSEA = .07. There was no significant difference between US/international groups as the models were not significantly different from each other,  $X^2 (df=7) = 8.75, p = .271$ . Thus, there was no basis for concluding that US and international students differed significantly in how their perceived career preparedness was predicted. The model showed that satisfaction was explained by the level of students' preparedness and that the hypothesized predictor variables, other than graduate training, did not have direct or indirect effect on satisfaction.

**Explaining the effects of I/UCRC training on preparedness.** This section focuses on I/UCRC students only ( $N=173$ ) who are nested within 38 I/UCRCs. It is important to provide the reminder that fidelity level is measured at the center level, not individual (student) level of analyses.  $H_3$ ,  $H_4$  and  $H_5$  respectively looked at whether students' dosage (dissertation focus, duration of time at I/UCRC and percentage of time spent on I/UCRC activities) and I/UCRC training proxies (industry, cross-sector professional development and multidisciplinary/team experiences) affected the outcome and whether their effects were mediated by three components of social capital: industry network size ( $H_3$ ), industry network strength ( $H_4$ ) and norms and values about collaborations ( $H_5$ ).  $RQ_2$  aimed to address whether US citizenship moderated the relationships described in hypotheses 3 through 5.

Multilevel modeling analyses of an unconditional model with preparedness and satisfaction indicated non-significant Interclass Correlation Coefficients (ICC) which means that there was no significant second level group or between centers variance to conduct hierarchical analyses. Thus, center fidelity was excluded as it was not appropriate to look at the students as being nested in I/UCRCs.

Tables B5 - B8 in Appendix C show results of the preliminary analyses for Model B. Table B5 demonstrates that the highest correlation of preparedness was with one of the training proxies, cross-sector professional development experience ( $r = .528$ ). Correlation of preparedness was significant but more moderate with satisfaction ( $r = .466$ ). To be consistent with Model A, satisfaction was considered as the final outcome rather than mediator. Table B6 shows that only duration of time at I/UCRC did not have significant beta with the outcome. Thus, it was excluded from the further analyses. Table B8 shows that significant regression weights in multiple regression analyses belong to: cross-sector professional development experience (proxy for training), percentage of time spent on I/UCRC activities



(proxy for training) and norms and values. Thus, these three variables were the strongest predictors of preparedness. Correlations in Table B5 show that percentage of time spent on I/UCRC activities did not have significant correlations with any of the three predictors. According to Baron and Kenny (1986), this variable cannot possibly have had any mediating effect and, thus, had not been tested as mediator but might have been valuable as a direct effect. Finally, table B7 shows the results of the final step in the preliminary analyses that showed that all mediations were significant and partial and the most promising mediators were: norms and values and industry network strength.

Based on the preliminary results, cross-sector professional development experience looked like the strongest predictor in Model B. In the first basic path model with the main predictor and the outcome, proxy for training, cross-sector professional development experience, explained slightly more variance in preparedness (28%) than the training, the main predictor, in Model A (26%). Following the logic of Model A, the next step was to include additional mediators in the model. Figure 8 demonstrates the simple Model B. Due to a small number of parameters, probability could not be computed as the model did not converge. Otherwise, the model had an adequate fit, CFI = .96, RMSEA = .04 and it explained 28% of variance in preparedness and 22% of variance in satisfaction.



Figure 8. Simple Model B on the Sample of I/UCRC Students

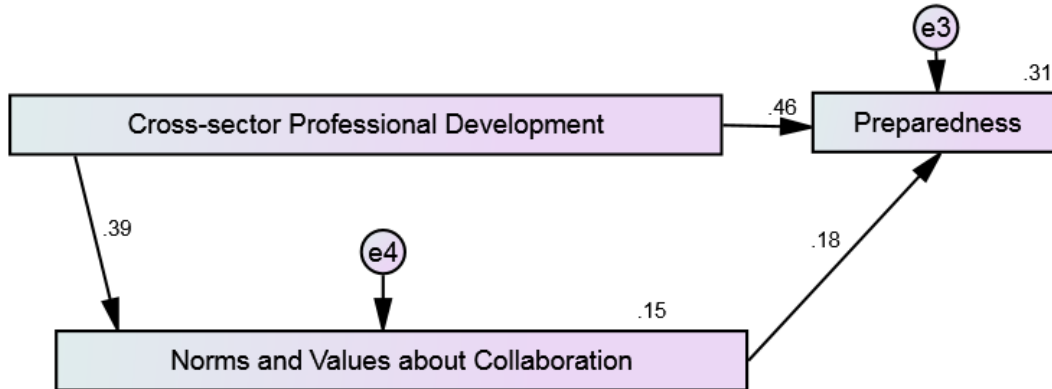


Figure 9. Three Mediators Model B on the Sample of I/UCRC Students

Since more variables had significant relationships with preparedness, an additional mediator, norms and values about collaborations, was added to the model. This results show that the new model in Figure 9 explained slightly more variance in the main outcome (31%). This model still did not converge and probability was not computed, CFI = 1.00, RMSEA = .41.

The final model in Figure 10 included two mediators, industry network strength and norms and values, of the effect of cross-sector professional development experience and an additional predictor that represented dosage of the center involvement, specifically, percentage of time spent on I/UCRC activities. This final model had a good fit,  $X^2 (df=7) = 11.92, p = .103$ , CFI = .97, RMSEA = .06 and highest variance explained in preparedness (34%) and the same amount of variance explained in satisfaction (22%) as the first simple model (Figure 8). The model had a small shortcoming: the standardized beta weight that represents the effect of industry network strength on preparedness was not significant ( $\beta = .114, p = .068$ ). Given that selection process of the final model depended on a combination of explanatory power (percentage of variance explained in the outcomes), good fit and individual parameters, this model was selected because it provides the most logical representation of what happens in the I/UCRCs.

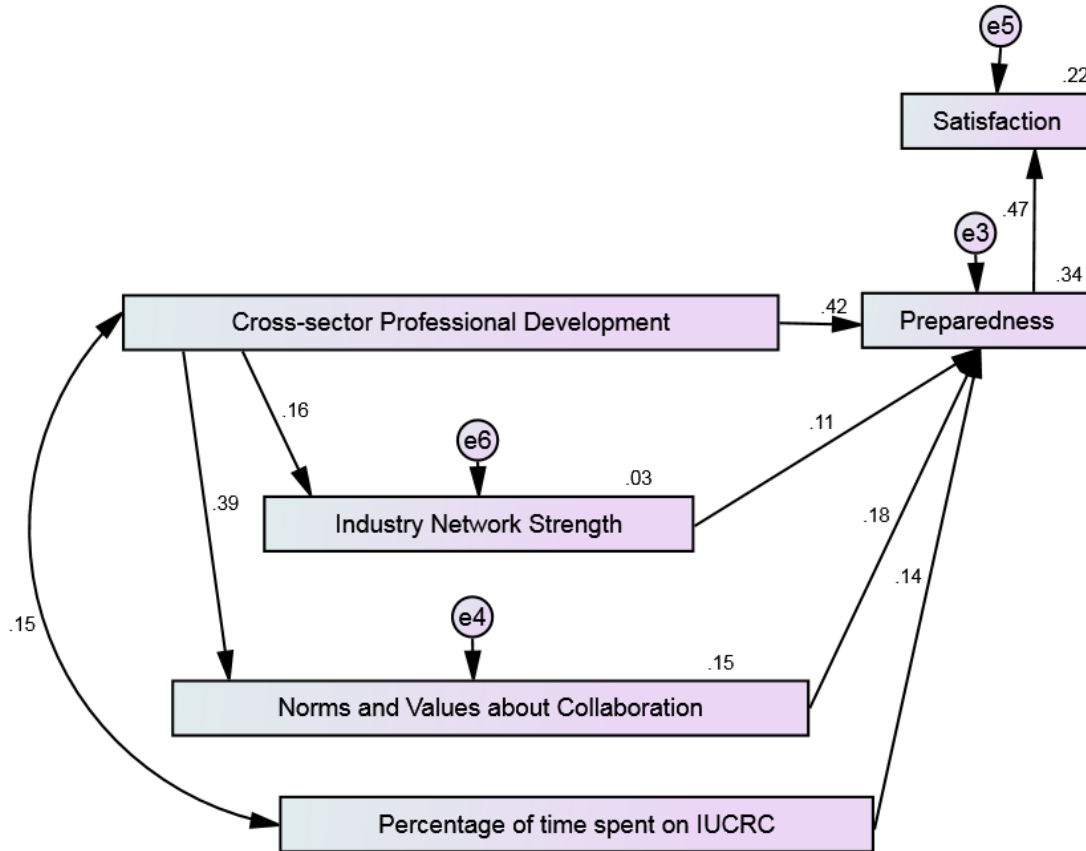


Figure 10. Final Model B on the Sample of I/UCRC Students

The results showed partial support for  $H_{4c}$  and  $H_{5c}$  where cross-sector professional development experience not only had a direct effect on the outcome, but also indirect effect mediated by industry network strength ( $H_{4c}$ ) and norms and values about collaborations ( $H_{5c}$ ). Also, there was a direct effect of center dosage, percentage of time spent on I/UCRC activities, on preparedness, but it did not support any hypotheses.

Model B provided mechanisms that explain the effects of center proxy cross-sector professional development experience on preparedness, but not the mechanism of center dosage. Multi-group analyses of the Model B in AMOS demonstrated that there was no differences in the model for US citizens and international students,  $X^2 (df=8) = 12.34, p = .137$ . Thus, the answer to  $RQ_2$  was that there is no moderation effect of US citizenship on relationships in Model B. Model B explained less variance in satisfaction (22%) than Model A (32%).

## Discussion

The two models, on the full and I/UCRC-only samples, examined different mechanisms that explain the effect of training (Model A), the training proxies (Model A and Model B), social capital components (Model A and Model B) and dosage of I/UCRC involvement (Model B) on students' preparedness and satisfaction. Previous research showed that the major components of social capital were directly influenced by the type of training. However, it was not clear whether social capital helps to explain *other* outcomes. Thus, this study's original aim was to determine the role of social capital and other mechanisms of the effect of training on other outcomes for students who receive traditional departmental and the I/UCRC training.

**Full sample.** Model A showed that graduate training had a strong direct effect on preparedness where I/UCRC students report being more prepared for their careers. More rich industry experience represented important mechanisms of the positive effect of I/UCRC training on how students perceived themselves in comparison with their peers while stronger industry network boosted the effect of industry experience on the outcome. Thus, H<sub>1a</sub> was fully supported where industry experience was a significant mediator of the effect of training on preparedness. It was not surprising that industry experience was a strong mediator as most of the S&E students know that they will go work for industry upon graduation. The lack of the direct effect of training on strength of industry network, however, demonstrates that the I/UCRC training does not guarantee acquisition of a strong industry network. Its acquisition depends on industry experiences students are exposed to. Thus, it is fair to conclude that industry experience is the most important mechanism of the I/UCRC training and probably the strongest proxy of the I/UCRC training when comparing to traditionally-trained students.

H<sub>2b</sub> was partially supported as strength of industry network was a second level mediator of the relationship between graduate training and preparedness. Two other components of social capital, size of industry network (H<sub>2a</sub>), which was measured as simple count of industry connections in students' professional network, and norms and values (H<sub>2c</sub>), seemed not to have an effect on preparedness and satisfaction. Other types of experiences, cross-sector professional development (H<sub>1b</sub>) and multidisciplinary/team (H<sub>1c</sub>) were not proven to be a significant mediator and direct predictor of preparedness or satisfaction. Given the all-inclusive nature of satisfaction as outcome, it makes sense logically that students who

perceived themselves as more prepared were more satisfied and that preparedness and satisfaction share some of their mediators.

Finally, a large direct effect of training on preparedness shows that there might be other mechanism(s) that this model did not account for. For instance, both samples of students included multiple S&E disciplines that are very different from each other and, thus, may contribute to the differences in the outcome.

**I/UCRC only.** Many things are happening at I/UCRCs, but it is not clear which mechanisms affect students' outcomes. In addition, previous research shows that the I/UCRC students vary significantly on the extent they are involved with the centers and centers vary considerably in how they follow various practices (Schneider, 2007). Thus, Model B investigated mechanisms of the effect of the I/UCRC graduate training on preparedness and, subsequently, on satisfaction. This model was more exploratory than Model A as it looked at which I/UCRC proxies (types of experiences) and I/UCRC dosage variables defined the I/UCRC training the best and whether they had direct and mediated by social capital effect on preparedness.

