ABSTRACT

LEONCHUK, OLENA. Professional Social Capital and Graduate Training of Future Scientists in Science & Engineering Disciplines. (Under the direction of Denis O. Gray.)

With the rise of cooperation of universities with industry and government in the last 30 years, more graduate students are exposed to collaborations across sectors, disciplines and organization boundaries. Science and Engineering (S&E) disciplines, particularly, have shown to benefit from these collaborations as they often work with problems that require complex solutions where collaboration and exchange of different expertise are almost inevitable. One of the establishments that enable this cooperation is Cooperative Research Centers (CRCs). Previous evaluation of the CRCs offers some information about students' experiences. However, little is known about professional social capital students acquire during their training and carry on to their professional careers.

According to Bozeman's Science and Technology Human Capital theory (Bozeman, Dietz and Gaughan, 2001), professional social capital is an important, but often ignored component of evaluation of the scientific outcomes. Social capital as manifested in professional connections, shared norms and trust are as valuable component of research as technical skills and knowledge. Bozeman claims that evaluation of the scientific outcomes and policies should involve human capital component that captures not only long-term outcomes, such as intellectual property and patents, but also the processes behind their creation.

This study looks at the professional social capital, perceived career preparedness and satisfaction with graduate training and whether these outcomes differ by the type of graduate training: traditional training confined within university departments and training within NSF Industry/University Cooperative Research Centers (I/UCRC), one type of CRCs. The study also looks at the international students who comprise more than 50% of the graduate STEM population in the U.S. universities. In addition to its focus on social capital outcomes, the study investigates whether type of training and other variables affect international students' plans and intentions to remain in US and/or become US citizen after graduation.

Professional social capital is captured at the time of graduate training of the future scientists and engineers. Similarly to any type of social capital, it contains two parts: bridging and bonding social capital (Patulny and Svendsen, 2007). Bridging represents available

social networks, particularly, size of a person's network and strength of the network connections. Bonding social capital represents mechanisms that enable one's social network. They represent trust and availability of positive norms and values about collaboration. In the context of the S&E graduate students, bridging social capital represents students' social connections to and intended use of different kinds of professionals (US academics, non-US academics and non-academics). Bonding social capital represents the extent to which students view different kinds of collaborations. Perceived career preparedness and satisfaction with graduate training were examined as outcome measures.

The study uses quasi-experimental research design. Graduate students trained in the team-based and sector-crossing I/UCRCs were compared to students who experienced a more traditional disciplinary training guided by an advisory committee. The contact information for the study participants was collected in two different ways. Since the authors of this study are part of the I/UCRC evaluation project's team, we were able to receive contact information for center graduate students from the I/UCRC directors with assistance from the NSF. An electronic confidential survey was used as a tool to collect information from the S&E graduate students in the US universities. The traditional training control group was created by obtaining contact information for graduate students at matched universities and disciplines from public sources. Two groups were given the same survey instrument with some modification in wording and reduction of questions that are related specifically to the I/UCRC group.

The final sample represents completed responses from 173 center students and 87 non-center students. Descriptive statistics of the sample demonstrate that two groups are compatible in: graduate standing (100% PhDs), age (M = 26 y. o.), gender (23% female), immigration status (66% international students) and time spent in graduate school (M = 2 years). Preliminary findings of the study demonstrate that center students have higher scores on some measures of professional social capital but not others. Analyses also reveal that international students do not always share these benefits. Center students also have higher level of satisfaction and perceived career preparedness. Implications for policy and practice will be discussed.

Professional Social Capital and Graduate Training of Future Scientists in Science & Engineering Disciplines

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 innovation policy, science & engineering workforce and international students. Upon her graduation, she sees herself as a data scientist with skills in data analytics and research methods.

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INTRODUCTION

The Role of Information Age and Global Market Economy

In the current era of information age, technological innovations have become a new type of international currency along with natural and economic resources of the countries. The open nature of today's world with looser economic and immigration borders opens up new opportunities for nations to compete on the global market of technological innovations. Historical events such as the fall of the USSR contributed greatly to the development of this global market, by introducing new players, its former Republics, to this innovation game (National Research Council, 2005). According to the National Science Board's overview of Science and Engineering Indicators, countries like India, Brazil, and, particularly, China are strengthening their positions in the global research and development (R&D) initiatives (2014). It is hard to measure innovations, but crude measures of outputs from nations' R&D activities such as publications and patents by their scientists demonstrate these changes. Since the millennium, the global share of articles originated in the EU and the US are declining from 35% to 31% and from 30% to 26% respectively during the period of 2001-2011. Increasingly, scientists outside of the US are becoming a significant part of the US science and technology's (S&T) R&D co-authoring 35% of the US' articles in 2012 that demonstrates a significant rise from 1997's 16%.

The US academic institutions are the center of the US collaborations, where 53% of its total articles are coauthored with the foreign institutions or other US sectors. The fundamental goal of the universities to increase body of knowledge despite any borders along with this sharp rise in borderless exchange of knowledge is expected to only increase due to the open world economy and advanced communication technologies. The development of collaborations, therefore, in the information era is inevitable.

The US is also generous in sharing higher education with the rest of the world. It hosts the largest percent of the international students and their numbers continue to growth. In some disciplines, international students even outnumber the American students. For instance, the international students comprise more than 50% of all S&T students in the US (National Research Council, 2005).

Such issues become a topic of the national interests of the US and its competitiveness on the global market. The sharing nature of the US academic institutions on the one hand is an important tool for exchange of knowledge; on the other hand, it also helps other countries to compete with the US on the global arena where national interests are at stake. Nevertheless, there are two sides of the coin: the same institutions which are the center of the US collaborations represent an opportunity for the US to grow its private sector competitiveness. For instance, the US universities in the same fashion collaborate with industry which is knowledgeable about commercial nature of innovation. With this additional expertise from industry to recognize the potential use of a discovery, the US universities' share of patents approved by the U.S. Patent and Trademark Office increased 50% from 2009 to 2012. Therefore, the US universities and their collaborative capabilities are a significant force behind the US's R&D on the global market. More importantly, such sharp increase in S&T collaborations either with other nations or other sectors demonstrates that today, one of the major professional demands for scientists are ability to collaborate in a successful manner and the presence of the professional networks that these scientists can draw upon.

Changes in the National Innovation System

This collaborative environment of a global market, with blurred boundaries between countries and between sectors, echoes the changes of the nations' innovation systems as a whole. Gray, Boardman and Rivers highlight three of these changes: "the collectivization of research, the emergence of a cooperative paradigm for guiding research policy in the United States and abroad, and the development and implementation of "open" approaches to innovation by industry and other stakeholders" (Boardman, Gray & Rivers, 2013).

Collectivization of research is characterized by the increased number of informal and formal collaborations. Scientists of today more often than less work in teams with others in order to solve more complex problems often requiring usage of advanced equipment and expertise from other fields and sectors (Ziman, 1984). In the modern literature, this phenomenon is called "team science" (Stokols et al., 2008).

The second development is strategic policy direction of the US and other governments to promote collaborations of scientists. Particularly, this cooperative paradigm

represents the government intervention in developing innovation capacity of academia and other sectors. One of the ways it is being done is by supporting research directed at the first needs of the society such as renewable energy or supporting fundamental research that lays down the fundament for any discovery.

The third change that has been occurring in the information era is the concept of openness of the innovation process in industry. Private sector has been doing more sharing of information and ideas because the interdependency on the current global market makes it possible to have such open model be successful for businesses' own interests. Chesbrough, Vanhaverbeke and West (2006) describe this open innovation model as "an alternative to the internally focused and vertically integrated model of industrial innovation" (Boardman et al. 2013). This approach is not going to work for all the individual industry actors. However, it represents new opportunities for industry where long term benefits from networking with other players of the S&T innovation arena exceed the costs associated with exposure of sensitive information or with the lost money from a product that went open source.

Technology Transfer and Scientific & Technical Human Capital

The changes in the national system demonstrate that the process of innovation combines in itself multiple actors with their own demands and objectives that need to be met. Communication technologies and open market make it easier to transfer knowledge between these actors in order to produce innovations. However, this process of technology transfer still remains very complex. In order to evaluate the national innovation system and eventually design new policies that can improve it, one needs to know about the components of technology transfer process that drives innovations. There are different theories on the technology transfer process, however, the most comprehensive model belongs to Bozeman and it is called Contingent Effectiveness model of technology transfer which is primarily based on empirical research and its main assumption is that "parties to technology transfer have multiple goals and effectiveness criteria" (Bozeman, 2000). The figure 1 demonstrates the components of the technology process proposed by Bozeman.

Scientific & Technical Human Capital (STHC) is a significant part of this process and listed in the four components of the model: characteristics of transfer object, of transfer agent

(university scientists), of transfer recipient and of the transfer object use. It shows that STHC plays a significant role in most dimensions of the technology transfer process. The Table 1 demonstrates the importance of STHC as one of the main effectiveness criteria for the technology transfer process. It also highlights the relative lack of attention to these criteria in comparison with criteria such as economic development and political reward that tend to dominate decision making of the policy makers in designing a national innovation system.

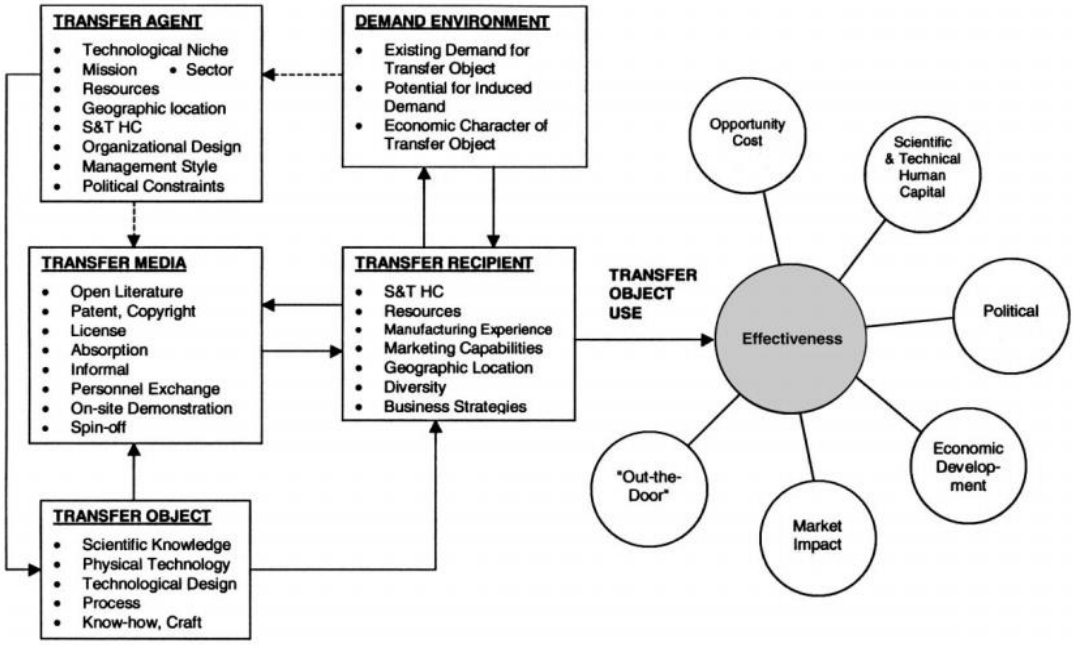

Fig. 1. Contingent Effectiveness Model of technology transfer.

Figure 1. Contingent Effectiveness Model of Technology Transfer.

According to Bozeman, STHC is "the sum of scientists' and engineers' scientific and technical knowledge, work relevant skills and social ties and resources" (Bozeman, Dietz, & Gaughan, 2001). This theory draws upon "recognition of the dynamic interplay between scientists' human capital and their social networks" (Bozeman et. al, 2001; Bozeman & Rogers, 2002). This research study is based on the premises of the STHC theory where

scientists' social capital is as a significant determinant of the successful technology transfer process that enhances innovations. The study looks at the organizations that play an important role in technology transfer. The globally-recognized US research universities is the organizational subject of these study, particularly, their cooperative research centers that are described in more details in the following section.

Table 1

Technology Transfer Effectiveness Criteria

Effectiveness criterion	**Focus**	**Relation to research and practice**
"Out-the-Door"	Based on the fact that one organization has received the technology provided by another, no consideration of its impact.	Extremely common in practice, uncommon as an evaluation measure (except in studies measuring degree of participation in technology transfer).
Market Impact	Has the transfer resulted in a commercial impact, a product, profit or market share change?	Pervasive in both practice and research.
Economic Development	Similar to Market Impact but gauges effects on a regional or national economy rather than a single firm or industry.	Pervasive in both practice and research.
Political Reward	Based on the expectation of political reward (e.g., increased funding) flowing from participation in technology transfer.	Pervasive in practice, rarely examined in research.
Opportunity Costs	Examines not only alternative uses of resources but also possible impacts on other (than technology transfer) missions of the transfer agent or recipient.	A concern among practitioners, rarely examined except in formal benefit-cost studies.
Scientific and Technical Human Capital	Considers the impacts of technology transfer on the enhanced scientific and technical skills, technically-relevant social capital, and infrastructure (e.g., networks, users groups) supporting scientific and technical work.	A concern among practitioners, rarely examined in research.

CRC and I/UCRC

The changes in the S&T innovation process resulted in development of the programs and norms that enhance collaborations and provide opportunities for different sectors to share

their knowledge. Universities have become major players of this knowledge sharing initiatives. They have opened their doors to one of the common forms of organizations that promote technology transfer and enhance innovations - cooperative research centers.

There is a lack of consensus on what cooperative research centers (CRC) are. There have been many definitions that incorrectly place conceptually CRCs on the two ends of spectrum: one that defines CRC as an organization that is not very different from academic departments and other that places CRCs as an entity fully dependent on external stakeholders (Gray et al., 2013). After reviewing the definitions in the literature, Gray, Boardman and Rivers provide a comprehensive definition that reflects CRC in what the CRC represent in reality:

> A cooperative research center (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 collaborations, knowledge and technology transfer, and ultimately innovation. (2013)

They underline three components that need to be present in any CRC: organizational structure, research performing, and cross-sector collaborations. First, each CRC should represent an organization and the minimum requirement that make up one such as leadership structure, a physical office and website or newsletter with information for its stakeholders. Second, each CRC should have research as the main focus. Therefore, university's technology transfer office cannot be a CRC. Third and last, CRCs should represent collaborations of different sectors. CRC cannot represent, for instance, industry consortium, it has to be consortium of industry with other sector such as academia.