H<sub>3c</sub>, H<sub>4c</sub> and H<sub>5c</sub> were fully supported for cross-sector professional development type of experience which was mediated by two components of social capital: strength of industry network (availability component of social capital) and norms and values about collaborations (mobilization component). This indicated that cross-sector professional development experience is a central component of I/UCRC training that explains the differentiating factor in success of students trained in the centers. Note that norms and values, the proxy for mobilizing resources embedded in students' networks, was one of the explanatory mechanisms among I/UCRC students, but not for the full sample of I/UCRC and traditionally-trained students. Thus, what defines students' preparedness when they are already exposed to a more advanced training such as I/UCRC is how positively they view working with others. It is also consistent with social capital theory where access to resources embedded in social connections alone does not constitute social capital; there should be an action-oriented intent to use these resources. Similar to Model A, a strong direct effect of the main predictor cross-sector professional development experience demonstrates that there may be other mechanisms that the model did not account for.

Satisfaction, on the other hand was explained to a lesser extent in Model B (22%) than in Model A (32%). It could be attributed to the smaller variance in satisfaction among I/UCRC students versus the whole sample of I/UCRC and traditionally trained students. The individual factors unique to students such as personal situation and personality type could play a bigger role in explaining satisfaction among students trained at I/UCRC who are less likely be unsatisfied due to type of training.

The percentage of time spent on I/UCRC activities (dosage) had direct effect on preparedness. The finding demonstrates that dosage matters and that students need a sufficient level of involvement in order to benefit from the I/UCRC participation. However, the mechanism of this relationship was not as clear.

It is important to note which I/UCRC training proxies and dosage variables were not significant predictors of preparedness for the I/UCRC students: (a) project focus, (b) duration of time at I/UCRC, (c) industry experience and (d) multidisciplinary/team experience. It was a little bit surprising that the focus of the students' project (on I/UCRC or non-I/UCRC research) was not a significant predictor or a mediator given the results of the previous research (Leonchuk, 2015). This could be explained by the fact that students are often involved on multiple projects in I/UCRCs and that they may gain a relevant I/UCRC experience even if their dissertation is not focused on I/UCRC research. More information, however, is needed to explain the role of research projects in students' outcomes.

The fact that duration of time at I/UCRC was not as important as percentage of time spent on I/UCRC activities is in some ways good news for the programs like the I/UCRC. It means that quality rather than quantity of the I/UCRC involvement matters and that students do not have to be involved with an I/UCRC for all the years they are in school in order to benefit. Industry experience, however, is not the main explanatory mechanism for the I/UCRC students. This may indicate that industry experience was the main proxy for the I/UCRC training as it *dropped* as a predictor for the I/UCRC students.

**Both samples.** In previous research, US citizenship affected the role of training on social capital. This effect dropped when looking at the consecutive effect of social capital on preparedness and satisfaction and US citizenship was no longer a significant moderator of the relationships described in the models. The lack of the moderation effect could be explained

by the fact that international students are not a homogeneous group and larger sample size needed to investigate them in more depth.

Overall, the results of Study 1 demonstrated different mechanisms of the positive effect of I/UCRC training or its proxies on preparedness. Thus, I/UCRC training can be presented as one of the best practices for graduate students training in S&E disciplines.

**Limitations.** Given that there are no measures of professional social capital of individuals, the study provided a good start on developing social capital measures that could be adopted by scientific community. Thus, the measure of social capital was not a limitation, but rather a step forward towards better operationalization of the term for the future research.

Probably the biggest limitation of the current study is the self-reported outcome measure – perceived career preparedness - and too general and abstract outcome measure of satisfaction. It would definitely be beneficial to look at more or more objective or “hard” measures of students’ outcomes in addition to preparedness. However, on the contrary to faculty or student alumni, these more concrete outcome measures are not available for student population.

Finally, even though the control group was matched well on demographics with the groups of students trained at I/UCRCs, the fact is that there are few students in the US research intense universities that do not received some kind of collaborative and/or industry component in their training.

**Future research.** Future focus on *alumni* of the I/UCRC-type programs instead of students may help to identify a more definitive outcome than perceived career preparedness and satisfaction. However, it is more challenging to track alumni on longitudinal basis as they are often not even aware they have been part of a CRC.

Additional information could also be useful in building a more comprehensive explanatory model of students’ outcomes. Some of this information may include: students-mentors relationships; students’ personality traits and career goals.

**Implications for STI policy.** Are CRCs valuable source of students training? My research shows that the answer is yes. Students benefit in the way it was not documented before and professional social capital plays an important role in these students’ outcomes. Overall, CRCs probably have long term effects and impacts students’ career trajectories as graduate training is an important period of formation of social capital that students will

exploit later, 5-10 years from now. Thus, my research provides a valuable contribution to understanding the effect of CRCs on students as nobody has looked at social capital as a mechanism of this relationship in the past.

**Center training.** As expected, center training varies among students, particularly, in terms of cross-sector professional development experiences and percentage of time students spend on the center activities. Thus, the proxies for center training are important factors to consider when measuring I/UCRCs and may be CRC students' success. On the other hand, it is clear that industry involvement is the main differentiating factor in the success of the students who are trained in the centers. Nevertheless, other factors are not accounted for since there is a strong direct effect of training on the outcome.

**Implications for program managers and center directors.** In the sample of I/UCRC students, cross-sector professional development training affected mobilization component of social capital. Thus, it is fair to assume that through cross-sector professional development experiences students bond with other people which makes them more likely to think positively of working and collaborating with other professionals. These experiences, thus, should be offered or encouraged by managers and designers of the program that have students training component and faculty in general who work with students directly.

Cross-sector professional development experiences also seem to be a healthy mechanism of having students “get their hands dirty” which would be a typical experience for somebody already working. Not surprisingly, percentage of time spent on I/UCRC activities has a direct effect on the outcome. This explains why 14% of students in the I/UCRC sample did not think they were part of an I/UCRC (Leonchuk, 2015).

**Lessons learned from applying S&T human capital model on students.** Students are challenging population to study due to the lack of definite outcome measure(s) and relatively small period of professional activity. Social capital is also complex and challenging to understand. Nevertheless, empirical studies like this help to inform social capital theory by providing more necessary information about operationalization of the concept and about its role in the larger picture of things. Thus, social capital scholars need to get away from just theorizing and begin to help deconstruct the complexity.

The path models demonstrate that students' experiences and involvement with one training over another affect social capital outcomes and that these social capital components



affect other outcomes like preparedness. Thus, social capital is not only an outcome of the type of training, but it is also an important mechanism that explains students' outcomes that are directly related to students' future success.

Overall, different social capital components represent different pieces of information about the population and should be interpreted separately. For instance, what makes resources available in one's network is different from what makes an individual to use these resources. Especially, it is difficult to measure and interpret the third component of social capital, "mobilization of resources in purposeful actions" (Lin, 1999), as there are too many factors that may affect it.

Social capital as a concept is similar to general well-being and social support. The main logic is that availability of individuals who can help you with your concerns (here, professional development, mentoring etc.) yields positive outcomes for an individual in that area of his or her life. Thus, this positive role of social capital does not differ among different contexts and populations. Whether it is health (Furuta et al. 2012; Rose, 2000; Rojas & Carlson, 2006), financial security and stability (Agarwal et al, 2001; Agarwal, Chomsisengphet & Liu, 2001; Dufhues et al. 2011) or professional growth for entrepreneurs (Fornoni, Arribas & Vila (2010), availability of resources in one's social network results in positive outcomes.

## Study 2: Case Study of the I/UCRC Social Network

### Introduction to Social Network Analyses

As described earlier, one of the goals of this dissertation is to obtain a better understanding of student's embeddedness within their respective centers. Social network methodology is essential tool used to understand an individual's position within a network and ultimately measure social capital (Lin, 1999). It is based on sociometric theory that views people in the context of their connections to others (Häuberer, 2011; Reagans & McEvily, 2003). At the very core, social networks provide information about whether individuals are connected and how strong their connection is to others. These connections can be measured differently depending on the nature of the relationship.

Given that it is not intuitive to see society as a network of social connections, visual representation is essential to understanding social network analyses. Network graphs provide additional clues in interpreting the statistical results. On a network graph, people are marked as nodes (vertices) in form of a circle or other type of figure and their connections are represented as lines (edges) of different thickness to reflect strength of those connections.

Networks can be ego-centric or whole. Ego-centric networks always have a central node (ego) while all other nodes are called alters. Ego-centric networks compare *individuals* on their network characteristics and are typically measured using name generator or position generator techniques (Scott, 2012). When a network is measured using name generator technique, a person is asked to provide 8-10 names of people, their characteristics (e.g. gender, age) and how strong their relationships are. In case of position generator, a person is asked to indicate the number of connections to people who belong to particular occupations (e.g. lawyers, service workers). A typical whole network has a defined boundary such as school, department or course when studying networks of students. A whole network approach shows structural characteristics of alters in relationship to other alters and overall group dynamic (Laumann, Marsen & Prensky, 1989). Whole networks are often based on a matrix of communication frequencies of all participants.

Social network analysis (SNA) has been used in many different populations and settings, but my focus will be on its application in the context of the STI programs and projects like the I/UCRC. Social network analysis can be very complex. The current study is

by no means a complex SNA study in terms of size and complexity of the analysis and it primarily aims to capture students' embeddedness aspect of social capital proposed by Lin (1999).

**Empirical literature on scientists' social capital and networks.** Most studies that look at scientists' social networks look at the bibliometric data of publications in academic journals. These kinds of networks are typically limited to studies of established scientists who have years of publishing activity. Also, these networks do not capture scientists' professional social surroundings in their departments or centers. Thus, the literature reviewed here focused on the following: a) it looked at R&D or research groups or teams; b) it looked at the groups or teams who have a complex and intellectually-intense task at hand.

Most studies found were done in corporate settings with the goal of predicting team and/or individual performance with information about employees' social networks. The detailed information about the studies is presented in Table 13. Half of the studies reviewed with known data sources used a simple communication frequency network to create a data matrix that makes it possible to calculate structural characteristics of a team network. The following section describes the most relevant network characteristics that were measured and that were found to be significant predictors of the team's or individual's performance.

***Density and heterogeneity.*** Two studies found network density to be a significant predictor of team's outcome. Density was a positive predictor of productivity (Reagan & Zuckerman, 2001) and medium level of density was associated with highest level of creativity (Leenders, Van Engelen & Kratzer, 2003). Only one study measured and found heterogeneity (in employee's tenure or time spent at organization) as a significant positive predictor of productivity (Reagans & Zuckerman, 2001). Teams in which individuals had more contact with individuals at the different level of tenure in organization were more productive. This finding demonstrates that it is important for teams to promote environment where new employees are more connected to more senior employees.

***Degree and eigenvector.*** Degree Centrality was measured in two studies (Lee et al., 2010; Mote, 2005) and was one of the significant predictors in one of them (Lee et al., 2010). Higher degree centrality was positively associated with individual creativity only in the task force type of group, but not in the R&D group that worked on a more complex project (Mote, 2005). This indicates that R&D groups probably require a more complex explanation for

creativity than a simple measure of the group's average of individuals' number of connections. In Mote's study, degree centrality was calculated based on data about researchers' affiliation with a project team and department(s). Lee's study did not include description of the data or centrality measure.

Interestingly, degree centrality has been a positive predictor for the expertise recognition in organizational teams (Su, 2012). Thus, the recognition of each other's expertise, which also assumes skill set, may be one of the mechanisms that explain the effect of degree centrality on task team's creativity. In research-intense institutions like the departments that participate in I/UCRCs professors may not be aware of each other's expertise until they join a center. It is reasonable to assume that with collaboration of multiple institutions, the gap in knowledge about other faculty or students' expertise is even greater. This would inevitably affect performance of research teams that work on complex problems. Thus, degree centrality, in the context of current study may reflect the extent to which professionals know about each other's unique skills and expertise.

Eigenvector Centrality was measured and has been a significant positive predictor of productivity in only in one study (Mote, 2005). The measure was based on data on researchers' affiliation with research projects and departments (2 mode project-by-center matrix). Eigenvector provides information about who are the most central actors in the network or who have "the smallest farness from others" (Hannaman & Riddle, 2005). In the context of Mote's study, researchers who are the most central in the network of projects and departments are the most productive as they are able to collaborate more and produce more publications and patens.

**Summary.** Overall, the studies have shown that social network analysis approach allows evaluating scientific outcomes at the different levels of analysis, group and individual, which can improve evaluation practices of STI programs and projects. Even though the studies reviewed in this section focused on private sector, their results can inform research on industry-university collaborations and, especially, research on I/UCRC due to their strong industry component.

Table 13

*Empirical Studies on Social Networks*

Authors	Level of analysis	Outcome (DV)	Data Gathering & Structure	Main Network Predictors (IVs)	Findings
Cummings & Cross, 2003	182 working groups within a global organization (average group size = 8)	Performance on "complex project" (M <sub>length</sub> = 15 months) after 6 months	Emailed 20-30 minutes survey. Communication frequency represents core of the data (Never, monthly, weekly, daily, and hourly).	<i>Hierarchy</i> ; <i>Core-periphery</i> (based on continuous measure of fit); <i>Structural Holes</i> of group leader.	All three predictors were negatively related to performance ( <i>controlling for mean level of group communication</i> )
Cross & Cummings, 2004	Engineers: 101 employees, 125 consultants for petrochemical company	Performance of a individuals as part of "knowledge-intensive work" in a group setting	Two 40-55 min. surveys. Name generator (up to 20) for expertise awareness network and information network.	<i>Betweenness Centrality</i> ; <i>Boundary Spanning</i> ; <i>N of ties outside organization</i> ; <i>Hierarchy</i> (N of ties with those higher)	All predictors were associated with higher individual performance with exception of hierarchy (it was significant only for consultants)
Lee, Chae & Seo, 2010	Two types of teams: task force (74 members from 3 companies) and R&D (63 from 6)	Individual creativity	Online survey on network of relationships between members (data unknown)	<i>Degree Centrality</i> and <i>Structural Holes</i> (dyadic constraint)	Structural holes positively influenced creativity of both; Degree Centrality positively influenced only task force.
Mote, 2005	20 R&D projects in large multi-disciplinary national lab. (at least 300K, 2 <sup>nd</sup> year of funding, represent all areas of investment)	Productivity	Based on project and department affiliation of researchers (2-mode project-by-center matrix)	<i>Degree Centrality</i> , <i>Betweenness</i> , <i>Closeness</i> and <i>Eigenvector Centrality</i>	<i>Eigenvector Centrality</i> and <i>Betweenness</i> were significant predictors
Cummings & Pletcher, 2011	"Knowledge-intensive work" 177 teams with 1,304 members at large multinational food company	Performance at company-level competition	Information about project's characteristics and who is part of the team	<i>N of ties outside a project team</i> (non-core contributors)	Larger N of non-core team members was associated with higher project's success as competition
Leenders, Van Engelen & Kratzer, 2003	44 new product teams in 11 organizations totaling 243 individuals	Creativity	Roster-based survey at a team meeting about communication frequencies	<i>Density</i>	U-curve of relationships between IV and DV
Reagans & Zuckerman, 2001	224 R&D teams with 2,007 members in 29 corporations	Productivity	Survey of team members that included frequency of communication question	<i>Density</i> and <i>Heterogeneity</i> (tenure of a members), comm. frequency (0="never," 4="daily")	Higher scores in both IVs were associated with higher scores of DV

## Method

**Research questions.** Study 2 looks at the students in their close professional environment – an I/UCRC - and how students are positioned in relationships to other I/UCRC stakeholders: faculty, industry members and other students. With this approach I hope to understand student’s social capital in terms of their *embeddedness* rather than *resources* in their social network (Lin, 2001; Lin, Fu & Hsung, 2001). Particularly, I want to see whether students’ network characteristics differ among US and international students given a large proportion of international students in this population and results of previous research that showed that international students do not have the same exposure to industry network as their US peers (Leonchuk, 2015). Study 2 is an exploratory case study of an I/UCRC and its students, so it primarily looks at the descriptive information and aims to answer the following research questions:

RQ<sub>1</sub>: Is students’ citizenship status associated with the following students’ social networks’ characteristics:

- a) In-degree and out-degree centrality
- b) Eigenvector centrality
- c) Heterogeneity of students’ network connections

Even though the focus of study 2 is student’s *individual* network position, it also aims to capture information about overall center’s social network. Specifically, it looks at visual properties of the network that can show how individual students relate to other center’s stakeholders.

**Population and procedures.** Originally, the goal of Study 2 was to select at least two I/UCRCs that have different levels of fidelity to a consortium model (see Method section for Study 1 for definition of fidelity). However, this strategy was not feasible. In the recent years, NSF has been encouraging all I/UCRCs to move toward high fidelity consortium model so it was very hard to find a single I/UCRC that was low fidelity. Also, it was hard to receive cooperation from the director of more than one I/UCRC to participate in this study as most I/UCRCs have multiple sites and coordination between them requires a lot of time and resources. Thus, the study looks at a single I/UCRC that is high fidelity to the consortium model. According to the latest available 2014-2015 report from the I/UCRC evaluation team at North Carolina State University (NC State), the participating I/UCRC has three university

sites totaling 15-20 university faculty, 25-30 students (50% international) and 30-40 industry members.<sup>7</sup> It is important to note that the proportion of doctoral students in this is significantly lower than the average I/UCRC (31% compared to 50%). This center has been an active I/UCRC for 7 years.

Data collection involved a number of specific steps. First, after Institutional Review Board (IRB) at NC State approved the study's methodology, I asked the center's director for permission to conduct the study with his center's students. After permission was granted, I obtained a roster of all students and their email addresses and also a roster of all center's active personnel. Then, students were sent an email from their director encouraging them to complete the study online. I then sent an email with the link to the online Qualtrics survey to students. The questionnaire was designed to be completed only by the center's students. During these steps, I have continually received support from the center's evaluator who is very familiar with how this center operates.

**Main variables, instruments and measures.** Appendix E contains the copy of the online survey that was sent to students. The survey consists of three types of questions: students' demographic characteristics (Q2-6, 9-12), plans and other outcomes (Q13-19) and students' social network (Q8).

The outcome variables include two variables from Study 1, satisfaction and preparedness (page 26), plans for working in particular industry (Q15) and availability of an internship or job offer (Q16). More specifically, Q16 looks at availability of an internship or job offer from an organization that has been or is the I/UCRC's member and an organization that has not had any connection with the center.

The main purpose of the study 2 is to examine the I/UCRC students' *embeddedness* or position in their social network. Thus, the central variable for the study is the students' social network and its characteristics, particularly: a) degree centrality; b) eigenvector centrality; c) heterogeneity of students' network connections. These measures are calculated using data about communication frequency of students with all identified center's personnel generated by answers to Q8. This approach is based on sociometric technique that looks at social networking data of a whole network with distinct organizational boundaries, in this case boundaries of the I/UCRC (Contractor & Eisenberg, 1990). In Q8, each survey

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<sup>7</sup> In order to protect the privacy of the center, the ranges rather than actual numbers are provided.

respondent had to provide the frequency of communication with each person from the *roster* of all identified center's personnel that included names of faculty (n = 30 including 3 directors), industry members (n = 35), postdocs (n = 4) and other students (n = 40). The question focuses on students' communication with each person on the topic related to the I/UCRC research or operations in the last 6 months and has the following response options: 1) More than twice a week; 2) About twice a week; 3) About once a week; 4) 2-3 times a month; 5) About once a month; 6) Less than once a month; 7) Never. The frequency of communication is directional as only students had an opportunity to provide their answers to question 8.

The three network characteristics represent measures at individual student level of analyses. Social networking add-on to Excel NodeXL is used to calculate these measures. Degree and eigenvector centrality are calculated automatically based on the matrix of how the center's personnel is connected among each other. Table 14 provides description and examples of these two measures. *Degree centrality* is the simplest and most correlated with other centrality measures ( $r = .70$ ) and represents a number of connections of a node (Valente et al, 2008). It is also the most often used measure of centrality because it is easy to explain to non-expert audience. In simple words, degree centrality is "a measure of popularity" (Grimes, 2012). *Eigenvector centrality*, on the other hand, looks at individual's connections' connectivity. An individual's eigenvector centrality equals degree centralities of the individual's connections (Grimes, 2012). Eigenvector provides information about who are the most central actors in the network (Hannaman & Riddle, 2005). It is one of the centrality measures that measure *closeness* of a node and it is called eigenvector because it uses factor analysis to measure this network characteristic.

Degree centrality is a directional measure which means it can be calculated as out-degree and in-degree which corresponds to whether a node of an interest (ego) or other nodes (alters) indicates the connection. Out-degree centrality is a number of connections that a person indicates and in-degree centrality is a number of connections that stem from other people in the network to that person. Generally speaking, out-degree centrality is a measure of how much a person reaches out to other people in the network and in-degree centrality is a measure of how much



Table 14

*Centrality Measures*

Measure	Definition	Utility	Answers	Example
Degree	Number of links that lead into or out of the node	Useful in assessing which nodes are central with respect to spreading information and influencing others in their immediate 'neighborhood'	How many people can this person each directly?	How many people has this person collaborated with?
Eigenvector	A node's eigenvector is proportional to the sum of the eigenvectors of all nodes directly connected to it.	Useful in determining who is connected to the most connected nodes.	How well is this person connected to other well-connected people?	In network of paper citations: who is the author that is most cited by other well-cited authors?

that person is being approached by others in that network. In case of graduate students, students will most likely have more variance in out-degree centrality as they tend to reach out to other people such as faculty and industry for professional guidance.

*Heterogeneity of connections* measure tends to be customized depending on the population and the goals of a study and is measured by using characteristics of individual's connections. It represents a diversity of individual's connections where diversity is represented by a category of interest (e.g. gender, level of education, occupation). For example, Reagan and Zuckerman (2001) measured heterogeneity in terms of tenure (time spent) of an employee in an organization. This study looks at the composition of different groups in students' social network. These groups are: other students, faculty, industry members, postdocs and center's directors. The final score is calculated using the Index of Qualitative Variation (IQV) which ranges from 0 to 100% heterogeneity of connections represents the number of groups a student indicated to have a connection.

## Results

**Sample and data.** The data were collected using an online questionnaire from students whose names and email addresses were obtained from the center's director. The survey was sent to 44 individuals, 40 students and 4 postdocs. It was sent to postdocs because it was not clear from the record given by director whether those four postdocs were students or postdocs. Out of 44, the survey was started by 29 respondents. Two respondents dropped out from the survey without providing most data, thus, they were excluded. Out of the remaining 27 students, 5 identified themselves as postdocs and one as a law student.

There were two types of data generated by survey's respondents which would be described as different samples. The first type represented data from 27 responses. It was the traditional study sample that I provided description of demographic characteristics and scores on the outcomes measures in the next section. The second type of data was *generated* by 27 complete responses. These data represented the I/UCRC network and show information about network's composition (e.g. how much industry members, faculty, students the network has), structural position of its members in relationships to others and strength of the connection between its members. These data also showed the individual network characteristics of the 27 respondents: *in-degree* and *out-degree centrality*, *eigenvector centrality* and *heterogeneity* of students' connections. Finally, these data were used to visualize the center's network in NodeXL social networking add-on to Excel.

### **Descriptive information about students.**

The final sample contained 27 students, however, only 13 of them were doctoral students; two were undergraduate students, five were postdocs, six were Master's students and one was a law student (Table 15). Also, only one doctoral student was a US citizen. Unfortunately, the highly unbalanced nature of the sample prevented me from addressing question 1 a-c.

Table 15

*Demographic Characteristics of the Study 2 Sample*

University Site	Degree Level					Total	
	Master's	Doctoral	Undergr ad.	Postd oc	Other		
Lead	US	2	0	2	0	0	4
	Intern.	2	10	0	3	0	15
	Total	4	10	2	3	0	19
Non-Lead	US	2	1	0	1	1	5
	Intern.	0	2	0	1	0	3
	Total	2	3	0	2	1	8
Total	US	4	1	2	1	1	9
		66.7%	7.7%	100.0%	20.0%	100.0%	33.3%
	Intern.	2	12	0	4	0	18
		33.3%	92.3%	0.0%	80.0%	0.0%	66.7%
	Total	6	13	2	5	1	27
	22.2%	48.1%	7.4%	18.5%	3.7%	100.0%	

The majority of students in the sample were international ( $N = 18$ , 67%), male ( $N = 21$ , 78%), and primarily represented the lead university site of the I/UCRC ( $N = 19$ , 72%). Five respondents indicated spending only 0 to 6 months with the center. Given the small sample of students and exploratory nature of study 2, they were included in the sample. Interestingly, only half of all students ( $N = 12$ , 46%, total  $N = 26$ ) presented their research or center research to industry members at an annual center meeting which is an important component of the I/UCRC training.