The current study focuses on one type of CRC, the Industry-University Collaborative Research Centers (I/UCRCs) that conduct research in engineering and sciences. The program is sponsored by the Division of Industrial Innovation and Partnership of the National Science Foundation for more than 30 years. In the 2013-2014 fiscal year, total of 66 centers were part of the program, with around 900 industry scientists, 1,700 graduate students and 300 undergraduate and more than 1,000 members. More than half of the members represent large businesses; about 25% of the members represent small business classified as having less than

500 employees, about 10% of members are federal government and the rest are either state/local government, unidentified organization, non-profit, or foreign government. The main goal of the I/UCRC program is to fuel collaboration between industry and university for the advancement of the national innovation capacity while training a new generation of scientists who gain experience of doing research in a collaborative fashion.

Over the years, the National Science foundation has encouraged the I/UCRCs to increase their number of university sites which resulted in the total of 175 university sites participating in the centers. Large research intense universities like Ohio State and NC State have more than one I/UCRC, therefore, the number of the different universities being involved with the centers is significantly smaller.

I/UCRC stakeholders

There are five stakeholders groups of the I/UCRC program: the NSF, industry members, university faculty, administrative personnel, and students. During the regular process of the center operations, the faculty with students at universities is conducting the research while the industry members provide funds to carry research and vote on which research projects to be selected at the centers.

The I/UCRC program is an NSF initiative. The government helps the participating centers to follow the requirements of the program and provide limited funding for the centers' administration. Also, under the NSF requirements, each center must have its own evaluator, a professional who collects data on center's operations, provides an annual report to the NSF and helps the center to follow the model of cooperative environment envisioned by the NSF. The NSF provides no more than 10% of the total program funding (Gray, Leonchuk, McGowen & Michaelis, 2014). Most funding comes from centers' members. However, the NSF accreditation means more than just money. The association of a center with the NSF and the I/UCRC program represents prestigious position that helps to build trust with potential members and makes it easy to apply for other federal funding. Therefore, the I/UCRC leadership represents a critical form of stakeholders whose decisions affect the whole program.

According to the I/UCRC statue, a single center must have at least three current members. However, some centers have up to 80 members. Depending on the research conducted at the center and the number of the university sites, the number of the members can vary. The I/UCRC are supposed to follow the consortium model where each member's interest is taken into account (Gray, Rudolph, & Lindblad, 2001). However, this objective is hard to achieve on practice where large companies have more influence on what research projects should be selected. The members pay an annual fee to the center which can vary from 30,000 to 75,000 USD, most centers fall into a category of 35,000 – 50,000 USD. A single member can buy more than one membership in which case, this member acquires more leverage in the center's overall decision on what research projects it selects to work on. The role of the NSF is to enforce the rules that equalize the membership privileges to the extent possible.

The main benefits that members gain from their membership are: avoidance of cost of internal R&D that they can do in the center for a much lower price; professional networking with university scientists and industry competitors; and hiring students from the centers without having to spend money on recruiting of well-trained professions who are also familiar with the a company's research and have experience working with both, industry and academia (Gray & Steenhuis, 2003). Depending on a type of an organization, for instance, large or small business, members get other benefits. For instance, during semiannual meetings that each center has, when faculty and students present research projects and proposals for selection and discussion, many small businesses seem to benefit just from hearing comments and questions from large businesses who dominate their industry. Small businesses can observe how the leaders in their industry think about research and what direction they are going.

University faculty represent the other group of the I/UCRC stakeholders. They work for university and, at the same time, they are part of an I/UCRC on their campus. Being part of the I/UCRC does not only help financially to conduct research of their interests and to pay for tuitions of students who are involved with the center's research, but also to receive industry's expertise on how to differentiate discoveries that have potential to be

commercialized or which of these discoveries make sense to file a patent on. Additional financial benefits from being part of the center and involvement in more applied areas of research make faculty more satisfied with their I/UCRC's experiences (Coberly & Gray, 2010). Each center also has a director, who is a faculty at university. However, the role of a center director is more complex since, in addition to his university responsibilities, he has to manage a center like a business trying to comply with the NSF requirements and satisfy the center's stakeholders. His job has been known to be very challenging due to the lack of time and lack of the necessary experience in business management (Craig, Hess, McGinnis & Gray, 2009).

Even though the NSF provides some support for administration of the centers, often the center's management directs all available resources to supporting center's research and its graduate students. This primary objective leaves little funding for center's administration and staff even though the centers' operations and semiannual meetings require lots of planning and organizational structure. The centers with multiple sites tend to have administrators, but still many centers struggle to hire a full time professional to perform this important role. This group of stakeholders is least known in terms of its satisfaction and work load.

The final stakeholder's group is the students, majority of who are graduate students. The students are driving force behind the research that is done in the centers. Many students use the research project they are doing for the center as their thesis or dissertation gaining experience working directly with industry and other scientists. The level of involvement and the length of time spent in the centers, however, vary and there is some evidence from annual evaluation of the program that some students help with administrative work rather than with research. Based on the previous studies, students are satisfied with their experiences: male students, however, are more satisfied when they get to do hands on experience such as using equipment and applying the research to practice (Schneider, 2007). Students' academic freedom does not seem to be affected by their involvement with a center (Behrens & Gray, 2001).

Purpose of Research

The last category of the stakeholders, students who are significantly involved with the I/UCRCs, are believed to gain a unique opportunity to work with industry and other scientists on their centers' research projects. They also tend to participate at the meetings where industry and scientists discuss the research in terms of its potential to be applied to the real products or to become a new technology. Students also communicate with industry during the research process. These observations of students' experiences at I/UCRCs demonstrate that students at the centers may be more exposed to a network of people from different sectors and disciplines and may be more experienced in collaborating than students at the traditional university settings, academic departments. This study, therefore, focuses on graduate students' social capital, or social networks based on mutual trust and common norms of conducting science. Students with higher level of social capital are believed to be more prepared for the demands of the current interactive world order, where collaborations are almost inevitable. Therefore, the goal of the study is to compare students with different graduate training, traditional or I/UCRC, and assess if their training have any influence on the professional social capital a student acquires during his or her graduate training.

The other question the study is trying to address is mainly related to the international students. International students that comprise more than a half of this population have a choice to come back to their home country or to stay in the US. Their decision has implications on the US competitiveness in the S&T sector. Therefore, the study also looks at the students' future plans and if they differ depending on which training they have been exposed to, I/UCRC or traditional.

LITERATURE REVIEW

Theory of Social Capital

This section of the literature review summarizes the conceptual meaning of social capital (SC) and the challenges associated with the concept and its measurements. It highlights importance of the term in explaining social phenomena and implications for individuals and groups. The section takes top-down approach, first explaining the origins of the term and associated issues and misconceptions, followed by general definitions and

measurements of SC. Finally, the section demonstrates how the concept of SC is used in the context of S&T national policy and graduate training in the national research-intensive universities.

The concept of SC represents potential opportunity to explain variety of social phenomena through the lens of the social interactions. In the past, it has been more difficult to study social interactions because the data required were not easily available. With the rise of the Internet, communication devices, and social media like Facebook and twitter, more data became available on people's behavior. Therefore, in the last 20 years, the concept of SC has been getting lots of attention world-wide promising to explain better human behavior.

Probably the most likely origins of the concept of SC and reasons why it is so widely adopted are the theories of contagion. These theories' main assumption is that network connections make one "contagious" with information, attitudes and beliefs from others in the same network (Burt, 1992; Contractor & Eisenberg, 1990). With more exposure to network, an individual is more likely to adopt the same attitudes and believes and be more exposed to the information shared among other members in the network (Carley & Kaufer, 1993).

Factors that influence disagreements about definition of Social Capital

SC is a widely used term, but after more than 25 years of research, a variety of outstanding issues still remain. They include lack of conceptual clarity ("what measures what?), confusion about causality ("what leads to what?"), measurement inconsistencies, and the possibility of the negative effects of SC ("what are the consequences of what?") (Patulny & Svendsen, 2007; Portes & Landolt, 1996). To understand why this is the case, it is important to showcase the scope of all potential usages of SC in sociology, political science and economics that undermine the consensus of the scientific community on the conceptualization of the term.

First, the differences in definitions of social capital often represent reflection of ideologies and goals of disciplines that heavily engage this concept in their theories and research (Robison et al. 2002). Disciplines like economics, psychology and sociology represent different schools of thought which results in these differences. For instance, economic definitions of social capital tend to put main emphasis on the capital aspect of the

term and consider SC as one of the kinds of capital along with financial and human capital (Robinson, Schmidt and Siles, 2000). While economists tend to look at SC in terms of gains and losses, psychologist and sociologist consider it primarily in realms of social relationships and interactions.

Therefore, depending on the field where a particular study is being done, the researchers choose the SC definition that suits their goals. The example of the definition that puts more value onto relationships part of SC is Francis Fukuyama's definition where SC is "shared norms or values that promote social cooperation, instantiated in actual social relationships" (Fukuyama, 2002). Sociologist Nan Lin, on the other hand, provides definition that falls strongly in the realm of the potential benefits large SC can produce, "investment in social relations with expected returns in the marketplace," where he is convinced that social connections are exclusively driven by desire to gain something in return as supposed to natural progression of one's social surroundings (2001). In addition to the term's promise for social scientists to explain a range of different outcomes, SC is often misused by policymakers for whom the overarching nature of SC allow them to focus on the economic objectives "while [at the same time] restating the importance of the social" (Halpern, 2005).

Second, the definition of SC and its complexity are determined by its level of analysis. Depending on the focus of the research and whether SC is measured at an individual, group, community, or nation levels, the set of components of SC considered differ. The term has been widely used in the research on a community's' economic development and significantly influenced by the World Bank and its efforts to explain development of a community through the lens of SC (Dasgupta & Serageldin, 2000; Woolcock, & Narayan, 2000; Woolcock, 1998). This approach is based on a conclusion that higher degree of SC leads to more economic development of a community. However, little research has been done to test this inference resulting in a great deal of criticism of the World Bank conclusions by the scientific community (Harriss, 2002; Bebbington et al., 2004). On the other hand, individual-level SC has been widely used in the empirical studies with different populations with little doubt about its measurement. Moreover, some argue that SC

should be measured at the individual level regardless of the level of analysis one is interested in because SC of individuals comprises SC at the group and community levels (Yang, 2007).[1]

Finally, according to Robinson, Schmid and Siles (2002), there is no consensus on the definition because majority of definitions of SC often do not even provide explanations for "what SC is," but rather they answer questions on "where it resides", "what it does," "what social capital can do," and "what SC can be used to accomplish" (Coleman, 1990; Narayan & Pritchett, 1997; Burt, 1992; Putnam, 1993; Woolcock, 1998). Therefore, depending on the discipline and the goal of the research, social capital is often defined not simply by what it is, but rather by its potential outcomes. As community psychologists Perkins, Hughey and Speer (2002) noted:

> The reason SC is ambiguous and controversial is that it has been defined differently to suit different ends, or left undefined. … SC has become to most a vague buzzword, used by different people to mean many different things and thus to mean very little. (2002)

Scientific community's interest in and implementation of the concept of SC in fields like economics, political science, management and psychology demonstrates that SC has a large potential to explain the social phenomena and predict their outcomes. Nevertheless, it faces critical conceptual challenges that have to be addressed to provide reliable definition and measurement of the term. One of the main goals of this paper is to provide a comprehensive review of the literature and draw an informed conclusion on this issue.

Scholarly consensus on Social Capital definition

Form of capital

Nevertheless, consensus still exists on some critical characteristics of SC. First, there is agreement that SC is *capital* similar to any other forms of capital such as economic and human capital. In the relationship to the classical theory of capital, Table 2 demonstrates the distinction of the forms of capital and their difference from capital described in the classic theory.

[1] Section on measurement of social capital provides more detailed description of individual level of analysis and its implications for social capital research overall.

Table 2

Theories of Capital

	The Classical Theory	**The New-Capital Theory**			
		Human Capital	**Cultural Capital**	**Social Capital**	
Theorist	Marx	Schultz, Becker	Bourdieu	Lin, Burt, Marsden, Flap, Coleman	Bourdieu, Coleman, Putnam
Explanation	Social relations: Exploitation by the capitalists (bourgeoisie) of the proletariat	Accumulation of surplus value by laborer	Reproduction of dominant symbols and meanings (values)	Access to and use of resources embedded in social networks	Solidarity and reproduction of group
Capital	A. Part of surplus value between the use value and the exchange value of the commodity. B. Investment in the production and circulation of commodities	Investment in technical skills and knowledge	Internalization or misrecognition of dominant values	Investment in social networks	Investment in mutual recognition and acknowledgment
Level of Analysis	Structural (classes)	Individual	Individual/class	Individual	Group/Individual

According to Lin, the classical theory of capital by Marx has little relevance to the fact that today anybody "can now invest, and thus acquire certain capital of their own (be they skills and knowledge in the case of human capital), they … can now generate surplus values in trading their labor or work in the production and consumption markets" (Lin, 1999, p. 29). In other words, despite inequality in the world, there is no such strict separation between classes anymore, proletariat and bourgeoisie, where the former is being marginalized by the later. In the general sense, social capital is "investment in social relations with expected returns" (Lin, 1999, p. 30). In a more relevant to its measurement view, SC represents "resources embedded in a social structure which are accessed and/or mobilized in purposive actions" (Lin, 2001.)

What distinguishes SC from other forms of capital, according to sociologist James Coleman, is that SC has a twofold nature. A holder of SC is both, a person who "wholly self-

interested" and utilizes SC as any other forms of capital for his or her benefits and a person who is a part of society and whose actions are "governed by social norms, rules, and obligations" (Coleman, 1988).

In relationships with human capital, that entails skills, knowledge and experience of an individual or a group, Coleman argues that SC is part of human capital (Human capital, 2014; Coleman, 1988). In his vision, SC represents social channels through which human capital can be shared with others. He draws his example of SC from family situation when he emphasizes that human capital of parents may not apply to their children if they practice it outside family, such as work and social relationships with other adults. SC in the family situation is *presence* of adults for a child and their *attention*, or in other words, a social tie and strength of that tie in a child network through which information and human capital can be transmitted (p. 112, 1988).

Embedded in relationships

Second, social capital "exists in a social relationship" which means that on the contrary to other forms of capital, SC cannot belong to an entity, neither its benefits can be related to that one entity (Robinson, Schmid & Siles, 2002). SC is dependent on the connection to others and, thus, cannot exist without them. Coleman explains: "Unlike other forms of capital, social capital inheres in the structure of relations between actors and among actors" (p. 98, 1988). He makes an important distinction of SC from other forms of capital in terms of who can possess this form of capital. Coleman argues that in a context of physical and human capital, the person who invests in this capital will gain direct benefit from it. When a person invests in SC, on the other hand, a social structure is created which enables SC to become a shared capital among other people in a person's network (p. 116, 1988). Therefore, even if SC can be measured at individual level, the resources that all people in this network possess become diluted to the social structure or a community where it resides. This distinguishing function of social capital makes it possible to see the resources embedded in the network structure as shared among its members. Therefore, this unique characteristic of SC widens the scope of implications that the SC's quality and size has not only for an individual or a group, but also for all the connections in their networks.

Defining Social Capital

These and other complicating factors have contributed to a lack of consensus on the construct and inspired a response from some scientists to clarify the term of SC. One of the most successful and interactive attempts was a creation of website *Social Capital Research* by the Australian sociologist Tristan Clarige who saw the need to clarify the concept of SC and make it more user-friendly for other researchers (Clarige, 2004). This paper will use some of his classifications of definitions and theoretical differences of SC authors in order to explain which SC definition and theoretical foundation is used in this study. Table 3 provides all definitions of SC and their differences and similarities.

As Table 3 demonstrates, the definitions of SC vary tremendously. In order to focus on what SC is, descriptions of what the potential outcomes and roles of SC are excluded. The objective is to derive from definitions nouns and their describing adjectives and find common themes in these definitions. More emphasis is made on the definitions of authors, such as Burt, Bourdieu, Coleman, Fukuyama and Putman, who are most influential in this topic across disciplines of economics, sociology and psychology: "resources which are linked to possession of a durable network of … relationships", "social obligations" (as 'connections') (Bourdieu, 1996); "the sum of the resources … that accrue … of possessing a durable network" (Bourdieu & Wacquant, 1992); "friends, colleagues, and more general contacts" (Burt, 1992); "opportunities in network" (Burt, 1997); "ability of people to work together" (Fukuyama, 1995); "set of informal values or norms shared among members" (Fukuyama, 1997).

The definitions demonstrate consensus that network connection are essential component of SC of an individual or a group. However, the other component of the SC, potential resources embedded in these connections, will vary depending on characteristics of population being studied, its existential needs or areas it seeks to succeed in.

Forms of Social Capital: Bridging, Bonding and Linking

The themes observed in definitions can be classified into two distinct SC components developed by Putman and widely adopted by most scholars in the last 10 years: social connections and presence of trust and shared norms between those who are connected.

Table 3

Definitions of Social Capital by Bridging and Bonding Types

Authors	Definitions of Social Capital
Bridging (communal/external)	
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) .
Bourdieu & Wacquant	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).
Burt	Friends, colleagues, and more general contacts through whom you receive opportunities to use your financial and human capital' (1992, p. 9).
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).
Portes	'The ability of actors to secure benefits by virtue of membership in social networks or other social structures' (1998, p. 6).
Bonding (linking/internal)	
Brehm Rahn	'The web of cooperative relationships between citizens that facilitate resolution of collective action problems' (1997, p. 999).
Coleman	'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).
Fukuyama	'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).
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).
Putnam	'Features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit' (Putnam 1995, p. 67).
Both Types	
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) .
Woolcock	Information, trust, norms of reciprocity inhering in one's social networks (1998, p. 153)

Further, the connections tend to fall under two categories proposed by Putman: bonding and bridging where former represents connections between people connected by high level of trust and shared norms, while the later represents ties between people that socially tend to not share many things in common or be heterogeneous (Putnam, 2000).

Bonding social connections characterized by shared social norms and strong trust which unite or "bond" people together (Putman, 2000). Bonding SC represents the inward components that is built upon and promotes homogeneity in groups (Burt, 1999; Putman, 2000). According to social networking, these strong network connections (ties) can result in positive and also negative outcomes as strong ties can potentially encourage either "bounded solidarity" and "enforceable trust" or exclusiveness and domination of some members of a group or network over the other (Putnam, 2000; Portes & Landolt, 1996; Portes, 1998, p. 10).

Bridging SC represents weak social ties between individuals. These ties represent the rest of network of an individual's social connections that are not defined by such strong ties that people would have with their families and close friends. Rather they represent connections with people whom an individual may or may not have strong connections with. Bridging ties tend to be between people who historically would not have a significant amount of interactions or shared values. For instance, these could be scientists representing different disciplines, people from different occupations or people with different socioeconomic backgrounds. In other words, bridging ties tend to bridge people who are heterogeneous in nature (Putnam, 2000).

Coleman independently describes three forms of SC that mirror Putnam's classification. First one is "obligations, expectations, and trustworthiness of structures" without these three gluing components of SC, he argues, a group or an organization would not be able to exist. Second form of Coleman's SC is "information channels" or social networks that allow for exchange of information between individuals and groups and represent bridging and bonding connections. Finally, there is SC of "norms and effective sanctions" which create a safe environment for social interactions (Coleman, 1988).

Some other scholars, especially in health-related fields, consider social capital consisting of three, not two, distinct types: bonding, bridging and *linking* (Stone, 2003;

Poortinga, 2012). This classification is adopted by the Office of National Statistics and the Organization for Economic Cooperation and Development (OECD): "Bonds: Links to people based on a sense of common identity ("people like us") – such as family, close friends and people who share our culture or ethnicity. Bridges: Links that stretch beyond a shared sense of identity, for example to distant friends, colleagues and associates. Linkages: Links to people or groups further up or lower down the social ladder." (Office of National Statistics; Keely, 2007). The classification seems to be more precise at first, however, the new third linking connections tend to always be part of either bonding or bridging connections and separating it from them is not necessary. One can have a bridging tie with a coworker who is higher at the organizational ladder which represents a linking tie. Linking connections, thus, is not going to be used in this study explicitly as they are embedded in other two types of connections.

Connecting Mechanism: Trust, Norms, Values and Attitudes

Individuals cannot have connections if there is nothing that connects them together. That is why many definitions, especially, those that describe bonding connections, are accompanied by notions of trust, norms and values (Putnam, 1995). Since SC is embedded in social relationships, trust and common value system are critical for the connections between people to grow, multiply and strengthen. Trust, in particular, plays a special role in human connections:

> A society that relies on generalized reciprocity is more efficient than a distrustful society, for the same reason that money is more efficient then barter. Trust lubricates social life. (Putnam, 1993, p.3)

It is hard, however, to locate trust in relationship to social capital. According to Fu, trust can be both at the same time: precondition of social capital and a product of social capital (Fu, 2004).

While it is hard to identify what comes first, trust or shared values, individuals should share norms and values that favorably view mutual reciprocity and cooperation. Some authors also characterized it as solidarity (Fu, 2004). Due to professional nature of social capital used in this study, the focus will be mainly on the shared norms and values about

collaboration and working with different kinds of professionals. Trust is assumed to be imbedded in these shared norms and values. Thus, this psycho-social dimension of social capital should be addressed in any comprehensive assessment. For the purpose of this study and clarity of the concept, below is a diagram that summarizes the main two components of SC: actual network connections and connecting mechanism that make these connections thrive.

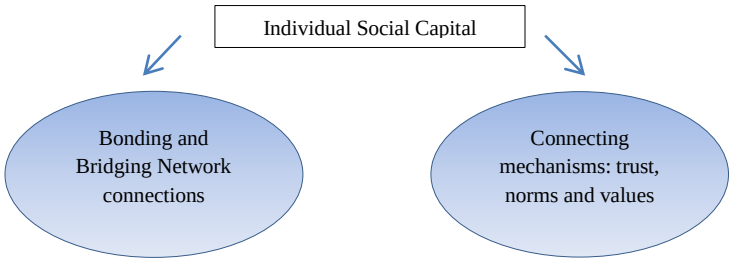

Figure 2. Components of Social Capital.

Measuring Social Capital

Measuring Social Capital connections

The most common way to measure connections between individuals is social network analysis (SNA), method pioneered and developed by sociologists. This technique is used to measure the connections of students, bonding and bridging, as a part of their social capital. SNA looks at social networks and provides specific characteristics of these networks where people in a network are called *nodes* or *actors* and their connections are *ties*, *links* or *edges* (Wasserman & Faust, 1994).

This study focuses on ego-centric networks of students with two types of nodes: *ego* (students) and *alters* (people that students are connected to). Ego represents a center of a personal network while there is no such central point in whole networks Ego-centric networks limit their scope differently depending on how many connections they want to

capture and the ways they are measured (Marsden, 1990). The examples are online social networks sites like Facebook and Myspace (Ellison, 2007).

In the realm of SNA, social capital of the students is seen through three main dimensions: *alters* or individuals whose social capital is being measured; *resources* they need to obtain their specific goals and the *ways* they can obtain those resources (Flap, 2002; Lin, 2001a; Van der Gaag, 2004). In the context of this study: *alters* are S&T PhD students; *ways* are relationship or connection to professionals who have a significant impact on students' training such as advisors, researchers and industry representatives and who have *resources* or opportunities that help students to become an expert in a particular research area.

Measuring Trust, Norms and Values

While most aspects of SC are measured directly via SNA, trust, norms and values represent psycho-social dimensions of SC. Therefore, one must take a different tact for these constructs. Like other psychosocial variables, trust, norms and values are typically measured via self-report questionnaires using a scale of items with Likert-type response options (Goddard, 2003; Onyx & Bullen, 2000). The study will measure attitudes towards mutual reciprocity and cooperation with other professionals (norms and values). The items will contain some known negative sides of collaborations in order to reflect the typical ways in which collaborative processes happen in real world. The five response choices will range from *strongly agree* to *strongly disagree.*

Scientific & Technical Human Capital Literature

The previous section demonstrated that SC is defined and measured differently depending on the population, the level of analysis, the research questions and discipline. This section provides definition and measurement of SC specific to S&E innovation process as this is the framework of analysis for the population of the S&E graduate students. Quantifiable measurements of patents and innovations enclosed tend to be traditional ways to evaluate outcomes of scientific process (Bozeman et. al. 2001). However, these measures do not take into account other outcomes of scientific process such as scientists' networks acquired in the process which they can draw upon in their future research initiatives the

research process that is taking place behind these achievements accounts for many years of scientists' work before a discovery of something new happens.

Barry Bozeman is a prominent scholar in the area of evaluation of the national S&T policies. His works shift the evaluation focus from economics-inspired *cost and benefits* approach that looks at the pure outcomes such as patents and innovations disclosures to the social processes of doing science such as collaborations and scientists' social networks and connections. He argues that it is impossible to understand the effectiveness of S&T policies without understanding the relationships within scientific community because "scientists [brains of science] do not exist in social vacuum" and, thus, do not produce science alone (Bozeman, Dietz & Gaughan, 2001). In other words, Bozeman's approach focus on the human side of innovation and the role of institutions, universities and businesses, in restraining or promoting it. He calls his model of evaluation the Scientific and Technological Human Capital (STHC) and defines it as:

> S&T human capital encompasses not only the individual human capital endowments normally included in such models, but also the sum total of researchers' tacit knowledge, craft knowledge, and know - how.

Even though it is named as human capital, the author emphasizes the social capital as part of the total human capital of the researchers following the footsteps of Coleman who defined social capital as a part of human capital (Coleman, 1990):

> 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)

The STHC was formed in the late 1990s, but has already inspired numerous works on evaluating social aspect of doing science (Turpin et.al., 2010; Patterson, 2005). Globalization and development of communication technologies had a particular impact on popularity of this approach as in many parts of the world it became evident that science was increasingly

affected by scientists' collaborations and networks beyond national boundaries. The work of Tim Turpin, Richard Woolley and Jane Marceau reflects that researchers simply cannot exclude scientists' networks in Australia and China while studying Australia's S&T policy because scientists in these two counties consistently work together and exchange their knowledge (Turpin et al., 2010).

In addition to studies of collaborations of scientists from different nations, studies on migration of high skilled labor and diaspora knowledge networks benefit from the STHC approach (Patterson, 2005). For instance, one study on different diaspora in the US found that diaspora with meaningful connections to home country, such as Asians, result in positive benefits for home countries or having "brain circulation" between the home and host counties. On the other hand, high skilled diaspora from Sub-Sahara Africa tend to not have strong connections to their homeland which results in losing human capital for those countries or having a "brain drain" (Patterson, 2005).[2]

Moreover, this approach for the national evaluation of scientific outcomes is found to be relevant to the evaluation of scientific outcomes of a nation independently from the trend that Bozeman authored. French researcher Dr. Meyer refers to the Human Resources in Science and Technology (HRST) and takes the same line of argument as Bozeman while making it clear that SC as part of STHC has been ignored because of the complexity inherited in its evaluation due to high mobility and diverse communication of scientists (Meyer, 2001). He argues that evaluation of scientists' networks, within and across the national boarders, makes it possible to identify how science happens from the social perspectives:

> By emphasizing relational and network logistics, the above-mentioned recent approaches break with conventional explanations of human capital. These approaches indeed present individuals as being involved in knowledge-intensive activities, deeply

[2] The idea about diaspora and knowledge networks was inspired by Xiao Si Niu's dissertation-in-progress "Dispersed Knowledge Networks and their Implications for National Innovation Systems: An Investigation of Australia and China's Scientific Relationships." My head of committee, Dr. Denis Gray, is serving on Mr. Niu's advisory committee.