During 2014-2015 fiscal year, this center reported having 50% international students and this proportion contradicts the sample of the doctoral students in this study ( $N = 13$ ) 92% of which were international students. It is possible that more international doctoral students joined the center since 2015, however. This discrepancy may be also due to response bias where international students may be more compliant in following up with the request to complete the online questionnaire from their center director. Given their dependency on the student visa and different immigration requirements, they may have taken more seriously any request by authority than their US peers.

Out of 19 students, 13 (50%,  $n = 26$ ) wanted to work for industry, 9 (35%) for academia, 1 (4%) for start-up upon graduation. Two students provided different answers: “Any non corrupt establishment that will pay decently” and “accounting.”

With respect to outcomes, two had an internship or job offer from the center’s member and three had the offer from an organization that has never been a member. The two students who had their offers from center’s members are doctoral students and three students who had offers from non-member companies pursuing Master’s degree. Scores for overall satisfaction with their training have 5 respondents who are not satisfied: the most unsatisfied is a postdoc and four others are doctoral students (Figure 1). Perceived preparedness of students with their training has a more normal distribution with mean = 14.5, median = 16.0, standard deviation = 4.93, min value = 4 and max value = 20. The distribution resembles the preparedness reported by I/UCRC doctoral students ( $N = 173$ ) from Study 1 ( $M = 16.8$ , median = 17.0,  $SD = 2.43$ , min = 10 and max = 20) than traditionally-trained students ( $N = 87$ ,  $M = 14.9$ , median = 15.0,  $SD = 2.60$ , min = 8, max = 20).

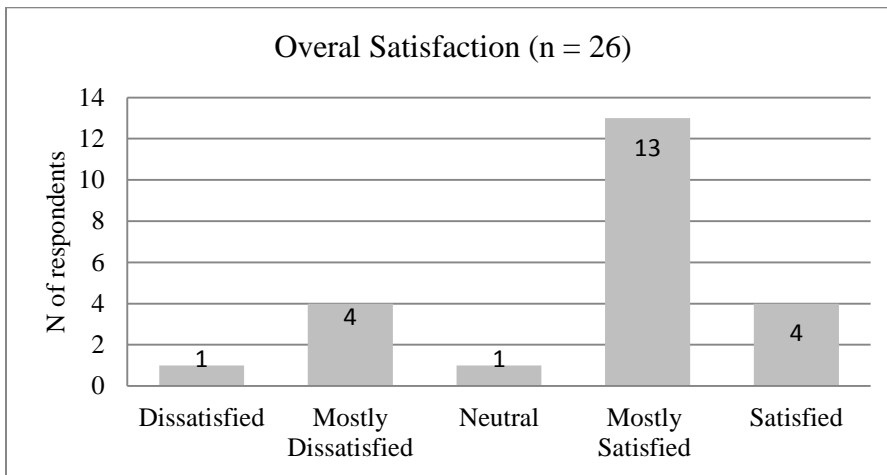


Figure 11. Overall Satisfaction with Training

**Social network data of students.** The networking data are generated using answers from 27 total respondents (21 students, 5 postdocs and 1 law student) to the question (Appendix E, Q8) about the frequency of communication with each person on the roster of 109 names of center's personnel. The identified network contains 92 individuals (vertices/nodes) and 280 unique connections (edges).<sup>8</sup> The 92 identified people in the center's network came from the following categories: directors ( $N = 3$ ), postdocs ( $N = 5$ ), faculty ( $N = 20$ ), industry members ( $N = 24$ ) and students ( $N = 40$ ). Out of 92 people, only 22 represent the second (not lead) site of the I/UCRC. Table 16 includes descriptive information about the four centrality scores. Eigenvector centrality had very small variance making it impossible to interpret its values for the current study.<sup>9</sup>

Distribution of scores for in-degree and out-degree centrality is provided in Figures 2 and 3. Both scores have close to normal distribution, thus, that these measures can potentially be useful in evaluating students' network position in case of the larger sample size. Table 16 shows that an average student is connected to 10 people in the center's network (out-degree) while the range of the number of connections vary between 2 and 35 where 35 is more of an outlier. As expected, out-degree centrality of a student has a larger range of values as students are in the position to ask for help more than being asked. However, it could also be due to the fact that the data are provided only by fraction of the center's personnel. Heterogeneity score was calculated using the Index of Qualitative Variation (IQV) which ranges from 0% to 100% and represents the diversity of connections in students' network. It is based on the out-degree centrality and is usually are not affected by the sample size.

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<sup>8</sup> Twenty-seven respondents not report any contact with 17 people on the 109 person roster.

<sup>9</sup> Probably, because it requires a larger number of people indicating their frequency of communication as it is calculated using the number of connections not only of an ego (student), but also of student's connections (nodes).

Table 16

*Students' Network Measures (N=27)*

	Mean	Median	SD	Minimum	Maximum
In-degree	2.11	2.00	1.55	0	5
Out-degree	10.22	9.00	7.29	2	35
Eigenvector	.0172	.0142	.0122	.0024	.0478
IQV	76.03	83.30	22.71	0	98.80

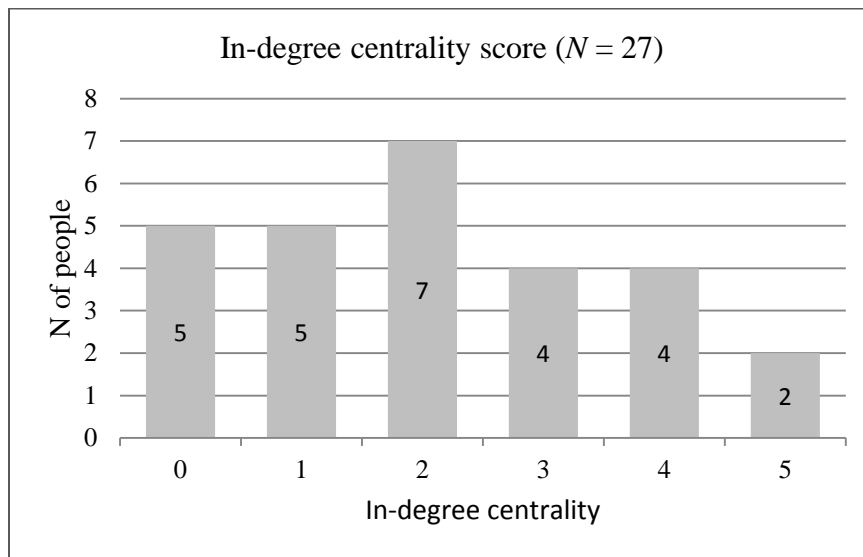
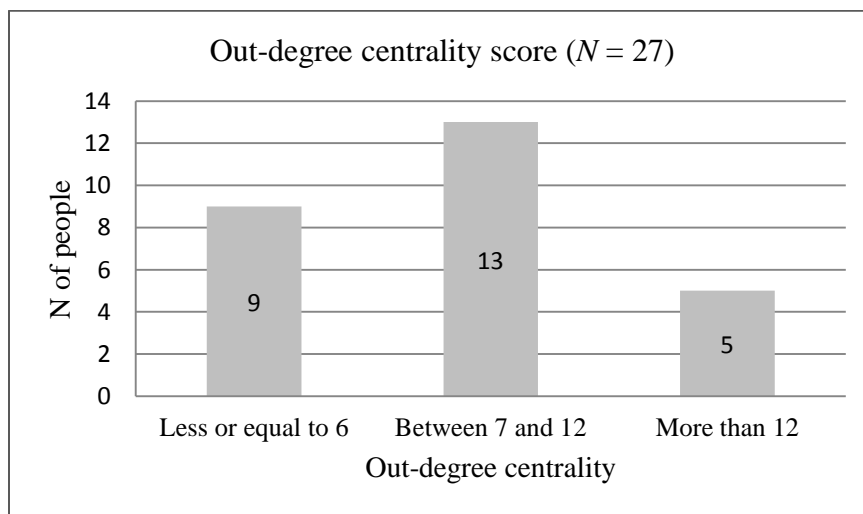
*Figure 12. In-Degree Centrality**Figure 13. Out-Degree Centrality*

Table 17 represents descriptive information about the number of connections students indicate for each personnel type of the I/UCRC. Given the small variance in number of connections who are postdocs, faculty and postdocs are combined into one category. The IQV score was calculated by using the number of people students indicated in the categories represented in Table 17. For example, if student has indicated any communication frequency with 3 faculty, 2 industry and 5 students, that student had the IQV score of 83%. On the other hand, if a student was connected to only one type of group his/her score would be 0% because there was no diversity of type of connections.

Since industry involvement is one of the most important aspects of the I/UCRC training, I looked at students' industry connections in more detail. The number of industry connections was transformed into a dichotomous variable with 0 meaning no industry member from a roster was a connection and 1 meaning at least one industry member was selected as a connection. As a result, seven (26%) out of 27 students had no industry members in their individual social network. More importantly, three of these seven students are doctoral candidates who have spent more than 6 months with the I/UCRC.

Table 17

*Descriptive Information about Students' Heterogeneity Score*

	N student	N faculty	N postdoc	N fp <sup>^</sup>	N industry	N director	Heterogeneity Score
Mean	2.96	2.48	.59	3.07	3.15	1.19	3.19
Median	2.00	2.00	.00	2.00	2.00	1.00	3.00
SD	2.564	1.649	1.118	2.385	3.820	1.039	.921
Min	0	1	0	1	0	0	1
Max	9	7	4	11	13	3	4

<sup>^</sup>Category that combines faculty and postdocs

The results of independent t-tests of the network measures by citizenship status showed no significant differences between US and international students on various network variables. While this suggests that there is no difference in network position between US and international students, as I will discuss below, given the sample limitations this finding

should be interpreted carefully. For exploratory purposes the correlation of network measures with various outcome measures was examined (Table 18). The students' outcome measures borrowed from Study 1, satisfaction and preparedness, had a very significant correlation of  $r = .878, p < .001$ . It is important to note that in Study 1 the correlation between satisfaction and preparedness was medium high,  $r = .543, p < .001$ . Given that the sample in study 1 was much closer to the national sample of the S&E students than the sample from study 2, the high correlation between the study 2 outcomes was probably the result of the biased sample. Satisfaction does not have significant correlation coefficient with any network measures. On the other hand, preparedness has a significant positive correlation with out-degree centrality – the measure of how much students reach out to others for help or advice. The rest of the significant bivariate relationships are also positive.