> rooted in their networks, with their own skills being historically and physically contextualized. (p. 96)

Finally, even back in 1991, Michel Callon talked about importance of social networks of different "actors" in the process of S&T innovations and proposed social network approach to measure interactions of different actors which he calls techno-economic network (TEN):

> Technology rarely flows in a predictable and unilinear manner within a relatively stable social and industrial context (Foray, 1989). Models which assume this cannot explain its radical, and sometimes revolutionary, character. 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)

Thus, STHC approach seems to be widely accepted in the literature on high skilled labor of the S&T development of nations. This approach opens up an opportunity for evaluating national S&T policies in the context of the actual process of doing science that does not happen in vacuum and involves intense knowledge exchange within networks of scientists. It also allows studying complex issues such as the impacts of migration and immigration of high skilled labor for the home and host counties. Finally, the STHC approach helps to define institutional environment or national policy that may enhance the growth of SC of scientists, as part of their human capital, by providing infrastructure for development and maintenance of social networks that are necessary for knowledge exchange. This paper uses this approach as the main theoretical framework for evaluating SC of the S&E graduate students in the U.S. research intense universities.

Particularly, this study looks at graduate students in S&E disciplines at the U.S. research-intensive universities. The goal of the study is to find out if professional social capital of students differs depending on whether they are trained in a traditional more dyadic mode or within a center. As the literature on S&E students demonstrates, however, students' experiences during their graduate training vary significantly. Even students involved in center-based training get a different dosage of center-like experiences such as working in teams and with professionals from other disciplines and institutions. Moreover, this variation

is present not only among CRCs' students, but also among students who are receiving their graduate training in more traditional settings where students are receiving their training mainly within boundaries of their department and main supervisor. The traditional students can also be exposed to experiences of working with different kinds of professionals and in teams. For instance, their advisor can do research for a company or their department may be working closely with a research hub on campus. Therefore, the next central assumption is that students who are exposed to more center-like experiences of working in teams and other professionals receive more social capital.

Empirical Social Capital Literature

Individual Social Capital and its Measurement in the Literature

This section provides a summary of findings from the studies that use SC as one of its main variables. The detailed description of all studies is included in Appendix B. The studies are summarized according to the role SC plays in their research design: whether researchers look at SC from purely descriptive approach, SC is used as a predictor (IV) of other variables, or SC as an outcome (DV):

SC = Predictor → SC Described → SC = Outcome

The first search criterion was the focus on individual level of analysis, or SC of individuals and their personal networks. The following key words and their combinations were used to find relevant empirical literature through the Google Scholar and the Triangle Research Libraries Network comprised of four large universities[3]: *social capital, individual social capital, graduate students, scholars, scientists, science and technologies, STEM (science, technology, engineering and math), social/knowledge/professional networks, lose ties, weak ties, scientific and technological human capital, bonding/bridging social capital, collaborations, and university-industry collaborations.* The studies were also classified into two groups based on their area of interest: SC and its relationship with health and SC in the context of financial stability. There are studies that look at the other variables associated

[3] The four universities of the Triangle Research Libraries Network are: North Carolina State University, University of North Carolina at Chapel Hill, Duke University, and North Carolina Central University.

Table 4

Empirical Studies of Social Capital

Author(s)'s Name	Population	Measuring SC	Analysis	Results
Fornoni, Arribas & Vila (2010) Descriptive	Entrepreneurs in Argentina 2000-2005; stratified sample of 300 start-ups from SME database of Sepyme	N/A	Goodness-of-fit statistics; chi-square; to test hypothesis - matrix Φ (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 from different & dispersed areas (rural and urban) over 18 y. o.	IV: HC - the New Russian Barometer Survey: 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, Chomsisengph et & Liu (2001) IV for personal bankruptcy	Loan=level panet 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 ia 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
Gelissen (2012) DV – effect of welfare state	Eurobarometer 62.2 survey in 2004 of 27 the EU states; sample N = 25,467	DV: SC as access to help outside family network	Path analysis; multi-level modeling techniques; ordinal logistic and ordinary least squares regression in multi-level models	Positive effect of welfare state on resources, attitudes and behavior of individuals that are conducive to their SC
Ynalvez & Shrum (2008) DV – Internet access & utilization and grad. training	Iinterviews 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-ration)	Half of alters are in the same location; scientists with more access to internet have more alters; graduates from the US

with SC, such as the state political system and its influences on SC (Gelissen, 2012), but majority falls under these two categories (Table 4). The studies are reviewed by the way they define and measure social capital and to what extent they incorporate existing knowledge about the construct from the literature.

Bridging and Bonding Distinction in the Literature

It is important to note that studies reviewed in Appendix B use bonding and bridging distinction in different ways. In terms of SNA measurement of SC, bonding and bridging are ties and the section above describes the distinction between two. At the same time, bonding SC in theoretical and empirical literature on SC represents not only connections but also actual bonding mechanism behind them – trust, norms and values. Thus, it is important to keep in mind this distinction in order to avoid confusion.

Even though there is little consensus in the literature on definition of SC, many empirical studies used the bridging-bonding measures of SC in their research (Patulny & Svendsen, 2007; Lancee, 2010; Newell, Tansley & Huang, 2004; Ellison, Steinfield & Lampe, 2007; De Carolis & Saparito, 2006; Larsen et al. 2004). Nevertheless, studies with most reliable methodologies advise that both types of capital should be measured in order for a study to be valid. If one type of SC is more relevant to research objectives or population one can put more emphasis on one of two types, but both types should be captured for a measure to be valid. Patulny and Svendsen state that both components of SC should be measured and that there are still some empirical studies that focus only on one and, thus, jeopardize the reliability of their research (2007). The following are examples of empirical studies on SC with different populations that demonstrate the different levels of emphasis on one type of SC over another.

In the study of immigrants in the Netherlands, bridging SC networks are positively associated with economic impacts such as likelihood of employment and higher income while bonding ties with close friends and family have no impact on these economic outcomes (Lancee, 2010). This and other studies of SC and immigrant population demonstrate that SC and its components play an important role in the immigrant population adaptation and future in the host country.

The study on the performance of the project teams in the work settings shows that two components of SC, bridging and bonding, were positively associated with an effective performance of a team (Newell, Tansley & Huang, 2004). The researchers implemented qualitative methodology to find that bridging capital of the project team's members depended on its members' trust and basic norms, or bonding capital, that made it possible for their network connections to form and develop.

SC is also used in the studies of civil engagement. The study of Larsen at al. finds a strong positive relationship between bonding SC and civil activities people participate (2004). Again, the authors make a distinction between bonding and bridging capital and their implications for civil actions.

The prevalence of bridging SC was found in studying social networks such as Facebook (Ellison, Steinfield & Lampe, 2007). Social networks such as Facebook seem to represent an effective tool for increasing an individual's number of connections and exposures to people who they would not meet otherwise. In other words, these social sites represent people's bridging capital that does not require high level of involvement with its network members.

In summary, the selection of bridging, bonding and mix type of SC in the empirical literature seem to depend on the population and settings being studies. Depending on the settings, for instance, professional or personal, one type of SC may be more important than other. For studying entrepreneurs, bridging capital may be of more relevance as it looks at numerous connections that do not have to be characterized by a particular strength level (De Carolis & Saparito, 2006). Bonding networks of strong and exclusive ties that largely depend on trust and common norms, however, are being more relevant in studying family networks.

Summary

The studies that measure social capital demonstrate that empirical social capital literature does not adequately address probably the biggest issue related to research with SC – the conceptual strength of SC and its measurement. Most demonstrate reviewed here demonstrate that authors typically chose definition of SC from one theoretical scholar and design the measurement and the following analysis based on that single interpretation which

has shown to vary greatly from author to author. However, as theoretical literature section demonstrates, the different authors on SC often propose different theories which should be matched together in order for the concept to be valid in terms of theoretical and practical experiences provided in the literature. Based on the comprehensive review of the studies that measure the concept of social capital, out of the eight studies reviewed, only one study of the Philippines's scientists represents comprehensive understanding of the literature.

Also, the measurement of SC varies greatly between the studies. Even though SC measurement can be tailored to measure *specific* SC, such as SC of entrepreneurs or SC related to health or financial stability of individuals, the measurements completely lack the common direction and fundamental base varying from simple indicators of marital status, age and location to more specific indicators of SC such as networks derived from name and position generator techniques. This lack of consistency in measurement makes the valuable contributions to the literature impossible as majority of studies focus on the impact of SC on something else. It is not fundamentally sound to claim the particular relationships between variables if the predictive variable has low reliability in the first place. Therefore, one of the main goals of the current study is to provide measurement of SC that is methodologically valid and reliable and, thus, can be used in other studies that measure SC of similar population in a similar context.

Empirical S&E Students' Literature

This section of the paper provides a summary of the students' experiences at CRC and I/UCRC. Appendix C includes a detailed description of all the studies on students in the CRC and I/UCRC in the US and abroad. This section emphasizes experiences that are unique for students who are trained in the centers in comparison with students at the departments. It also seeks to identify any information on students' professional social capital and whether center-like experiences have any effect on it.

S&T doctoral students in I-U links

The big component of the I/UCRC is the collaborations and communication of industry and academia (I-U links) which is believed to be a significant differencing factor of students at the I/UCRC and those in traditional academic department. While literature likes to

focus more on how I-U cooperation influences faculty's career growth and satisfies industry needs, it also provides a distinct review of I-U links on S&T graduate students. There are different ways students are involved in these I-U links: grants, contracts or cooperative research centers (CRC). The last type of involvement is in the primary focus of this study as CRCs represent an environment where researchers from different sectors are working together to solve the scientific problems without many limitations to their collaborative behavior.

I-U cooperation has more implications for students' experiences than just exposure to industry. This type of collaborations open doors to other collaborations as industry provides additional financial help and a more goal-oriented approach which enables other type of collaborations. Thus, students at the CRCs are known to have more opportunities to work not only with industry, but also with professionals across disciplines, institutions and countries borders. And, according to STHC model proposed by Bozeman, however, this collaborative component of doing science is often ignored in the literature and by policy makers (Bozeman, Dietz, & Gaughan, 2001). Therefore, this literature review tries to establish whether studies on CRC students have addressed the issue of professional social capital or STHC and experiences that may influence it.

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

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

Since there are so many variables associated with students in the I-U links, there is a need to organize them and show how they are related to each other. This paper will follow a template of the literature review presented by Thune who summarized 20 studies on doctorate students in the I-U links (Thune, 2009). It is important to note however, that she included students from all types of the I-U links while this study investigates only students at the CRCs.

The studies reviewed by Thune were conducted in the US, Canada, Australia, France and Spain. She groups the variables that are used in the studies into the following categories: 1. *Preconditions* which include characteristics of students; 2. *Interaction* of students during their university training with industry; 3. *Outcomes* of these interactions. Variables under preconditions group describe students' individual characteristics such as their demographics, academic background and skills associated with their discipline. Variables of interaction group are: *organizational arrangement* (settings in which students are trained, for instance, cooperative research center such as I/UCRC), *supervision and mentoring arrangement* (university and/or industry personnel who supervise a student) and *negotiation of differences* (mechanisms that help to resolve given differences and needs of different stakeholders). Finally, outcomes of the students' I-U involvement represent students' *satisfaction* with their graduate training, educational *benefits* for students and other stakeholders (industry *recruitment* and students' professional prospects after graduation), and students' *career ambitions and trajectories*. This literature review of the CRC's students uses this classification to help to organize the multiple variables associated with S&T graduate students.

Preconditions

Soft Skills in Hard Sciences

Social capital of graduate students requires mechanisms which enable students to communicate successfully and share their knowledge with people of different disciplines and background. Such mechanisms represent opportunities to visit and present at the conferences,

have access to expertise of other professionals, and institutional structure that allows to work in teams when it is appropriate for a particular research objective. Federal and industrial grants and contracts along with I-U cooperative centers provide these opportunities. However, students should have appropriate skills to use these opportunities effectively which can be characterized as 'soft skills' and include the following skills for undergraduate students: experiences, team skills, communication skills, leadership skills, decision making/problem solving skills, and professionalism skills (Crawford, Lang, Fink, Dalton & Fielitz, 2011). Graduate students have higher requirements for soft skills whether they pursue academic or non-academic career as they often compete for higher level positions where being able to communicate successfully is a very important requirement The list of the skills they need to be competent in, according to Tri-Council and the UK Research Council's Training Requirement for Research Students, includes: communication and interpersonal skills, critical and creative thinking, personal effectiveness, integrity and ethical conduct, teaching competence, societal and civic responsibilities, leadership, research management, knowledge mobilization and knowledge translation and career management (Polziehn, 2011). Some studies suggest that students in engineering and sciences, particularly, lack these skills in their curriculum (Mohan, 2010).

Besides the characteristics of the training in "hard sciences" and their culture, some researchers take a different approach to demonstrate that "soft skill" are indeed missing component of the S&T graduate preparation. This research gathers feedback from S&T industrial sector employers and supervisors interviews in multiple studies on how they evaluate newly graduates in S&T as their employees (Tong, 2003; DeLange, 1996; Katz, 1993).

With the economic crises in 2008, the question of employable skills has particularly become important. There are arguments that in the new age of information era, the most employable skills are technical skills such as skills in computer science. However, sources that focus on general employability of the workforce such as Manpower Group, demonstrate that the 'soft skills' are the most required and often missing for positions with and without technical proficiency (Manpower Group, 2012). Basic spelling and proper grammar in

communication often is a reason an employee does not want to hire an individual. Moreover, the younger group of employees tends to score significantly lower than the older population on these basic skills.

This literature shows that demand for soft skills is important in most sectors of employment. Even though individuals with technical training especially on higher levels as doctorate students have competitive advantage in the information era of today, the high demands of globalization and interconnectedness require also high competencies in soft skills. Since social capital and networks are heavily dependent on individuals' soft skills, their lack in students' preparation is an important characteristic of the S&T doctoral students' training.