Table 18

*Bivariate Correlations of the Study 2 Outcomes*

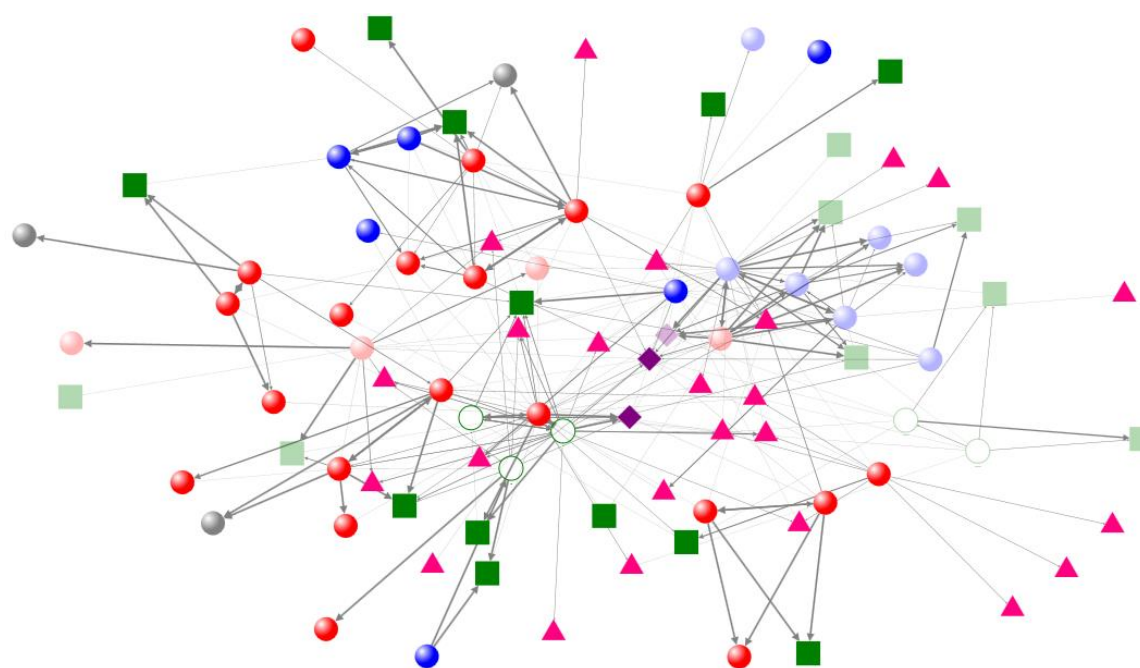
	Satisfaction $r$	Preparedness $r$
In-Degree Centrality	.116	.006
Out-Degree Centrality	.293	.475*
Eigenvector Centrality	.332	.340
IQV	-.001	.012
Satisfaction	1	.878**

Two-tailed significance. \* significant at 0.05, \*\* significant at 0.01.

The final step in the descriptive analyses for study 2 is to provide a meaningful visual representation of the center's social network based on 27 survey responses. Figure 4 shows the social network of the I/UCRC. Each type of person in the network is presented in different shape type: students = sphere, faculty = square, industry = triangle, postdoc = empty circle and director = diamond. The two university sites are represented in the opacity level: shapes that are less bright (more opaque) represent the second, non-lead, site of the center. Finally, students are color-coded based on their citizenship status: US students – blue, international students – red and gray for students with unknown citizenship status.



While the small sample size limits the ability to provide a confident interpretation of the network, I will attempt some tentative interpretations. Based on the visual representation of the center's network, students with different citizenship status seem to not show any difference in their social embeddedness. Both, US (blue spheres) and international students (red spheres) are located in the center and periphery of the whole network equally. In addition, concentrations of either red or blue colored spheres in different places indicate that there is not a great deal of communication between students with different citizenship status.



Sphere	Red Sphere	Blue Sphere	Gray Sphere	Green Square	Pink Triangle	Empty Circle	Purple Diamond	Tinted Forms
Student	International	US	Unknown <sup>^</sup>	Faculty	Industry	Postdoc	Director	2 <sup>nd</sup> university site

<sup>^</sup>Citizenship status is unknown.

*Figure 14.* The I/UCRC Social Network

The center's network also shows that personnel associated with each university site are grouped closer together. The left side of the network primarily consists of the lead site's personnel while most of the south east portion of the social network is populated with the non-lead site's personnel. Not surprisingly, center's directors (diamonds) are located at the

very center of the network which is the densest. Communication of postdocs (black circles), on the other hand, looks different depending on the site they belong to. The three postdocs from the lead site are located in a very dense location in their site's network while the non-lead site's two postdocs are farther away from their site's personnel.

Industry (triangles) and faculty (squares) of the center can be found everywhere on the network. There is no set pattern to their positioning: some are very central, thus, more interconnected, others are at the periphery with one or two network connections. Overall, in spite of the limitations in this dataset, the social network of the center represents a useful tool for understanding better social dynamics among its personnel, not only embeddedness of students.

**Summary and discussion.** This study represented an attempt to measure *embeddedness* of doctoral students in the network of one I/UCRC. Unfortunately, the sample's size and composition made it hard to answer the research questions 1 a-c on whether citizenship status affects the individual students' network outcomes.

Nevertheless, the network data provided by the 27 respondents who represented 22 students (1 law student as an outlier) and 5 postdocs demonstrate some interesting patterns on the visual representation of the I/UCRC network. It does not show that students are positioned differently depending on their citizenship status. Both types of students can be found at the periphery of the network and at its core. Thus, it showed that the likelihood in *accessing* the resources in the I/UCRC network can be similar among students with different citizenship status. On the other hand, the two types of students tend to stay in the surroundings of students with the same citizenship status. It could indicate potential impediments for the international students not receiving the same resources given their lack of interactions with the US peers. The network graph also showed that more international students than US have ties with industry. But, given the sample limitations, this observation was not conclusive.

Overall, despite the failure to acquire a representative sample of the S&E population of the doctoral students where the ratio of US to international students would be closer to 1:1, the center's network graph provides some clues about embeddedness of students in their professional network that other metrics cannot capture.

There are also some interesting relationships between students' social network and other outcomes. Specifically, perceived career preparedness had a positive relationship with out-degree centrality. This finding has important implications on research on S&E students as the ability to reach out to others for help or advice could be an important factor of students' success. This finding could potentially represent an insight into the literature on higher education and training programs for young professionals. The measure of out-degree centrality in some ways could be interpreted as extraversion. Given the multinational characteristic of the S&E students' population and its cultural variety, the importance and role of extraversion in the US professional environment could be emphasized more for students born outside of the US.

In addition, the size of individual industry network within the center boundaries seem to be positively associated with the number of people students' reach out to (out-degree,  $r = .849, p < .001$ ), the indicator of popularity of the students (eigenvector,  $r = .799, p < .001$ ) and heterogeneity of students connections ( $r = .429, p < .05$ ). So, it could be interpreted that the larger student's industry network, the more different contacts that students has, the more popular and the more outgoing he/she is.

**Limitations.** The results of study 2 should be interpreted carefully mainly because it is based only on one I/UCRC. Given the extensive research on I/UCRCs over more than thirty years (Sundstrom & Gray, 2010), the I/UCRC differ significantly on variety of characteristics: size, age, discipline, type of industry etc. The other significant limitation of study 2 is its sample's size and characteristics. Doctoral candidates were represented by only 12 students 11 of who were international. On the other hand, the center's operational data showed a 50-50 split suggesting a significant response bias in the survey. Thus, there were not enough students in the sample and not enough variance in citizenship status to answer research questions 1 a-c.

In addition, representation of the whole social network of the center was based on 28% (26 out of 92) of the center's personnel 20 of which were students, 5 postdocs and 1 a law student. Even though the network graph was somewhat informative, it could have been more useful if frequency of communication was collected from other types of groups such as faculty and industry members. Having more representation would also increase variation in individual network measures of in-degree, out-degree and, especially, eigenvector centrality

which was based not only on individual's network, but also network connection of people connected to that individual.

The approach focused on measuring the whole bounded network of a center. While it was appropriate for a case study, inability to capture *outside* network connections yields limited understanding of students' professional social networks that more likely than not include more than center's personnel. Similar to study on entrepreneurship (Fornoni, Arribas & Vila, 2010), network connections *outside* of an organization (center) could be a source of opportunities and resources unavailable within the borders of the organization.

Finally, the network measures and their interpretation could have been improved. For example, a measure of heterogeneity of connections was calculated using only out-degree centrality. Combined measures of in-degree and out-degree centrality would have produced a more accurate representation of students' heterogeneity of connections. Also, while visual interpretation of different groupings or clusters in the network was useful, it was not sufficient in drawing any conclusions. A more elaborate technique could have been used such as clustering that tops into cohesiveness characteristic of the center network.

***Evaluation of STI.*** Social network technique appears to be useful in evaluation of the collaborative environment that has somewhat defined project or institutional boundaries and that does not include a very large number of stakeholders. In addition, the results demonstrate that social network analysis of the institutional environment of the scientists such as their departments or research centers provide more comprehensive evaluation of the social aspect of the scientific process than bibliometric-based studies. At the very least, social network analysis approach can show us the amount and quality of communication at I/UCRCs as indication of collaboration.

### **Conclusion**

The two studies presented in this paper focused on different components of social capital. Study 1 looked at students' *access* to resources embedded in their social connections, particularly, industry connections, and the proxy for whether students will *mobilize* these resources. Study 2 looked at *embeddedness* of students in the social network of one I/UCRC. Both studies showed that social capital is a very hard concept to measure in any population because of its different dimensions. Nevertheless, social capital is a useful tool for comparing students' outcomes in different STI programs in order to assess the programs' effectiveness.

Unfortunately, I was not able to find validated measures of social capital and had to develop my own instruments. Measures, however, should incorporate the unique context of the students' training and their demographics in order to be valid. While the measures of social capital should be tailored to the specific context and population, they should also be built upon the work of scholars like Nah Lin who connected the complex theoretical foundation of social capital to its actual measurement. Finally, in my opinion social networks metrics should be part of any thorough examination of social capital.

Across disciplines, social capital appears to be a strong predictor of important individual outcomes associated with overall success and well-being in the form of better health (Furuta et al. 2012; Rose, 2000; Rojas & Carlson, 2006), more financial stability (Agarwal et al, 2001; Agarwal, Chomsisengphet & Liu, 2001; Dufhues et al. 2011) and more professional growth for entrepreneurs (Fornoni, Arribas & Vila (2010)). In most cases, however, social capital is a social channel that provides the flow of resources from one person to another. On the contrary to other types of capital, the channel that social capital represents is not established and can take different forms. It is not like human capital that is being acquired through institutions like family or educational institutions. Neither is it a financial capital that is being acquired through the laws of commerce. Social capital, on the other hand, follows the laws of social interactions which are much more diverse and are often not fully understood.

While conceptualization and measurement of social capital vary greatly, empirical researchers independently find that social capital is a multidimensional concept (Fornoni, Arribas & Vila, 2012; Inkpen & Tsang, 2005). While not all empirical studies adopt Lin's social network theory of social capital (1999), most studies use more than one dimension to measure social capital whether they measure it in the context of health (Furuta et al. 2012; Rose, 2000; Rojas & Carlson, 2006), financial stability (Agarwal, Chomsisengphet & Liu, 2001; Dufhues et al. 2011) or other context. Nevertheless, based on the literature reviewed in this work, Lin's in-depth investigation of social capital represents the most coherent theory driven and applicable framework for measuring social capital.

While the measurement of social capital can be complex and costly, the interconnectedness of people in the World Wide Web and high usage of email and social networks such as Facebook allows for a more automatic social network data collection and

analyses. For example, platforms like Facebook, Twitter and LinkedIn provide an easy way to capture and analyze their social network data. Some programs already have small scale interactive communication platforms that capture social network data. For example, the I/UCRC program has an online site called LIFE (Level of Interest Feedback Evaluation) where faculty and industry members discuss their projects. Data on this site could be mined to assessment social capital.

A focus on students and social capital represents one of the ways the S&T human capital model can be applied in evaluation of the STI programs. In contrast to existing STI metrics that focus on long-term outcomes that often exclude students all together, it provides information about the human side of science in its current state (e.g. students' graduate trainings, experiences, social networks). In addition, it represents an opportunity to look at science of tomorrow as the same students will be part of the scientific elite in the near future.

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**APPENDICES**

## Appendix A

### Background on Social Capital

Table A1

*Definitions of Social Capital by Clarige (2004)*

<b>Authors</b>	<b>Definitions of Social Capital</b>
Baker	A resource that actors derive from specific social structures and then use to pursue their interests; it is created by changes in the relationship among actors (1990, p. 619).
Belliveau, O'Reilly, Wade	An individual's personal network and elite institutional affiliations (1996, p. 1572) .
<b>Bourdieu &amp; Wacquant</b>	The sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition' (1992, p. 119).
Boxman, De Graai. Flap	The number of people who can be expected to provide support and the resources those people have at their disposal (1991, p. 52).
Brehm Rahn	'The web of cooperative relationships between citizens that facilitate resolution of collective action problems' (1997, p. 999).
<b>Burt</b>	Friends, colleagues, and more general contacts through whom you receive opportunities to use your financial and human capital' (1992, p. 9).
<b>Coleman</b>	'Social capital is defined by its function. It is not a single entity, but a variety of different entities having two characteristics in common: They all consist of some aspect of social structure, and they facilitate certain actions of individuals who are within the structure' (1990, p. 302).
<b>Fukuyama</b>	'Social capital can be defined simply as the existence of a certain set of informal values or norms shared among members of a group that permit cooperation among them' (1997).
Inglehart	'A culture of trust and tolerance, in which extensive networks of voluntary associations emerge' (1997, p. 188).
Knoke	'The process by which social actors create and mobilize their network connections within and between organizations to gain access to other social actors' resources' (1999, p. 18).
<b>Lin</b>	"Resources embedded in a social structure which are accessed and/or mobilized in purposive actions" (1999, p. 35).
Loury	'Naturally occurring social relationships among persons which promote or assist the acquisition of skills and traits valued in the marketplace. . . an asset which may be as significant as financial bequests in accounting for the maintenance of inequality in our society' (1992, p. 100).
Nahapiet and Ghoshal	'The sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit. Social capital thus comprises both the network and the assets that may be mobilized through that network' (1998, p. 243).
Pennar	'The web of social relationships that influences individual behavior and thereby affects economic growth' (1997, p. 154) .
Portes	'The ability of actors to secure benefits by virtue of membership in social networks or other social structures' (1998, p. 6).
Portes Sensenbrenner	'Those expectations for action within a collectivity that affect the economic goals and goal' seeking behavior of its members, even if these expectations are not oriented toward the economic sphere' (1993, p. 1323).
<b>Putnam</b>	'Features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit' (Putnam 1995, p. 67).