International Students

The number of international students is constantly growing in the world and in the U.S. universities in particular. S&E degrees have the highest popularity among international students and the U.S., as the leading country in the world with highest number of S&E doctorates earned, has the educational infrastructure to offer students all the necessary conditions for reaching their educational goals (NSB, 2012). There was a 64% growth in S&E doctoral degrees earned by foreign students in the U.S. from 2002 to 2008. The rate stayed constant in 2009 counting 13,400 S&E doctorate degrees earned by international students.

S&E disciplines are in highest demand among foreign graduate students, but third of undergraduates also chose them. In 2010, 32% of undergraduate international students earn their bachelors in S&E fields while the percentage of the S&E graduate degrees accounts for 60% (NSB, 2012). Most S&E graduate degrees earned by the foreign students are in computer sciences and engineering and students from India and China account for nearly two thirds of the total S&E doctorate degrees.

Finally, the numbers of the doctorate degrees earned in the U.S. by international students are higher in some areas than the doctorate degrees earned by the American students: "Foreign students earned 57% of all engineering doctorates, 54% of all computer science degrees, and 51% of physics doctoral degrees. Their overall share of S&E degrees

was one-third" (NSB, 2012). These numbers indicate that research on the young professionals in the fields of S&E, in a relationship to the larger topic of the R&D of the nation, must include international students as a distinct group the special characteristics of which should be taken into consideration in order to provide an accurate description of graduate training in the U.S.

Gender Differences

The lower numbers of women than men in STEM degrees is one of the hot topics in the current educational literature. There are multiple programs at the different levels of education that promote S&E degrees to girls and women and help them to manage professional and domestic obligations in order to pursue careers in hard sciences. However, even though women enrollment is significantly lower in the fields like engineering, computer sciences, physical sciences, and economics, almost half of the 611,600 of S&E graduate students in 2009 were women (NSB, 2012). Numbers like this and research on gender's preferences as determinants of who pursue what degrees make this topic a controversial one.

Some studies included on S&E students collaborating with industry provide useful insights on this topic. For instance, Schneider's study on the I/UCRC perceptions and satisfaction showed gender differences in relationship of their satisfaction level and the extent to which students had "hands-on" or "experiential" experiences during their training (Schneider, 2007). The exploratory analysis of the moderation of students' satisfaction indicate that men were more satisfied with their training when they had an opportunity to conduct research that involved "hands-on" experience while women had pretty high level of satisfaction no matter if they did or did not had the experiential component in their graduate training.

With more women entering STEM fields there is a need to know more about the gender related differences. Even though this study does not focus primarily on gender differences in STEM disciplines at the graduate level of education, it seeks to provide additional information to inform future policies.

Interaction and Outcomes

I-U Centers in the U.S.

In addition to different ways students are funded by the industry, depending on the type of the industry involvement, students' interaction with industry and collaborative experiences are different. The centers in the U.S. covered in the literature review are part of some NSF programs: I/UCRC and Engineering Research Centers (ERC). Study on students from Norway includes students being involved with industry in both, structures (CRC) and unstructured (faculty contracts) ways. Studies summarized below provide information on students' general experiences (interaction) and outcomes of their training with the goal to establish how much is known about students' professional social capital and what processes may influence it.

Summary

Empirical studies included in Appendix C about CRC and I/UCRC students in the US and abroad demonstrate that there is a growing interest in evaluating students' outcomes from I-U cooperation and identifying strengths and weaknesses of this approach to graduate training in comparison to the traditional approach.

One thing is clear is that within I-U links students' interactions with other professionals are very diverse. Literature shows that students receive industry funding in different ways and at different levels (I-U cooperatives or single-company funding; partial or full funding), have different frequency and depth of interaction with industry (often due to discipline or nature of the project), and experience different levels of multidisciplinary participation in their research.

Most students rate their I-U experiences as very satisfactory and appreciate industry funding not only simply as financial help but also as a mechanism that helps them to finish their programs on time and to understand better "real-world" problems that are often challenged by traditional academic settings and their high requirements. Moreover, there was no evidence found about negative effects of industry involvement on the students' outcomes including academic freedom. Therefore, industry seems to be a growing and constantly

present in S&E academic fields due to its positive effects on students and financial support of academia.

Nevertheless, although some studies looked at what could be termed SC-proxies, there were no studies found that looked at the graduate students' professional SC. The studies reviewed were focused on some aspects of it such as students' relationships with their mentors, connections to industry and general interactions of students during their training. This study tried to fill in this gap by summing up the human interactions that students have access to during their graduate training and providing a complete picture of the professional SC and networks that students are equipped with when they enter S&E work force either in industry or academia.

METHOD

Main Hypotheses and Research Questions

Graduate students are the future scientists that drive innovation and promote development in many aspects of life. They all receive highly valuable training which comprises their human capital. However, science as a whole has become more complex in that collaborations with other scientists and other sectors are inevitable. According to the Scientific & Technological Human Capital theory, science does not happen in vacuum and a significant part of the students' training is professional social capital that they carry onto their professional careers (Bozeman, Dietz & Gaughan, 2001).

More importantly, Bozeman emphasizes that experiences that are often observed in CRCs, such as working with teams and professionals from other disciplines and sectors, increases professional social capital of scientists. However, it is important to note that some of the social processes that used to be unique to CRCs, like working in teams, have diffused into non-center training arrangements so one must be prepared to assess the processes that happen in a student's training as well as the structural arrangement. Based on existing research, little is known about these relationships and effects. Given this background, the study will address the following hypotheses (which are based on existing research or theory) and questions (for which there is insufficient research to propose a hypothesis).

H1: Center students will acquire more of the following professional social capital outcomes than students trained in traditional settings:

1-a: Size of available professional social network.

1-b: Strength of professional social network connections as measures by availability of technical advice and input.

1-c: Strength of professional social network connections as measures by availability of introduction to an unknown professional(s).

1-d: The Norms and Values.

1-e: The number of LinkedIn connections.

Q1: To what extent does immigration status have an impact on or moderate the relationships between type of the graduate training and various professional social capital outcomes?

There are multiple variables that can indicate to what extent students are prepared to face the professional challenges upon their graduate school. This study does not measure in detail these variables, but it seeks to identify the perceived career preparedness of students. Thus, the following hypothesis and questions are being made:

H2: Center students will have a higher level of the perceived Career Preparedness than students trained in traditional settings.

Q2: To what extent does immigration status affect and/or moderate the relationships between type of the graduate training and the perceived Career Preparedness?

Since past research (Scott, Schaad & Brock, 1993) has reported that students trained in CRCs have viewing their graduate experience more positively than students trained in traditional arrangements and little is known about the mechanisms that produce these differences, I will test the following hypothesis:

H3: Center students will have a higher level of Satisfaction with their graduate training than students trained in traditional settings.

Q3: To what extent does immigration status affect and/or moderate the relationships between type of the graduate training and Satisfaction with graduate training?

Research on the I/UCRC centers shows that center students are involved with their centers at the different levels. Thus, it is important to see whether different level of involvement, or center dosage, results in different social capital and other outcomes. The following hypotheses focus specifically on center students and how their dosage of center involvement predicts the study outcomes.

H4: After controlling for the demographic covariates, center students with a higher dosage of center involvement will acquire more of the following professional social capital outcomes:

4-a: Size of available professional social network.

4-b: Strength of professional social network connections as measured by availability of technical advice and input.

4-c: Strength of professional social network connections as measured by availability of introduction to an unknown professional(s).

4-d: The Norms and Values.

4-e: The number of LinkedIn connections.

H5: After controlling for demographic covariates, center students with a higher dosage of the center's involvement will have higher level of the perceived Career Preparedness than students trained in traditional settings.

H6: After controlling for the demographic covariates, center students with a higher dosage of the center's involvement will have higher level of Satisfaction with graduate training than students trained in traditional settings.

It is hard to draw a clear line between degree to which graduate students are exposed to collaborative research whether they are affiliated with centers or not. Therefore, it is important to see whether outcomes of this study are predicted by the level of experiential, multidisciplinary, team-based, and industry experiences regardless of which group a student belongs to.

H7: After controlling for demographic covariates, students who have more collaborative, multidisciplinary and cross-sector experiences will acquire more of the following professional social capital outcomes:

7-a: Size of available professional social network.

7-b: Strength of professional social network connections as measures by availability of technical advice and input.

7-c: Strength of professional social network connections as measures by availability of introduction to an unknown professional(s).

7-d: The Norms and Values.

7-e: The number of LinkedIn connections.

H8: After controlling for demographic covariates, students who have more multidisciplinary, cross-sector and experiential experiences will have a higher level of the perceived Career Preparedness.

H9: After controlling for demographic covariates, students who have more multidisciplinary, cross-sector and experiential experiences will have a higher level of Satisfaction with their graduate training.

International students accounted for 66% of population and sample. However, in contrast to most US students, they face an important decision upon their graduation: to come back to their home country or to stay in the US, the country that they have been living most part of their adult life. Their decisions are not only personal; they also change the US demographics and the buildup of the US scientific human capital. Thus, the following questions are designed to find out whether international students' intentions on what to do after finishing graduate school differ by the type of training they receive in graduate school.

Q4: Does the type of graduate training predict international students' intentions to live and work in the U.S. after their graduation?

Q5: Does the type of graduate training predict international students' intentions to become a U.S. citizen?

Population and Sample

The population for the study was graduate students in S&T in the US intensive research universities. Two sub-groups were of interest: students who are affiliated with centers and students who have the most traditional training. Since I/UCRC is one type of CRC, I/UCRC students are selected to represent experimental group. The middle group,

students who have a mixture of the two arrangements or a different kind of arrangement such as working directly with industry, is left out from the focus of this study in order to limit the scope of the analyses to realistic proportions.

The author belonged to the I/UCRC evaluation team and has professional relationships with the NSF I/UCRC program directors and I/UCRC university sites directors. At the same time, control group represent students who are not connected to the author in any possible way which makes it challenging to even identify who they are. Thus, the first step of data collection was to identify I/UCRC students from whom to collect data that will set a direction to the rest of the sample procedures. Particularly, sample data collection consisted of four steps: (1) identify contact information (email) of the center (I/UCRC) students; (2) collect data from center students; (3) try to find a matching control sample of students who are not affiliated with any research center on campus; (4) collect data from control sample students.

Before the sample was collected, power analysis (G*Power software) was used to identify the adequate sample size. A priori power analyses of MANOVA special effects and interactions were chosen to perform this task as the study has multiple IVs, multiple DVs, and some variation within groups. The results indicate that I need total of 190 participants to have 90% power for detecting a small size effect when employing the traditional .05 criterion of statistical significance (See Appendix A). The goal of this study, thus, is to contact at least 100 students in each of two groups which make the total sample 200. The detailed description of the sampling and survey procedures are identified in the next section.

Procedures

Center 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.[4] 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 5 provides responses to the questionnaire, amount of missing data and responses that did not qualified for the study and, thus, were excluded from the analysis. A total of 612 center students out of 1,019 started the survey. Five respondents did not agree to consent form and 23 dropped after agreeing to consent form .Three questions were designed to select students for the study. The question 2 identified 11 undergraduate, 18 postdocs, 23 alumni and 4 other students who did not qualify due academic status. The question 4 identified 61 students who did not consider themselves affiliated with I/UCRC (responded "No") and were excluded from analysis. The question 29 identified 11 students who spent only 1-3 months in graduate school and also were excluded. The total 233 fully completed and qualified responses belong to 176 students pursuing PhD, 19 pursuing only Masters' and 38 Masters' students who were planning on to finish with PhD.

Table 5

Response Rate

Response Categories	Center	Non-Center
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
Final PhD	176	87

[4] The data on the total number of the graduate I/UCRC students is taken from the 2012-2013 I/UCRC Structural Report. Since the centers' structural information is not monitored to the small detailed level, the total number of the graduate students is an approximate, not precise.

Non-center Students

Creating the comparison, non-center students, group included the following steps. First, an attempt was made to match the sample to graduate standing (PhD and Masters only), discipline (department) and university. Descriptive information was used to find out which disciplines and universities were the most represented in the responses from center students.

Control students' contacts were taken from the websites of the most frequent universities center students belong to. Web sites f universities' departments were checked on the available information about their current graduate students email addresses. The author tried to match it to the experimental group as close as possible, however, not all the universities and disciplines had their students' emails available. Therefore, the author had to give preference to the universities whose website listed graduate students' information rather to the universities and disciplines that help to match the sample to center students. When the information about the students was available, students' emails were either copied by hand or collected using python coding language in free I-Python Notebook software.

It was harder to identify non-center students than center students. Control students were asked this screening question "Choose the answer that best describes the research project you are engaged in to satisfy your degree requirement" (Appendix H, Q4). Only students who chose one of the following answers were included as control group: (1) My Master's/PhD research project is an individual project that is being supervised by my main academic advisor(s) and thesis/dissertation committee; 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 thesis/dissertation committee.

The survey was sent to the total of 1,399 from the following universities and their corresponding departments: Arizona State University's computer science (N = 26); CAL Tech's computer science (N = 49); NC State's computer science (N = 685) and material science and engineering (N = 146); Ohio State University computer science and engineering (N = 193); Purdue electrical and computer science (N = 178) and material science (N = 66); and Virginia Commonwealth University's mechanical engineering (N = 56, the only university that does not have an I/UCRC) (Table X, Response Rate). Total of 398 started the

survey out of which 21 one did not qualified due to academic standing, 5 did not agree to consent and 24 dropped after few questions. In the remaining 348, 194 did not qualified as a control group either because they chose response 3 (N = 17), 4 (N = 169) or 5 (N = 8). In addition, 53 missing responses and 6 responses that identified only 1-3 months in graduate school were eliminated. The final number of the control sample was 95 (PhD = 87, MS = 3 and 5 MS students who were planning to continue to PhD).

Final Sample and Outliers

PhD students are the largest category of students working at the I/UCRC that account for 50% of the total population. In the sample of the center students, PhDs account for 76%, however, majority (92%) of the control group sample are PhDs. Thus, the study will focus only on the PhD students in both groups: experimental (N = 176) and control (N = 87). The data for both groups were checked for any outliers that may affect the analysis. Three responses that belong to center group were deleted. Two were extreme outliers for the Norms & Values scale scoring extremely low on all 8 questions (Appendix H, Q13). They were also outliers on other questions about the centers. Another outlier was a 78 y. o. man. Thus, the final center group sample had 173 responses.

Instrument and Measures

Data were collected via a web-based questionnaire. Appendix H contains the questionnaire and notes on which variables were modified or replaced for the appropriate group of respondents. The survey went through multiple revisions. The detailed components of the survey were presented to the I/UCRC evaluators and NSF directors during the annual program meeting. Feedback was gathered from these professionals some of whom have been part of the program for more than 20 years. Some evaluators were asked for additional feedback as they have done studies on center students in the past like Craig Scott. In the final drafting of the questionnaire, four researchers were asked to provide a more detailed feedback on the survey components, especially, on the scale items. These were Dr. Denis Gray, Dr. Lindsey McGowen, Dr. Drew Rivers, and Tim Michaelis. They all are or were part of the I/UCRC evaluation project and also are very familiar with the goals of this study. Thus, feedback from these professionals helped to insure validity of this study's measures.

The survey contained the same questions for two groups with few exceptions. First, non-center students did not have questions of their center involvement (Appendix H, Q5-9). Second, the question that classified students into their center and non-center groups was different for center and non-center students (detailed description of these questions was provided in the paragraphs above). Third, the wording of the survey was slightly modified for the non-center students so that there was no reference to I/UCRC program. The following sections describe variables that were used in this study. The first set of variables is demographic variables that tell the reader about the population of this study. The section is followed by more detailed descriptive information about the main IVs and DVs of the study.

Demographics

Table 6 provides descriptive information of three continuous variables: age (Q24), GPA (Q31) and time spent at graduate school (Q29). It demonstrates that there is no significant difference between groups on these variables.

Table 6

Descriptive Summary of Age, GPA, and Number of Months in Graduate School

	Center		Non-center		Total	
	M	SD	M	SD	Mean	SD
How old are you?	12.82	4.67	12.83	3.34	12.82	4.266
What is your approximate GPA in graduate school?	7.55	.69	7.39	.91	7.50	.774
What is the total number of months you have been in graduate school?	12.60	5.61	12.82	6.25	12.67	5.824

Notes: age is coded from 1 (16 years old) to 80 (95 years old); GPA is coded from 1 (2.00 - 2.25) to 8 (3.76 – 4.00); number of months in graduate school coded from 1 (1 – 3 months) to 34 (=/> 100).

According to NSF National Engineering Indicators, the number of women in graduate school in the technology-oriented fields is low in S&E fields, but still differs by discipline: 23% in engineering, 25% in computer sciences, and 33% in physical sciences (NRC, 2014).

Table 7 provides descriptive information about the proportion of gender and whether it differs among two groups (Appendix H, Q25). It demonstrates that there is no gender difference among two groups. However, it demonstrates that females account for about the same lowest percentage observed in the national data that belongs to students in engineering fields.

The number of the international students is also constantly growing in the US, where the majority of students are coming from China, India, South Korea and Arab Emirates

Table 7

Descriptive Summary of Gender

			Group		Total
			Center	Non-Center	
	Male	Count	129	67	196
		% within Group2	74.6%	77.0%	75.4%
	Female	Count	41	19	60
		% within Group2	23.7%	21.8%	23.1%
	Prefer not to answer	Count	3	1	4
		% within Group2	1.7%	1.1%	1.5%
Total		Count	173	87	260

(NRC, 2014). Thus, it is important to measure students' countries of origins (Q27) and their immigration/citizenship status (Q1). Table 8 provides descriptive information about student's immigration status that is coded as 1 for US citizen and 2 for international students. The table demonstrates that two groups of students are the same in proportion of US citizens to international students.

Table 8

Descriptive Summary of Immigration Status

			Group2		Total
			Center	Non-Center	
	US citizen/permanent resident	Count	76	38	114
		% within Group2	43.9%	43.7%	43.8%
	International F1 student	Count	97	49	146
		% within Group2	56.1%	56.3%	56.2%
		Count	173	87	260
		% within Group2	100.0%	100.0%	100.0%

Table 9 provides descriptive information about nationalities that are the most common across two groups. Category "Other" combines nationalities that were represented by a small number of students. The table demonstrates that the study's sample is similar to the national data where most international students in the S&E fields in the US universities represent Chinese or Indian nationalities.

Table 9

Descriptive Summary of most Common Nationalities

			Group2		Total
			Center	Non-center	
	Chinese	Count	36	12	48
		% within Group2	37.1%	24.5%	32.9%
	Indian	Count	23	14	37
		% within Group2	23.7%	28.6%	25.3%
	Iranian	Count	15	2	17
		% within Group2	15.5%	4.1%	11.6%
	Korean	Count	4	6	10
		% within Group2	4.1%	12.2%	6.8%
	Other	Count	19	15	34
		% within Group2	19.6%	30.6%	23.3%
Total		Count	97	49	146

With exception of Asian Americans, other ethnic minorities are underrepresented in S&T fields. One question specifies student's ethnicity of the graduate students (Q26). Table

10 provides descriptive summary of the ethnical variation of the total sample and across two groups. The numbers demonstrate that two samples do not differ significantly in terms of their ethical background and that the numbers are consistent with data from national sample where most graduate students in S&E fields are either white or non-US born Asians.

The data are collected from different research intense universities most of which have at least one I/UCRC on their campus. Appendix D provides a descriptive summary of which universities the sample students belong to by group and total sample. Even though the study focused only on the graduate students in the S&E fields, these fields are still very diverse.

Table 10

Descriptive Summary of Ethnicity/Race

			Group		Total
			Center	Non-Center	
	African American/Black	Count	1	3	4
		% within Group	0.6%	3.4%	1.5%
	Asian American	Count	65	29	94
		% within Group	37.6%	33.3%	36.2%
	European American/Caucasian/White	Count	68	33	101
		% within Group	39.3%	37.9%	38.8%
	Hispanic or Latin American	Count	7	3	10
		% within Group	4.0%	3.4%	3.8%
	I prefer not to answer	Count	23	17	40
		% within Group	13.3%	19.5%	15.4%
	Other (please, explain)	Count	9	2	11
		% within Group	5.2%	2.3%	4.2%
Total		Count	173	87	260

For the purpose of this study, the disciplines were combined into 4 large categories so that each category can represent adequate number of students. Table 11 describes the most common fields students from two groups belong to.

Table 11

Descriptive Summary of most Common Disciplines

		Group		Total
		Center	Non-Center	
Computer Science and Eng.	Count	17	39	56
	% within Group	10.4%	44.8%	22.3%
Electrical, Material Science and Mechanical Eng.	Count	112	40	152
	% within Group	68.3%	46.0%	60.6%
Other Engineering	Count	22	3	25
	% within Group	13.4%	3.4%	10.0%
Other (non-Engineering)	Count	13	5	18
	% within Group	7.9%	5.7%	7.2%
Total	Count	164	87	251

Center Dosage (center students only)

Since prior research indicated that centers vary in the extent to which their students participate in a center (Schneider, 2007), I measured to what extent students are involved with their centers, or *dosage of the center involvement*. Three questions (two continuous and one categorical) were used as indication of dosage: 1) Time in months spent in I/UCRC (M = 5.36 or 2 years, SD = 2.7); 2) Percentage of graduate time spent on I/UCRC activities (M = 14.38 or 70%, SD = 5.02); 3) And, whether student's research project is/was/will be based on the I/UCRC research (dichotomous). The first two variables were checked for extreme outliers. Time spent at I/UCRC had positively skewed distribution (S = .839, $S\ SE$ = .186): two students indicated spending 79-84 (6.8 years) and 91-96 (7.8 years) months in graduate school. They were recoded to the closest value, 61-66 months or 5.3 years. Figure 3 shows distribution of the variable with recoded outliers.

The second continuous variable had slightly positively skewed distribution, however, it reflected real distribution of the percentage spent on I/UCRC activities where majority (more than 50%) of students reported spending 66-70% of their time on I/UCRC. Thus, the distribution was not transformed (Figure 4).

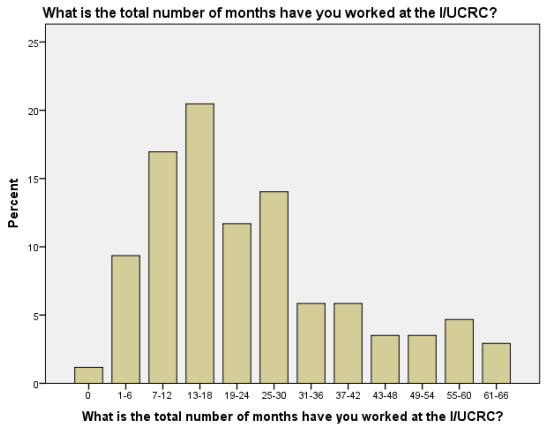

Figure 3. Distribution of Number of Months in I/UCRC.

The dichotomous variable was creating from the categorical variables described in the Table 12. For the purpose of this study, it was important to know whether students project is/was/or will be based on I/UCRC research rather than when it happened. Also, the number of students in each original category was not large enough to do statistical analysis with. Thus, categories 1, 2, and 5 were recoded into "Project is based on I/UCRC project" (coded as 2) and categories 3 and 4 into "Project isn't based on I/UCRC project" (coded as 1).

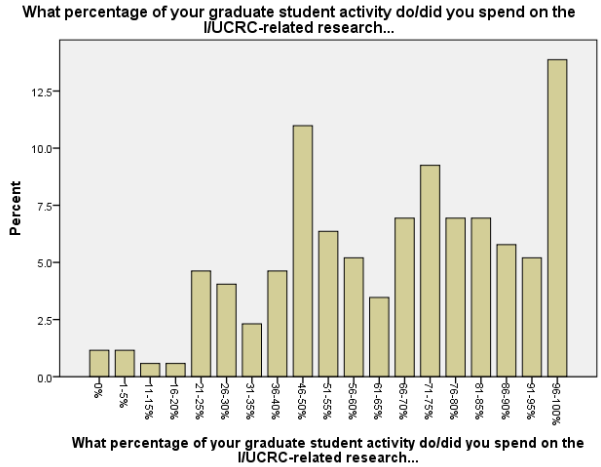

Figure 4. Distribution of Percentage of Total Activity Spent on I/UCRC Research.

The variables had low to medium significant correlations, but not high enough to claim them as a single scale (Table 13). Principal component analysis showed that three items load on a single factor, however, reliability analysis showed that the three items do not make a single scale (Alpha = .317). Thus, the items are used as a separate indicator of center dosage.

Graduate Training Experiences (IV)

As suggested above, CRCs differ in the extent to which they are "center-like". That is, individual centers (and even non-Centers) differ in the extent to which they offer students experiences that are team-based, collaborative, and multi-disciplinary. As a consequence, students were asked to provide self-report ratings on the extent to which the training they received involved those experiences (Appendix H, Q10). Table 14 provides the descriptive information for each item that represents graduate experiences.

Table 12

Descriptive Summary of Question 9: "Is your current, planned or finished thesis or dissertation based on I/UCRC research project?"

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes, it is. (1)	58	22.3	33.5	33.5
	Yes, it will be. (2)	67	25.8	38.7	72.3
	No, it is not/will not be based on I/UCRC project. (3)	22	8.5	12.7	85.0
	I don't know yet. (4)	21	8.1	12.1	97.1
	Yes, it was. (5)	5	1.9	2.9	100.0
	Total	173	66.5	100.0	
Missing	888 (non-center students)	87	33.5		
Total		260	100.0		

Means demonstrate that most respondents were exposed significantly to all experiences except "working or interacting with researchers who are not located in the US." This item was removed from the further factor analysis due to its different variance probably because of the international students' effect. Principal component analysis with

Table 13

Correlations of the three Dosage Variables

		Number of months	Percentage of your graduate student activity	Thesis/dissertation based on I/UCRC's project
Number of months worked at the I/UCRC	Pearson Correlation	1	.250**	.208**
	Sig. (1-tailed)		.000	.003
	N	171	171	171
Percentage of graduate student activity do/did you spend on the I/UCRC-related research	Pearson Correlation	.250**	1	.335**
	Sig. (1-tailed)	.000		.000
	N	171	173	173
Thesis or dissertation based on an I/UCRC's research project	Pearson Correlation	.208**	.335**	1
	Sig. (1-tailed)	.003	.000	
	N	171	173	173

**. Correlation is significant at the 0.01 level (1-tailed).

Varimax rotation was performed with ten variables that describe graduate experiences. Table 15 and Figure 5 demonstrate the results of factor analysis. Factors explained 64% variance.

Table 14

Descriptive Summary of Graduate Experiences

Graduate Experiences	M	SD	S	SE
1. Working or interacting with researchers from other disciplines.	3.91	1.43	-.38	.15
2. Working or interacting with researchers from industry.	4.15	1.50	-.67	.15
3. Working or interacting in teams of researchers.	4.38	1.31	-.72	.15
4. Presenting research findings to researchers and other professionals from different sectors and disciplines.	4.64	1.25	-1.14	.15
5. Working or interacting with researchers from other universities.	3.67	1.56	-.37	.15
6. Working in settings where there is a high level of interdependency between team members.	4.03	1.40	-.77	.15
7. Working or interacting with researchers who are not located in the U.S.	2.53	1.61	.51	.15
8. Being exposed to scientific techniques and expertise that are not usually available in my department.	3.83	1.50	-.37	.15
9. Learning how a particular concept can be applied to an actual problem or "a real world" situation.	4.93	1.05	-1.04	.15
10. Integrating and synthesizing information from different fields in order to solve problems.	4.62	1.25	-1.05	.15
11. Opportunities to develop my written and communication skills.	5.15	.86	-.69	.15

Table 16 demonstrates factor loadings. Variables load strongly on three factors. Five variables load on factor that can be described as multidisciplinary and team-based (Alpha = .795). Three variables that describe action oriented experiences rather than communication with other professionals load on the Experiential experiences factor (Alpha = 718). And, two factors loaded on the experiences with Industry factor (Alpha = .619). For all three factors, alpha did not increase if any of the variables was removed.