## Appendix B Empirical Literature on Social Capital

This section provides summary on how individual SC is conceptualized, measured and used in the empirical literature with the same or similar population. Table 2 provides the summary of the main studies reviewed. Surprisingly, given the extensive reference to the value of SC in theoretical and policy literatures, the empirical literature on this construct is relatively sparse. The studies are summarized according to the role SC plays in their research design: SC as described, SC as a predictor (IV) or SC as an outcome (DV).

SC is the most frequently used in its predictive role. The concept has been mostly used to predict personal health (Furuta, 2012; Rose, 2000; Rojas & Carlson, 2006), financial stability (Dufhues et al., 2011; Agarwal et al, 2001) and entrepreneurial activity (Davidsson & Honig, 2003). The studies that focus on health and financial stability for the most part use a general population that tends to be in some way less privileged: represents a lower level of socioeconomic status (Rojas & Carlson, 2006), located in developing countries (e.g. Russia, Thailand) and/or represents rural areas.

Ironically, these studies are also the weakest methodologically in defining and measuring SC. These authors tend to cite a single scholar on one selective definition of SC without demonstrating full comprehension of the complex concept. Thus, these studies' weak construct validity can be attributed to the lack of adequate expertise in SC literature and consequent poor execution of SC theory empirically.

One example is the study of Russian population in an economically stagnating city that based its SC measurement on a single critique of SC operationalization: "...we put forward Bourdieu as a possible way of moving beyond the tradition of conceptualizing social capital as a separate entity with no relation to class, power and status relationships, overlooking the political, economic and culture of a society" (Rose, 2000). Rose broadens the scope of SC to include traditionally economic and political concepts and brings his own dimensions of SC without any theoretical cohesion with the literature. His questions are classified into three dimensions: *social integration*, *generic SC scales* and *health specific SC*. Social integration combines indicators on an individual's access to different networks and general trust in his or her surroundings. It contains items on whether an individual: controls his/her own life; believes that most people can be trusted; has a communist in family; attends church; belongs

to organization; uses friends for information; is opinion leader; relies on government help; and lives in a village (vs. city) (p.1429). Generic type SC comprises questions that identify: 1) involvement of an individual with anti-modern networks (such as bribing officials), market networks, and informal networks; and 2) the extent to which an individual is excluded from these networks. Health-related SC includes 5 items: rely on friends & family when ill; paying to doctor; exercising in group; exercising alone; and smoking. This example demonstrates a type of study that uses SC as an overarching concept that can conveniently represent multiple things at once.

Another study defines SC post hoc: based on the data being available to carry out the research (Agarwal et al, 2001). In this study, SC is a predictor of financial stability of an individual, particularly, personal bankruptcy and default (2001). The authors include age, location, marital status and homeownership as the components of SC because this information is available from their loan-level dataset of credit cardholders. The authors cite SC research that shows it as a strong predictor of “many desirable socioeconomic outcomes.” By cramming the variables from their dataset to represent SC, the authors fall into the trap of making unwarranted assumptions about what SC is.

Studies that use SC as an outcome, on the other hand, demonstrate stronger methodology for assessing SC. One study that assesses impact of a country’s welfare system uses a custom measure based on the access to network connections that can provide help for different aspects of life (Gelissen, Van Oorschot & Finsveen, 2012). The measure is still incomplete but it has a relatively minor deviations from the issues discussed in theoretical literature. The second study is the most similar in population and the strongest methodologically to my research. The study looks at the role of internet access and utilization and graduate training composition in professional SC of scientists in public institutions in two different locations in the Philippines (Ynalvez & Shrum, 2008). SC is measured using an ego-centric networks approach – name generator – that tends to measure strong ties. Even though it focuses on the bonding type of SC, it acknowledged bridging type and works within the framework of the theoretical literature.

Table B.1

*Empirical Studies of Social Capital*

Author(s) & Year	Population	Measure of SC	Analysis	Results
Fornoni, Arribas & Vila (2010) Descriptive	Entrepreneurs in Argentina 2000-2005; stratified sample of 300 start-ups	N/A	Goodness-of-fit statistics; chi-square; to test hypothesis - matrix $\Phi$ (correlations)	Multi-dimensional measurement of SC is better than one-dimensional because its 3 parts do not correlate
Furuta et al. (2012) IV for oral health	Okayama University in Japan; 6 departments, 1,142 students 18-19 y.o.; 1,070 (93.7%) responded	IV: 6 Qs: 1 (family); 2 (neighborhood); 3 (school: vertical (teacher-student) trust, horizontal (students), students' collaborations	1. Chi-square; Pearson r - correlations of SC variables; IV & DV - 4 logistic regressions with odds ratios and CI=95%	Low neighborhood SC, high social control and low vertical trust in schools resulted in poor self-rated oral health
Rose, 2000 IV for health	1,904 Russians (rural and urban) over 18 y. o.	IV: HC education, age, gender, total house-hold income from all sources, subjective SES.	OLS multiple regression; three models for each hypothesis	Both HC & SC predict health, together and independently
Rojas & Carlson (2006) IV for health	1,795 adults from Taganrog, Russia 20 y.o. and older	IV: 3 questions on SC: Members of trade union or political organization; member of other organization; frequency of contact with neighbors	Multiple regressions (OLS) for IV-DV relationship; logistic regression to analyze relations between IV-s	SC is positively associated with better health
Agarwal, Chomsisengphet & Liu (2001) IV for personal bankruptcy	Loan-level panel data on more than 170,000 cardholders	IV: Age, homeownership, marital status, location (in home state or not). States' SC	Multivariate Cox proportional hazard model	SC at individual and state levels is associated with a lower levels of filing for bankruptcy
Dufhues et al. (2011) IV for loan repayment	3,621 villages' dwellers from rural Thailand	IV: Bonding (name generator), bridging (position generator) and linking (SIOPS) SC	Cluster analysis (k-means) for classifying SC and Binary probit regression for DV-IV relationship	Strong ties (bonding) SC had significant positive effect on loan repayment
Ynalvez & Shrum (2008) DV – Internet access & utilization and grad. training	Interviews with N=312 scientists; los Banos (N=180) and Munoz, Nueva Ecija (N=132) in the Philippines	DV: Ego-centric network; name generator (maximum 12 contacts); size, gender and location diversity of alters	Logistic and a normal error regression approach (DV was either binary-nominal or interval-ratio)	Half of alters are in the same location; scientists with more access to internet have more alters; graduates from the US
McFadyen & Cannella (2004)	Biomedical research scientists (N=173)	IV: coauthorship based on publications (N of relationships and strength of connections)	Panel data methodology to run correlations and heteroscedasticity	Positive relationships between N of coauthors and strength of relationships and knowledge creation
Gabbay & Zuckerman (1998)	Scientific researchers in 223 R&D laboratories of 29 major American corporations	Frequency of communication; contact density, network autocorrelation	Logistic Models	More density less promotion

## Appendix C

### Study 1: Survey Instrument

#### Informed Consent

What are some general things you should know about research studies?: You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact Ms. Olena Leonchuk.

What is the purpose of this study?: To learn more about the experiences of Science and Engineering students during their academic training.

What will happen if you take part in the study?: If you agree to participate in this study, you will be asked to complete a 15-20 minutes questionnaire.

Risks: There are no personal risks associated with this survey and there are no questions that should result in any physical or psychological discomfort of the participants.

Benefits: By completing this questionnaire, the participants will contribute valuable information that will help to improve the graduate education at the United States' universities and, eventually, help to solve world complex problems by improving the ways scientific process works.

Confidentiality: The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely on North Carolina State's secure server and only principal investigator will have access to it. No reference will be made in oral or written reports which could link you to the study. You will NOT be asked to write your name on any study materials so that no one can match your identity to the answers that you provide.

Compensation: All participants can choose to be entered into a drawing of two \$50 Amazon gift cards.

What if you are a student?: Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at your university.

What if you have questions about this study?: If you have questions at any time about the study or the procedures, you may contact the researcher, Olena Leonchuk, at oleonch@ncsu.edu.

What if you have questions about your rights as a research participant?: If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

Consent To Participate: "I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled." Agree (1); Disagree (2)



If Disagree Is Selected, Then Skip To End of Survey

Please, tell me some basic information about yourself.

Q1: What is your citizenship/immigration status?

US citizen/permanent resident (1)

International F1 student (2)

Other (please, explain) (3) \_\_\_\_\_

Q2: Indicate your current academic standing.

Graduate student pursuing PhD. (1)

Graduate student pursuing Master's degree. I do plan to pursue PhD. (2)

Graduate student pursuing Master's degree. I do not plan to pursue PhD. (3)

Former graduate student with Master's degree. (7)

Former graduate student with PhD. (8)

Undergraduate student. (4)

Postdoc. (5)

Other (please, explain) (6) \_\_\_\_\_

If Postdoc. Is Selected, Then Skip To End of Survey

If Undergraduate student. Is Selected, Then Skip To End of Survey

Q3: What is the name of your graduate school?

Arizona State University (1)

Auburn University (2)

Ball State University (3)

Boston University (4)

Brigham Young University (5)

Carnegie Mellon University (6)

...

Worcester Polytechnic Institute (80)

Wright State University (81)

Other (82)

*(This classifying question is for non-center students only)*

**Q4:** Please, choose the answer that best describes the research project you are engaged in to satisfy your degree requirements.

My Master's/PhD research project is an individual project that is being supervised by my main academic advisor(s) and thesis/dissertation committee. (1)

My Master's/PhD research project is part of a larger team-based project but is still supervised by my main advisor(s) and thesis/dissertation committee. (3)

My Master's/PhD research project is one of a number of projects being performed under a multi-investigator research center or institute on my campus and is supervised by my main advisor and a thesis/dissertation committee. (4)

My degree does not require a thesis or dissertation. (2)

Other (Please, explain) (5) \_\_\_\_\_

If N 4 Is Selected, Then Skip To End of Survey

*(This classifying question is for center students only)*

**Q4:** Are/were you affiliated with an Industry/University Cooperative Research Center (I/UCRC)?

Yes (1) No (2)

If No Is Selected, Then Skip To End of Survey

*(Questions 5 – 9 are for center students only)*

Please, tell me more about your graduate training.

**Q5:** What is the name of the I/UCRC you are/were affiliated with? *(Center students only\*)*

Advanced Forestry Systems (1)

Advanced Knowledge Enablement (2)

Advanced Non-Ferrous Structural Alloys (3)

...

Wheat Genetics (65)

Wood-Based Composites/ Sustainable Biomaterials (66)

Other (67)

**Q6:** How did you become involved with the I/UCRC? Please, check all that apply. *(Center students only)*

My academic adviser is part of the center's groups of scientists. (1)

I received an offer from the center director. (2)

I was involved with the center during my undergraduate studies and wanted to continue my involvement. (3)

Other (please, explain) (4) \_\_\_\_\_

**Q7:** What is the total number of months have you worked at the I/UCRC? (*Center students only*)

0 (1)

1-6 (2)

7-12 (3)

...

115-120 (21)

**Q8:** What percentage of your graduate student activity do/did you spend on the I/UCRC-related research and activities? (*Center students only*)

0% (1)

1-5% (2)

6-10% (3)

...