Table 15

Total Variance Explained for Graduate Experiences

Compo	Initial Eigenvalues			Rotation Sums of Squared Loadings		
nent	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.485	44.850	44.850	2.551	25.511	25.511
2	1.014	10.138	54.988	2.185	21.852	47.363
3	.963	9.633	64.621	1.726	17.258	64.621
4	.784	7.843	72.464			
5	.667	6.673	79.137			
6	.521	5.206	84.343			
7	.510	5.095	89.438			
8	.436	4.361	93.799			
9	.333	3.335	97.134			
10	.287	2.866	100.000			

Extraction Method: Principal Component Analysis.

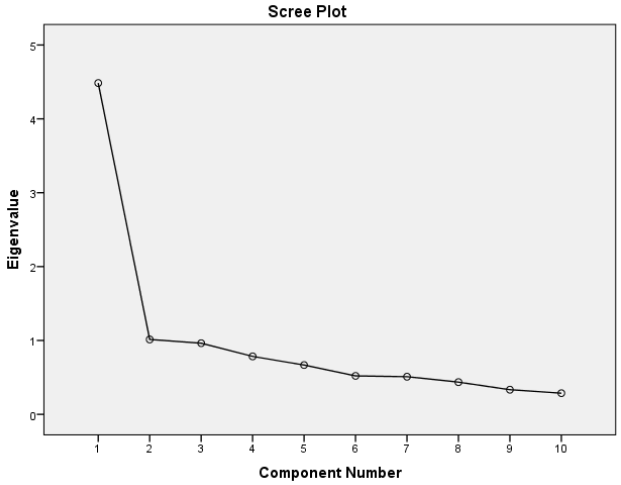

Figure 5. Eigenvalues Distribution Plot for Graduate Experiences.

Professional Social Capital (DV-1)

As described in the literature review, there is little agreement on the construct social capital and as a consequence, it has been measured in a variety of ways. Figure 6 highlights the various aspects of professional social capital (PSC) that are included in this study. Also, it provides the actual criteria by which social capital of students will be evaluated.

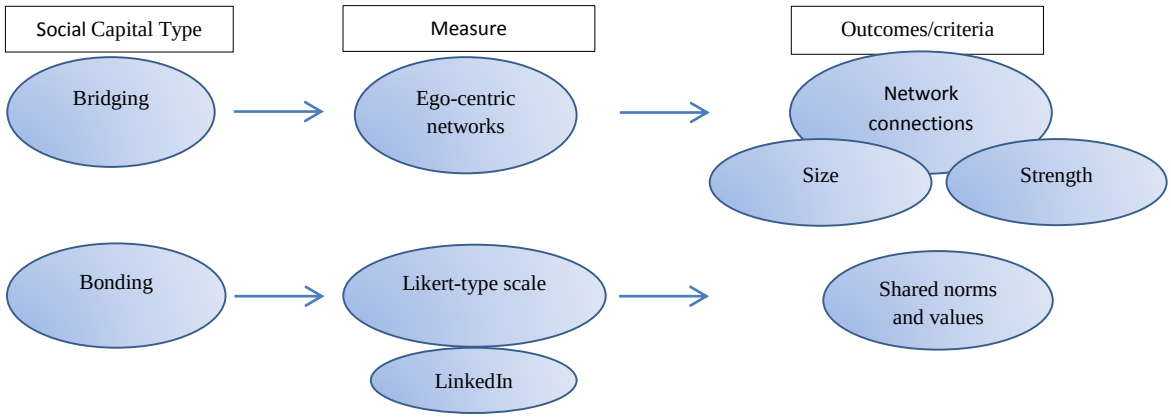

Figure 6. Social Capital, Measures and Outcomes.

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&T fields during their graduate training. The section below provides explanations on what specific characteristics of ego-centric networks and their measurement are and their application in terms of S&T graduate students.

Social Networks Connections (Bridging PSC)

The first part of PSC is social networks size or number of connections with different professionals and the strength of those connections. This social network part of social capital is called bridging because it describes the available network of connections one has to other

Table 16

Factor Loadings for Graduate Experiences

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

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 10 iterations.

b. Factor loadings > 0.5 are in bold.

professionals. Network size is measured by asking students about the number of professionals they know from the specific 14 categories (Appendix H, Q15). There was no range limit given for the numbers 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. For instance, when an extreme outlier with 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. Appendix E provides summary of descriptive information for each of the 14 categories before and after outliers were recoded.

One of the 14 categories was excluded from the analysis, "Academic advisers who are directing/supervising you with your thesis or dissertation." This category was dropped

because it did not have significant range. The remaining thirteen categories were combined intro three based on combination of logical grouping of categories and categories' factor loadings. The break-down of these three categories of the social network size were represented in the following way: US academic network (6 categories were combined); outside US academic network (2 categories); and non-academic network (5 categories combined). US academic professionals included: faculty from students' departments (1), graduate students and post-docs from department (2), faculty from other disciplines (3) and graduate students/postdocs (4) from the same university, and faculty (5) and graduate student/post-docs (6) from other universities in the US. Academic professionals outside of the US included two categories: (1) faculty and (2) graduate students/post-docs outside of the US. And, finally, non-academic professionals combined five categories: (1) representative of large companies, of small companies (2), of the US Federal or local government (3), non-profit organizations (4), and associations/foundations (5). These final categories were checked again for extreme outliers that were recoded into the closest values on the distribution.

Table 17 provides a summary of the distribution of the final variables used as measures of the bridging PSC. All variables were transformed according to the type of their skewedness, however, it did not work as it turned distribution from one skewedness to the opposite that may have affected the results of the hypothesis testing.

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 5 categories of professionals (Appendix H, Q16 & 17). Distribution of the original variables is included in Appendix E. Category of academic adviser was again excluded because most students indicated high chance of receiving advice and introduction from their main academic adviser(s) that resulted in significant negative skewedness. Remaining four categories were made into three: categories "department academics" and "academics from other universities and disciplines in the US" were combined into one "US academics" and the remaining two stayed the same, "non-US academics" and "non-academics" (Table 17).

Table 17

Description Summary of the Social Network Measures

	Mean	SD	S	SE
Academics in US	58.03	42.338	1.103	.152
Non-US academics	11.34	18.925	2.667	.152
Non-academics	12.53	14.322	2.181	.152
Advice from academics in US	7.83	1.587	-.624	.151
Advice from non-US academics	3.18	1.219	-.268	.151
Advice from non-academics	3.38	1.181	-.321	.151
Introduction from academics in US	7.95	1.705	-.871	.151
Introduction from non-US academics	3.35	1.253	-.418	.151
Introduction from non-academics	3.49	1.216	-.547	.151

Trust, Norms & Values (Bonding PSC)

Bonding part of social capital is a psychosocial measure that "glues" those network connections together. In the context of this study, this is norms and values about collaborations. For example, most of today's innovations and discoveries come from the environment which not only provides tangible resources such as equipment and space, but also enhances collaborations of people from different sectors and disciplines. Resent technological boom of Palo Alto's Silicon Valley is one of the primary examples of such environment.

Although many authors highlight the importance of these psychosocial aspects of SC, few scholars have attempted to address these constructs empirically and none have for scientists. As a consequence, I have rationally developed a set of items that attempt to tap into the following qualities: norms and values about collaborative process. Therefore, this dimension of social capital measures connecting mechanism that networks can be built on, maintained and developed in the context of graduate students' training. There are total 8 items measured on the Likert-type five response options range from *Strongly Agree* to *Strongly Disagree*. Table 18 lists the items' descriptive statistics.

Principal component analysis demonstrated one-factor solution and that the scale is reliable (Alpha = .820). Table 19 provides that the factor explains 46% of total variance and plot 7 confirms one-factor solution. Each variable had high loading on the factor (Table 20).

Thus, the total sum of all 8 variables is a single measure of the Norms and Values, one of the main predictors in this study.

Table 18

Descriptive Summary of the Norms and Values Variables

	Mean	SD	S	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

View of Size and Diversity

Another bonding variable is students' view of the size and diversity of their networks (Appendix H, Q14). The variable was measured with five-item Likert-type scale that ranged between responses "Not at all important" to "Extremely important." Table 21 provides a summary of descriptive information and shows that the distribution was slightly negatively skewed due to mostly positive view of size and diversity.

Table 19

Total Variance Explained for the Norms and Values

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	3.638	45.476	45.476
2	.909	11.359	56.835
3	.842	10.519	67.355
4	.704	8.796	76.151
5	.604	7.548	83.699
6	.531	6.637	90.335
7	.402	5.023	95.358
8	.371	4.642	100.000

Extraction Method: Principal Component Analysis.

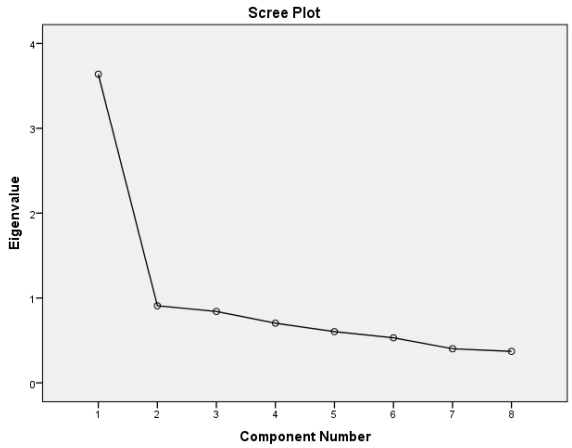

Figure 7. Eigenvalues Distribution Plot for the Norms and Values.

Bibliometrics

Technique like bibliometrics has been widely used in analyzing social and human capital of the established scientists. These are crude measures of co-authorships of scientists in publications, grants and conference presentations (Appendix H, Q18). However, the data

from this measure were not used in the final analysis due to a large amount of missing data. The respondents were not required to provide the answer to the bibliometrics questions.

LinkedIn

Students were asked to tell whether they have LinkedIn account. Results showed that 88% of students have LinkedIn account (Appendix H, Q19). Then, students provided the approximate number of their LinkedIn connections which is one of the additional

Table 20

Factor Loadings for the Norms and Values

	Component
1. I believe that science benefits from involvement of different sectors such as private businesses, government and academia.	.748
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.	.564
3. I view collaborations between industry and academia as positive despite differences in the ways they operate and things they value.	.661
4. I like working with researchers from different disciplines as I can use their knowledge in my area of work.	.732
5. I believe that any contemporary scientist must have strong communication skills in order to be able to solve today's problems.	.605
6. Despite extra time and resources spent on communication, I still think that working in teams is important for building innovation capacity.	.590
7. Despite the challenges associated with bringing professionals from different disciplines to work together, I still think that such collaborations are important for science.	.721
8. I believe that a problem-solving approach can contribute to science as much as development of theory.	.743

Extraction Method: Principal Component Analysis.
a. 1 component extracted.

Table 21

Descriptive Summary of the View of Network Size and Diversity

	Mean	SD	S	SE
How important is size of your professional social networks to your future professional career.	3.87	.863	-.370	.151
How important is diversity of your professional social networks to your future professional career.	3.79	.911	-.628	.151

measured of PSC (Appendix H, Q20). Figure 8 shows that the variable does not have a normal distribution. Transforming the variable resulted in distribution being skewed in the opposite, negative, direction. Since it will affect the results, the variable was used in its original form in the further analysis.

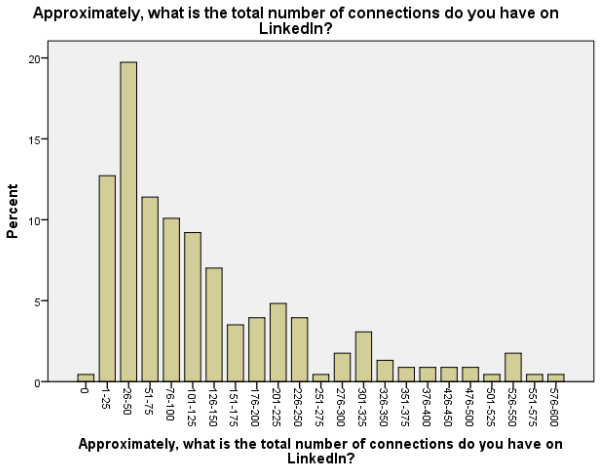

Figure 8. Distribution of Number of the LinkedIn Connections.

Immigration Plans (international students only) (DV)

This section is relevant only to international students, who account for more than 50% of graduate students in S&T. First question seeks to identify their preference on whether to stay in the U.S. or go back to their home country which has implications towards the global mobility of the highly trained professionals. Specifically, students were asked "what are your personal plans after graduation?" and given response options: go back to my home country; work for some time in the US and return to home country eventually; stay in the US permanently; and other (Appendix H, Q22). Second question asked whether a student considers become a US citizen (Appendix H, Q23). Distribution of these variables is provided in the results section.

Satisfaction (DV)

Finally, the last section focuses on satisfaction of students with their graduate training (Appendix H, Q33). The item is measured with five item Likert-type scale with *M* = 4.16, *SD* = .81 (Table 22). Since distribution was skewed towards positive values of satisfaction, the number of the students who choose responses Dissatisfied (*N* = 3) and Mostly Dissatisfied (*N* = 6) were very small. Thus, the variable was recoded into three-item scale.

Table 22

Descriptive Summary of Original Satisfaction Variable

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Dissatisfied	3	1.2	1.2	1.2
	Mostly Dissatisfied	6	2.3	2.3	3.5
	Neutral	31	11.9	11.9	15.4
	Mostly Satisfied	127	48.8	48.8	64.2
	Satisfied	93	35.8	35.8	100.0
	Total	260	100.0	100.0	

Recoded satisfaction had Mean = 2.20 and SD = .69 (Table Y). This was the variable used in the final analysis.