96-100% (21)

Q9 Is your current, planned or finished thesis or dissertation based on an I/UCRC's research project?

*(Center students only)*

Yes, it is. (1)

Yes, it will be. (2)

Yes, it was. (5)

No, it is not/will not be based on an I/UCRC project. (3)

I don't know yet. (4)

**Q10:** Thinking about your involvement in the I/UCRC, to what extent does/did it include:

*(Wording is changed for control students "thinking about your graduate training ...")*

	Not at all (1)	A little (3)	Fair/Mod erately (4)	Quite a bit (5)	Very (6)
Working or interacting with researchers from other disciplines. (1)					
Working or interacting with researchers from industry. (2)					
Working or interacting in teams of researchers. (3)					
Presenting research findings to researchers and other professionals from different sectors and disciplines. (4)					
Working or interacting with researchers from other universities. (5)					
Working in settings where there is a high level of interdependency between team members. (6)					
Working or interacting with researchers who are not located in the U.S. (7)					
Being exposed to scientific techniques and expertise that are not usually available in my department. (8)					
Learning how a particular concept can be applied to an actual problem or "a real world" situation. (9)					
Integrating and synthesizing information from different fields in order to solve problems. (10)					
Opportunities to develop my written and communication skills. (11)					

Think about your graduate training in general and answer the following questions.

Q11: In comparison with other students at your department who are/were not involved with I/UCRC, indicate to what extent do you agree or disagree with the following statements. *(For center students, words "who are/were not involved with I/UCRC" are dropped)*

	Fully Disagree (1)	Mainly Disagree (2)	Neither Agree nor Disagree (3)	Mainly Agree (4)	Fully Agree (5)
<p>My training has better prepared me to the demands of future employment. (1)</p> <p>I feel that I have expanded more my network of academic professionals who can give me advice and assistance in the future. (2)</p> <p>I feel that I have expanded more my network of industry professionals who can give me advice and assistance in the future. (3)</p> <p>I think I have more necessary skills to make a valuable contribution to an organization that is going to hire me. (4)</p>					

Q12: Please, describe how your graduate training can be improved.

Q13: Please, think about your graduate training as a scientist or engineer and indicate to what extent you agree or disagree with the following statements.

	Fully Disagree (1)	Mainly Disagree (2)	Neither Agree nor Disagree (3)	Mainly Agree (4)	Fully Agree (5)
<p>1. I believe that science benefits from involvement of different sectors such as private businesses, government and academia. (1)</p> <p>2. Sometimes, it may be challenging to work with people who come from different cultures, but the end results of such work are worth it. (2)</p> <p>3. I view collaborations between industry and academia as positive despite differences in the ways they operate and things they value. (3)</p> <p>4. I like working with researchers from different disciplines as I can use their knowledge in my area of work. (4)</p> <p>5. I believe that any contemporary scientist must have strong communication skills in order to be able to solve today's problems. (5)</p> <p>6. Despite extra time and resources spent on communication, I still think</p>					

that working in teams is important for building innovation capacity. (6)					
7. Despite the challenges associated with bringing professionals from different disciplines to work together, I still think that such collaborations are important for science. (7)					
8. I believe that a problem-solving approach can contribute to science as much as development of theory. (8)					

Social network is a network of social iterations and personal relationships.

**Q14:** How important are the size and diversity of your professional social networks to your future professional success?

	Not at all Important (1)	Somewhat Important (2)	Moderately Important (3)	Very Important (4)	Extremely Important (5)
Professional social network's size (1)					
Professional social network's diversity (2)					

**Q15:** Please, indicate a number of people do you know from the following categories.

	Total N (1)
Academic advisers who are directing/supervising you with your thesis or dissertation. (1)	
Faculty from your department. (2)	
Other graduate students or post-docs from your department. (3)	
Faculty from other disciplines/departments from your university. (4)	
Faculty from other universities in the United States. (5)	
Graduate students or post-docs outside of your department at your university. (6)	
Graduate students or post-docs from other universities. (7)	
Representatives of large privately owned companies (e.g. Google, Microsoft, Boeing etc.) (8)	
Representatives of small private companies (1 - 500 employees) (9)	
Representatives of the United States Federal, State or Local government. (10)	
Representatives of non-profit organizations, associations or foundations. (11)	
Entrepreneurs (start-ups' representatives) (12)	
Faculty from universities outside of the United States. (13)	
Graduate students or post-docs outside of the United States. (14)	

Thinking about different kinds of professionals you know, indicate the type of relationships you have with them. Choose N/A if you don't know people from a selected category.

**Q16:** I feel confident that I would be able to easily get technical advice and input on my main research project from:

	Fully Disagree (1)	Mainly Disagree (2)	Neither Agree nor Disagree (3)	Mainly Agree (4)	Fully Agree (5)	N/A (6)
Your academic adviser(s). (5)						
Other academic professionals (faculty, graduate students and post-docs) from my department. (1)						
Academic professionals (faculty, graduate students and post-docs) from other U.S. universities or disciplines. (2)						
Academic professionals (faculty, graduate students and post-docs) outside of the United States. (3)						
Non-academic professionals. (4)						

**Q17:** I feel confident that I would be able to get an introduction to a researcher who I did not already know from:

	Fully Disagree (1)	Mainly Disagree (2)	Neither Agree nor Disagree (3)	Mainly Agree (4)	Fully Agree (5)	N/A (6)
Your academic adviser(s). (5)						
Other academic professionals (faculty, graduate students and post-docs) from my department. (1)						
Academic professionals (faculty, graduate students and post-docs) from other U.S. universities or disciplines. (2)						
Academic professionals (faculty, graduate students and post-docs) outside of the United States. (3)						
Non-academic professionals. (4)						

Thinking about your academic achievements, indicate the approximate number for each of the following categories.

Q18: My work in my graduate program resulted in:

	Total N (1)	N with 1 co-author (2)	N with 2-3 co-authors (3)	N with 4 and more co-authors (4)	N with industry (5)	N with researchers from other discipline (6)
Journal publication (including those in press) (1)						
Proceedings publications (2)						
Presentations at scientific meetings (include poster presentations) (3)						

Tell me more about your professional online networking.

Q19: Do you have a LinkedIn account?

Yes (1) No (2)

Q20: Approximately, what is the total number of connections do you have on LinkedIn?

0 (1)

1-25 (2)

26-50 (3)

...

976-1000 (41)

>1000 (42)

Please, tell me about your future plans.

Answer If Indicate your current academic standing. Former graduate student with Master's degree. Is Not Selected And Indicate your current academic standing. Former graduate student with PhD. Is Not Selected

Q21: What is your employment preference upon graduation?

Work in academia (1)

Work in industry (2)

Work in government (3)

Non-profit/foundation. (4)

Start my own company (5)

Other (please, explain) (6) \_\_\_\_\_



Answer If Indicate your current academic standing. Former graduate student with PhD. Is Selected  
 And Indicate your current academic standing. Former graduate student with PhD. Is Selected

Q21F: What is your current employment status?

Working full time in industry in the U.S. (1)

Working full time in academia in the U.S. (2)

Working for the U.S. government (Federal/State/Local) (3)

Self-employed in the U.S. (6)

Unemployed (4)

Other (Please, explain) (5) \_\_\_\_\_

Answer If What is your citizenship/immigration status? US citizen/permanent resident Is Not  
 Selected And Indicate your current academic standing. Former graduate student with Master's degree.  
 Is Not Selected And Indicate your current academic standing. Former graduate student with PhD. Is  
 Not Selected

Q22: Based on what you intend now, what are your plans after graduation?

Go back to my home country. (1)

Work for some time in the US and return to my home country eventually. (2)

Stay in the US permanently. (3)

Other (Please, explain) (4) \_\_\_\_\_

Answer If Please, select your citizenship/immigration status. US citizen/permanent resident Is Not  
 Selected

Q23: Do you plan to become a US citizen?

Yes (1)

No (2)

Undecided (3)

Other (Please, explain.) (4) \_\_\_\_\_

You are almost done! Please, provide some additional information about yourself.

Q24: How old are you?

16 (1)

17 (2)

...

94 (79)

95 (80)

Q25: What is your gender?

Male (1)

Female (2)

Prefer not to answer (3)

Q26: What is your ethnicity/race?

African American/Black (1)

American Indian/Alaska Native (2)

Asian American (3)

European American/Caucasian/White (4)

Hispanic or Latin American (5)

Native Hawaiian or Other Pacific Islander (6)

I prefer not to answer (7)

Other (please, explain) (8) \_\_\_\_\_

Answer If What is your citizenship/immigration status? US citizen/permanent resident Is Not Selected

Q27: What is your nationality?

Argentine / Argentinean (1)

Australian (2)

...

Venezuelan (76)

Vietnamese (77)

Welsh (78)

Other (79)

Answer If What is your nationality? Other Is Selected

Q27a: If Other, please, indicate your nationality.

Q28: What is the name of your academic department?

Aerospace Engineering (1)

Biology (2)

Biological & Agricultural Engineering (3)

Biomedical Engineering (4)

Chemical Engineering (5)

Chemistry (6)

Civil Engineering (7)

Computer Science and Engineering (8)

Electrical Engineering (9)

Industrial and Systems Engineering (10)

Mathematics (11)

Material Science and Engineering (12)

Mechanical Engineering (13)

Nuclear Engineering (14)

Petroleum Engineering (15)

Physics and Astronomy (16)

Statistics (17)

Other (18)

Answer If What is the name of your department? Other Is Selected

Q28a: If Other, please, indicate the name of your academic department.

Q29: What is the total number of months you have been in graduate school?

1-3 (1)

4-6 (2)

...

94-96 (32)

97-99 (33)

100=> (34)

Q30 During your typical semester, approximately, what percentage each of the following financial sources supports (supported) your graduate school expenses (tuition and living expenses). Record 0% for each source that is not applicable. Note, sum must sum up to 100%.

	N (1)
Research Assistant (RA) at Industry/University Cooperative Research Center (IUCRC) (1)	
Research Assistant (RA) for a single faculty's project(s) (2)	
Research Assistant (RA) at other research center (3)	
Teaching Assistant (TA) award (4)	
Industry that funds university research (5)	
Support from my country (international students only) (6)	
I have a job(s) outside of university (7)	
Other (please, explain) (8)	
Total (9)	

Q31: What is your approximate grade point average (GPA) in graduate school?

2.00-2.25 (1)

2.26-2.50 (2)

2.51-2.75 (3)

2.76-3.00 (4)

3.01-3.25 (5)

3.26-3.50 (6)

3.51-3.75 (7)

3.76-4.00 (8)

Q32: During your school years, undergraduate or graduate, have you ever worked for a company/industry or governmental organization doing work related to your current area of study?  
Check all that apply.

Never (1)

Yes, I had/have an internship/Co-op (2)

Yes, I had a part-time job (3)

Yes, I had a full-time job (4)

Yes, I currently have a part-time job (5)

Yes, I currently have a full-time job (6)

Other (please, explain) (7) \_\_\_\_\_

Q33: Last but not least. Please rate your level of satisfaction with your graduate training.

	Dissatisfied (1)	Mostly Dissatisfied (2)	Neutral (3)	Mostly Satisfied (4)	Satisfied (5)
Overall graduate training experience. (1)					

Answer If Informed Consent What are some general things you should know about research studies? You a... Agree Is Selected

Thank you for completing the study. I wish you all the best luck in your career as a scientist or engineer! If you would like to be entered into a drawing of two \$50 Amazon gift cards, please, open this link in a new window to enter into a drawing.

Appendix D  
Study 1

Tables with Preliminary Results for Model A and Model B

Model A

Table D1

Model A: Correlations of the Main Variables

	A	B	C	D	E	F	G	H	I
A. Satisfaction	1								
B. Preparedness	.543**								
C. Training <sup>a</sup>	.258**	.343**							
D. Citizenship <sup>b</sup>	.054	.043	.002						
E. Norms and Values	.227**	.340**	.217**	.092					
F. Industry Network Size	.119	.201**	.158*	.182**	.166**				
G. Industry Network Strength	.061	.233**	.128*	.195**	.095	.282**			
H. Mult./Team Experience	.315**	.389**	.048	-.099	.211**	.014	.122*		
I. Industry Experience	.389**	.475**	.372**	-.122*	.327**	.079	.144*	.515**	
J. Cross-sector Prof. Dev.	.385**	.448**	.162**	-.015	.355**	.138*	.116	.637**	.464**

\*\* . Correlation is significant at the 0.01 level (2-tailed). \* . Correlation is significant at the 0.05 level (2-tailed).

a. Training coded "1" for Traditional Training, "2" for IUCRC;

b. Immigration status coded as "1" for international students, "2" for US students

Table D2

## Model A: Univariable Results for Preparedness

Variable	B	Std. Err.	95% CI	$\beta$	t-value	p
Training	1.919	.327	(1.275, 2.563)	.343	5.866	.000
Satisfaction	2.092	.201	(1.696, 2.488)	.543	10.396	.000
Norms & Values	.241	.041	(.159, .323)	.340	5.807	.000
Industry Network Size	.037	.011	(.015, .059)	.201	3.272	.001
Industry Network Strength	.283	.074	(.138, .428)	.233	3.842	.000
Multidisciplinary/Team Experience	.192	.028	(.136, .248)	.389	6.783	.000
Industry Experience	.570	.066	(.441, .700)	.475	8.681	.000
Cross-sector Prof. Dev. Experience	.434	.054	(.328, .540)	.448	8.054	.000

Table D3

## Model A: Multiple Regression Results for Preparedness

	Mean	SD	B	$\beta$
Intercept			4.357	
Training	1.67	.47	.770**	.138
Satisfaction	2.20	.69	1.333**	.346
Norms and Values	35.06	3.73	.071	.100
Industry Network Size			.011	.060
Industry Network Strength			.151*	.124
Multidisciplinary/Team Experience	19.82	5.36	.053	.106
Industry Experience	9.08	2.20	.158*	.132
Cross-sector Prof. Dev.	14.42	2.73	.103	.106
		<i>F</i> (8, 247)	=	26.49*
				*
		R	=	.680
		R <sup>2</sup>	=	.462
		Adjusted R <sup>2</sup>	=	.444

\*Significant at  $p < .05$ , \*\*Significant at  $p < .01$

Table D4

## Model A Mediation Results

Relationship	Direct w/o M	Direct with M	Indirect	R <sup>2</sup> w/o M	R <sup>2</sup> with M
Training – Sat – Preparedness	$\beta=.34^{**}$	$\beta=.22^{**}$	p=.001	12%	34%
Training – Industry Strength - Preparedness	$\beta=.34^{**}$	$\beta=.32^{**}$	p=.020	12%	15%
Training – Norms & Values - Preparedness	$\beta=.34^{**}$	$\beta=.28^{**}$	p=.001	12%	19%
Training – Industry Exp. - Preparedness	$\beta=.34^{**}$	$\beta=.19^{**}$	p=.001	12%	26%
Training – Industry Exp. - Sat	$\beta=.26^{**}$	$\beta=.13^*$	p=.001	7%	17%
Training – Industry Exp. - Sat - Preparedness <sup>^</sup>	$\beta=.34^{**}$	$\beta=.22^{**}$	p=.001	7%	32%

\*Significant at  $p < .05$ , \*\*Significant at  $p < .01$

<sup>^</sup>Sequential mediation effect of Industry Experiences and Satisfaction

## Model B

Table D5

## Model B: Correlations of the main variables

	A	B	C	D	E	F	G	H	I	J	K
A. Citizenship	1										
B. Preparedness	.102	1									
Predictors											
C. Duration of time at IUCRC	.172*	.133	1								
D. Percentage of time spent on IUCRC activities	.102	.220**	.281**	1							
E. Project focus	-.057	.232**	.253**	.335**	1						
F. Mult./Team Experience	-.087	.414**	-.041	.130	.249**	1					
G. Industry Experience	-.123	.416**	.061	.136	.311**	.593**	1				
H. Cross-sector Prof. Dev.	-.046	.528**	-.001	.146	.273**	.630**	.568**	1			
Mediators											
I. Norms and Values	.101	.356**	-.031	.023	.154*	.254**	.348**	.386**	1		
J. Industry Network Size	.204**	.188*	.217**	.074	.097	.035	.021	.170*	.141	1	
K. Industry Network Strength	.280**	.213**	.124	.110	.133	.173*	.028	.161*	.089	.289**	1
L. Satisfaction	.020	.466**	.053	.054	.103	.340**	.359**	.414**	.217**	.093	.071

\*Significant at  $p < .05$ , \*\*Significant at  $p < .01$



Table D6

## Model B: Univariate Results for Preparedness

Variable	B	SE	95% CI	$\beta$	t-value	p
Project Satisfaction	1.301	.417	(.477, 2.125)	.232	3.117	.002
Norms & Values	1.683	.243	(1.204, 2.163)	.466	6.927	.000
Industry Network Size	.242	.048	(.147, .337)	.356	5.013	.000
Industry Network Strength	.030	.012	(.006, .054)	.188	2.489	.014
Multidisciplinary/Team Experience	.231	.080	(.072, .389)	.213	2.870	.005
Industry Experience	.182	.030	(.122, .242)	.414	5.985	.000
Cross-sector Professional Development	.514	.086	(.346, .683)	.416	6.014	.000
Time at IUCRC	.480	.059	(.364, .596)	.528	8.176	.000
Time spent on IUCRC activities	.399	.230	(-.056, .854)	.133	1.732	.085
	.107	.036	(.035, .178)	.220	2.955	.004

Table D7

## Model A Mediation Results

Relationship	Direct w/o M	Direct w M	Indirect	R <sup>2</sup> w/o M	R <sup>2</sup> w M
Cross-sector Prof. Dev. – Sat – Preparedness	$\beta = .53^{**}$	$\beta = .40^{**}$	p = .011	28%	35%
Cross-sector Prof. Dev. – Industry Strength – Preparedness	$\beta = .53^{**}$	$\beta = .51^{**}$	p = .069	28%	30%
Cross-sector Prof. Dev.– Norms & Values – Preparedness	$\beta = .53^{**}$	$\beta = .46^{**}$	p = .012	28%	31%

\*Significant at  $p < .05$ , \*\*Significant at  $p < .01$

Table D8

## Model B: Multiple Regression Results for Preparedness

Variable	Mean	SD	B	$\beta$
Intercept			5.353	
Project	1.75	.43	.373	.067
Satisfaction	2.33	.67	1.013**	.281
Norms and Values	35.67	3.58	.086*	.127
Industry Network Size	14.25	15.32	.010	.062
Industry Network Strength	7.06	2.25	.088	.080
Multidisciplinary/Team	20.10	5.53	.036	.082
Experience				
Industry Experience	9.68	2.00	.074	.060
Cross-sector Professional	14.77	2.67	.219**	.240
Development				
Time spent on IUCRC activities			.074*	.152
		F (8, 160)	=	13.79*
		R	=	.639
		R <sup>2</sup>	=	.408
		Adjusted		
		R <sup>2</sup>	=	.379

\*Significant at  $p < .05$ , \*\*Significant at  $p < .01$

## Appendix E

### Study 2

#### Case Study Social Network Survey

Informed Consent: *What are some general things you should know about research studies?* You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact Ms. Olena Leonchuk.

*What is the purpose of this study?* To learn more about the experiences of Science and Engineering students during their academic training. What will happen if you take part in the study? If you agree to participate in this study, you will be asked to complete a 15-20 minutes questionnaire.

*Risks* There are no personal risks associated with this survey and there are no questions that should result in any physical or psychological discomfort of the participants.

*Benefits* By completing this questionnaire, the participants will contribute valuable information that will help to improve the graduate education at the United States' universities and, eventually, help to solve world complex problems by improving the ways scientific process works. You will also be entered into a drawing to win one \$40 Amazon gift card.

*Confidentiality* The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely on North Carolina State's secure server and only principal investigator will have access to it. No reference will be made in oral or written reports which could link you to the study. You will NOT be asked to write your name on any study materials so that no one can match your identity to the answers that you provide. *Compensation* There will not be financial or other compensation for your time.

*What if you are a student?* Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at your university. What if you have questions about this study? If you have questions at any time about the study or the procedures, you may contact the researcher, Olena Leonchuk, at oleonch@ncsu.edu.

*What if you have questions about your rights as a research participant?* If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

*Consent To Participate* "I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Yes (1)

No (2)

If No Is Selected, Then Skip To End of Survey

Q2 What is your full name?

First name: (1)

Last name: (2)

Q3 What is your gender?

Male (1)

Female (2)

I prefer not to answer (3)

Q4 What is your immigration status?

US citizen or permanent resident (1)

International student (F1, J1 visa or OPT) (2)

Other (3) \_\_\_\_\_

If US citizen or permanent res... Is Selected, Then Skip To How long have you been involved with ...

Q5 Which country are you from? \_\_\_\_\_

Q6 How long have you been involved with the Water Equipment and Policy (WEP) center?

0-6 months (1)

7-12 months (2)

13-18 months (3)

19-24 months (4)

More than 24 months (5)

Q7 This is the most important part of the questionnaire that asks about your communication patterns with other people involved with WEP.

Q8

In the last 6 months, how often did you communicate electronically or in-person with \_\_\_\_ on a professional topic? The topics of your communication can be about but not limited to: research project(s), presentation/publication, coordination with others, discussion about topics related to academic research (e.g. news, policy) and any professional activity related to the I/UCRC operations such as I/UCRC meetings.

	More than twice a week (1)	About twice a week (2)	About once a week (3)	2-3 times a month (4)	About once a month (5)	Less than once a month (6)	Never (7)
Name							

Q9 What is your graduate status?

I am working on my Master's degree and not planning on continuing to PhD (1)

I am working on my Master's degree and planning on to continue to PhD. (2)

I am working on my Doctorate degree (3)

I am an undergraduate student (4)

I am a postdoc (5)

Other (6) \_\_\_\_\_

If I am an undergraduate student Is Selected, Then Skip To Is your current thesis or dissertation.

Answer If What is your immigration status? International student (F1, J1 visa or OPT) Is Selected  
And What is your immigration status? Other Is Selected

Q10 Where did you receive your Bachelor degree?

USA (1)

Not USA (2)

Answer If Where did you receive your Bachelor degree? Not USA Is Selected

Q11 Please provide the country where you receive your Bachelor degree.

Q12 Is your current thesis or dissertation based on the WEP center research?

Yes, it is. (1)

Yes, it will be. (2)

No, it is not/will not be based on WEP project. (3)

I don't know yet. (4)

Yes, it was. (5)

Other (6) \_\_\_\_\_

Q13 In the last 12 months, have you presented your or center research at any of the center's meetings?

Yes (1)

No (2)

Other (3) \_\_\_\_\_

Q14 What is the total number of times have you ever presented your or center research at the center meetings? \_\_\_\_\_

Q15 Which sector do you plan to work after graduation (or after you finish your postdoc)?

Industry (1)

Academia (2)

Government (3)

Start-up (4)

Other (5) \_\_\_\_\_

Q16 Do you have an internship or job offer from:

	Yes (1)	No (2)
Center's current or former member (1)		
Industry/government/non-profit that has never been a member of the center (2)		

Answer If What is your immigration status? International student (F1, J1 visa or OPT) Is Selected  
And What is your immigration status? Other Is Selected

Q17 What do you plan to do after graduation?

Stay in the US (1)

Stay in the US for some time and then go back to my home country or elsewhere (2)

Go back to my country (3)

Other (4) \_\_\_\_\_

Q18 In comparison with other students (or postdocs), indicate to what extent do you agree or disagree with the following statements.

	Fully Disagree (1)	Disagree (2)	Neither Disagree nor Agree (3)	Agree (4)	Fully Agree (5)
My training has better prepared me to the demands of future employment. (1)					
I feel that I have expanded more my network of academic professionals who can give me advice and assistance in the future. (2)					
I feel that I have expanded more my network of industry professionals who can give me advice and assistance in the future. (3)					
I think I have more necessary skills to make a valuable contribution to an organization that is going to hire me. (4)					

Q19 Please rate your level of satisfaction with your training.

Dissatisfied (1)

Mostly Dissatisfied (2)

Neutral (3)

Mostly Satisfied (4)

Satisfied (5)

Q20 Thank you so much for your time! Your name is automatically entered into the drawing of the \$40 Amazon gift card. You will receive the notification email if you win the drawing two weeks after the completion of this survey.