Table 23

Descriptive Summary of the Recoded Satisfaction Variable

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

Perceived Career Preparedness (DV):

Perceived Career Preparedness (PCP) was another outcome of the study that was not a part of the professional social capital measures (Appendix H, Q11). Students were asked to rate themselves on the items included in the Table 24: "In comparison with other students at your department, to what extent do you agree or disagree with the following statements."

Table 24

Descriptive Summary of the Perceived Career Preparedness

Variable	Mean	SD	S	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

Principal component analyses were conducted to tests the items on their psychometric properties (Table 25). The Tables 25 and 26 and the Figure 9 demonstrate that the items loaded on a single factor and explained 61% of the variance. Reliability analysis of Alpha demonstrated that the four items represent the scale with reliability coefficient of .761.

Table 25

Total Variance Explained for the Perceived Career Preparedness

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.421	60.535	60.535	2.421	60.535	60.535
2	.692	17.300	77.834			
3	.575	14.386	92.220			
4	.311	7.780	100.000			

Extraction Method: Principal Component Analysis.

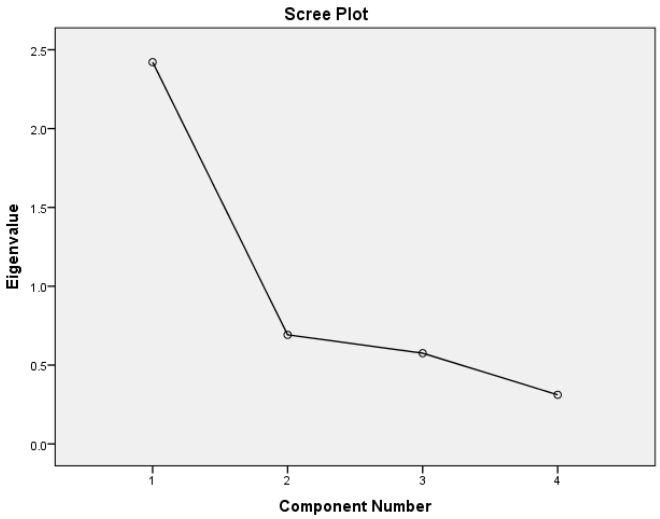

Figure 9. Eigenvalues Distribution Plot for the Perceived Career Preparedness.

Table 26

Factor Loadings for the Perceived Career Preparedness

	Component
My training has better prepared me to the demands of future employment.	.850
I feel that I have expanded more my network of academic professionals who can give me advice and assistance in the future.	.699
I feel that I have expanded more my network of industry professionals who can give me advice and assistance in the future.	.699
I think I have more necessary skills to make a valuable contribution to an organization that is going to hire me.	.850

Extraction Method: Principal Component Analysis.
a.1 components extracted.

Results

Before providing the results of the study, additional descriptive information was included for the better understanding of the study's sample of the graduate students. Appendix F includes means and standard deviations of the all study's outcomes for the total sample, the types of training, center and non-center, and immigration status, US citizen and international student.

The study's main outcomes were also tested on the way they relate to each other and to study's demographic variables. One-tailed bivariate correlations were performed on all study's outcomes and demographic variables. The following demographic variables did not have significant correlations with the study's outcomes and thus, were not included as covariates in the analyses of the total sample (center and non-center students): age, gender, nationality, ethnicity, time spent in graduate school and GPA. Appendix G contains the correlation table with study's outcomes and immigration status variable since it was identified as a study's covariate due to its significant correlations with most of the outcomes. Most of the outcomes had low to medium significant correlations with each other including the PSC outcomes. Thus, the study did not have problem with multicollinearity between its outcomes measures. Also, the correlations demonstrated that different measures of PSC do not correlate highly enough to form a single measure. The sections below provide detailed explanation of the results from each of the hypothesis and research question tested in this study.

Center vs. Non-Center

The first set of hypotheses examined how the type of graduate training affects the study's PSC and other outcomes. Hypotheses 1 (a-e) stated that IUCRC-based training resulted in significantly larger and stronger PSC than traditional training. Preliminary analyses of the correlations among various social capital measures indicated modest to low correlations among these outcomes. Given the exploratory nature of this study and these observed relationships, I choose to use ANOVA rather than MANOVA to test these hypotheses.

More specifically, a two-way ANOVA was performed to test H1 and answer the question (Q1) to what extent immigration status moderate these relationships. Thus, the combination of the hypothesis and the exploratory questions predicted that there is a significant impact of the type of graduate training on the PSC outcomes and that the relationships might be moderated by the immigration status.

The first set of dependent social network variables included three variables that measure size of students' networks: the numbers of US academics, non-US academics and

non-academics (H-1a). The first variable was the number of the U.S. academics. Analysis of variance demonstrated that there was no significant effect of the type of training, $F(1, 253) = .985$, $p = .322$, immigration status, $F(1, 253) = 2.691$, $p = .102$, and interaction, $F(1, 253) = .357$, $p = .551$.

The second dependent variable was the number of the non-U.S. academics (Table 27). Immigration status, $F(1, 252) = 33.986$, $p < .001$, $\eta^2 = .119$, was the only significant predictor of the number of non-US academics where international students scored significantly higher on the number of the non-U.S. academics (Figure 10). However, the assumption of equality of variance was violated because of the large difference in variance between US citizens (M exp. = 3.01, SD = 4.13; M c. = 5.32, SD = 9.88) and international students (M exp. = 16.03, SD = 21.80; M c. = 19.78, SD = 25.05) on the outcome. Since transformation of variables with non-normal distribution and large variance was not successful, the non-parametric one-way ANOVA was used to test whether immigration status predicts the number of the non-US academics. The three non-parametric ANOVAs tests were performed to see whether the number of non-US academics differ based on immigration status. All three were significant thus, the tests rejected the null hypothesis which means that international students have significantly higher number of the non-U.S. academics in their network, Mann-Whitney U Test $p < .001$, Kolmogorov-Smirnov $p < .001$, and Kruskal-Wallis $p < .001$. The model explained 13% of variance in the number of non-US academics.

Table 27

Tests of Between-Subjects Effects on the Number of Non-US Academics

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	517.07	1	517.072	1.645	.201	.006
Immigration Status	10680.40	1	10680.400	33.986	.000	.119
Group2 * Immigration St.	29.39	1	29.378	.093	.760	.000
Error	79192.63	252	314.256			
Total	124270.00	256				
Corrected Total	91327.75	255				

a. R Squared = .133 (Adjusted R Squared = .123); b. Levene's (p <.001), Welch (p < .001) and Brown-Forsythe (p < .001); c. Immigration Status coded as 1 – US citizen and 2 – international student

The next dependent variable, the number of non-academics, was significantly predicted by the type of training, $F(1, 252) = 6.957$, $p = .009$, and immigration status, $F(1, 252) = 6.576$, $p = .011$ (Table 28). Center students demonstrated larger network of non-

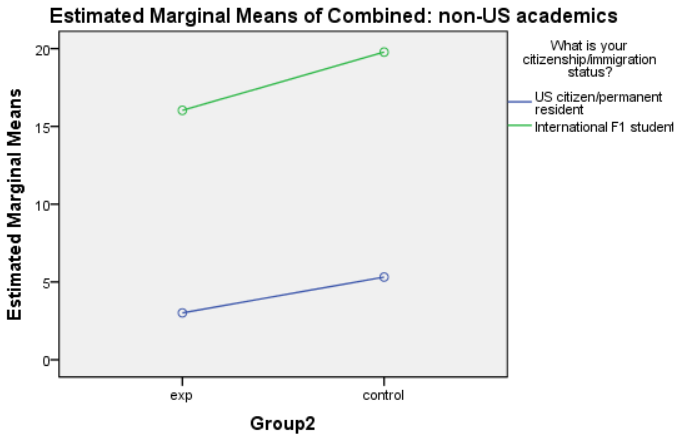

Figure 10. Type of Training Mean Difference of Size of US Academic Network.

academic professionals. Also, the US citizens showed larger non-academic network in comparison with the international students (Figure 11). The interaction of the type of training and immigration status was not a significant predictor of the size of non-academic network. The model explained only 6% of variance in the size of non-academic network. The assumption of equal variance was violated as well. Three non-parametric tests of one-way ANOVA were performed for each of the significant independent variables. The tests rejected the null hypothesis for both variables, Mann-Whitney U Test $p < .001$, Kolmogorov-Smirnov $p < .001$, and Kruskal-Wallis $p < .001$ (immigration status) and Mann-Whitney U Test $p < .001$, Kolmogorov-Smirnov $p < .001$, and Kruskal-Wallis $p < .001$ (the type of training). Thus, the size of the non-academic network was significantly higher for US citizens and for students trained at the centers.

Table 28

Tests of Between-Subjects Effects on the Number of Non-academics

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	1357.97	1	1357.974	6.957	.009	.027
Immigration Status	1283.59	1	1283.593	6.576	.011	.025
Group2 * Immigration St.	106.43	1	106.425	.545	.461	.002
Error	49185.76	252	195.182			
Total	92483.00	256				
Corrected Total	52307.81	255				

a. R Squared = .060 (Adjusted R Squared = .048)
b. Levene's (p = .025), Welch (p = .006), and Brown-Forsythe (p = .006)
c. Immigration Status coded as 1 – US citizen and 2 – international student

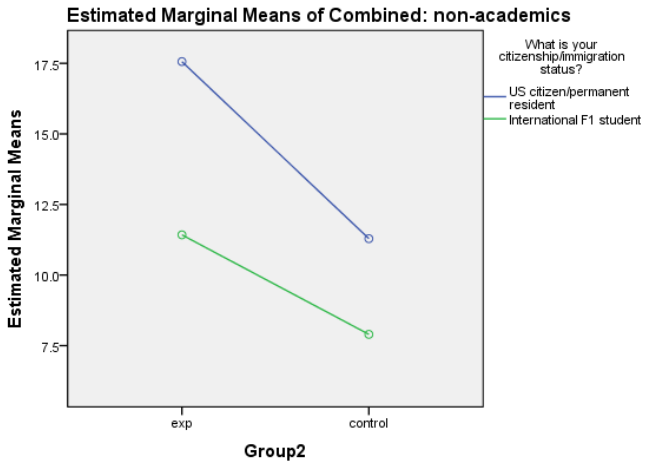

Figure 11. Type of Training Mean Difference of Size of Non-academic Network.

The second set of the PSC variables was the strength of network connections measured as a technical advice or input from: the US academics, non-US academics and non-academics (H1-b). These variables were measured by the five items Likert-type scale. The advice from US academics is the sum of the two variables: Departmental academics and Academics from other disciplines and institutions. The advice from US academics was not

significantly predicted by the type of training, F(1, 256) = .562, p = .454, immigration status, F(1, 256) = .235, p = 628, or interaction F(1, 256) = .004, p = 949.

Table 29 summarizes the results of the analysis for the advice from non-US academics that was significantly predicted by the immigration status, $F(1, 256) = 11.536$, $p = .001$, $\eta^2 = .043$. Figure 12 demonstrates that international students, regardless of their training, reported higher scores for the availability of advice from non-US academics. US citizens trained in the centers reported lower scores than US citizens trained in more traditional settings. The model explained 7% of variance in the availability of advice from non-US academics.

Table 29

Tests of Between-Subjects Effects on the Availability of Advice from non-US Academics

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	1.432	1	1.432	1.020	.314	.004
Immigration Status	16.201	1	16.201	11.536	.001	.043
Group2 * Immigration St.	1.920	1	1.920	1.367	.243	.005
Error	359.541	256	1.404			
Total	3022.000	260				
Corrected Total	385.138	259				

a. R Squared = .066 (Adjusted R Squared = .056)
b. Levene's p = .227
c. Immigration Status coded as 1 – US citizen and 2 – international student

Table 30 demonstrates that the availability of advice from non-academics was significantly predicted by the type of training, $F(1, 256) = 5.406$, $p = .021$, $\eta^2 = .021$, immigration status, $F(1, 256) = 5.33$, $p = .022$, $\eta^2 = .020$, and interaction of the two variables, $F(1, 256) = 8.567$, $p = .004$, $\eta^2 = .032$. Center students were significantly more likely to have higher availability of advice from their non-academic connections (Figure 13). US citizens, however, were less likely. The findings indicate that center trained US citizens had larger

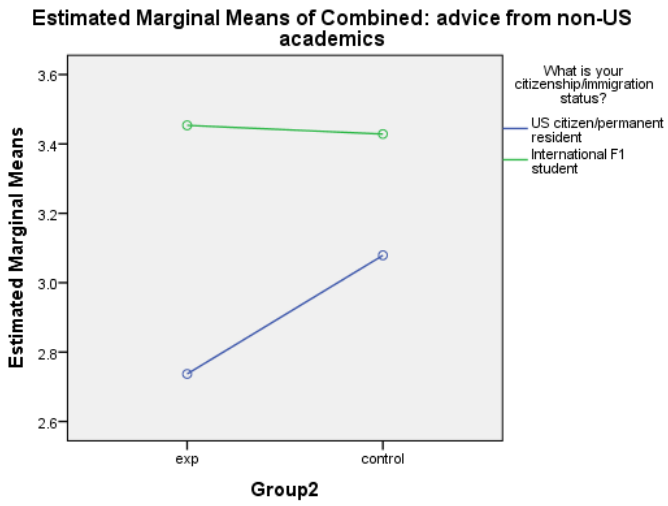

Figure 12. Type of Training Mean Difference of Availability of Advice from non-US Academics.

possibility of advice from non-academic professionals while center trained international students' possibility of receiving advice was the same or even worse than international students trained in traditional settings. The model explains 9% of variance in the non-academic advice.

The third set of the PSC variables represented the strength of students' network connections in the form of possibility of an introduction to other professionals from: the US academics, the non-US academics and non-academics (H-1c). The type of graduate training, $F(1, 256) = .987$, $p = .321$, $\eta^2 = .004$, immigration status , $F(1, 256) = .165$, $p = .685$, $\eta^2 = .001$, and interaction, $F(1, 256) = .1.083$, $p = .299$, $\eta^2 = .004$, did not significantly predict the introduction from the US academics.

Table 30

Tests of Between-Subjects Effects on the Advice from Non-academics

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	6.961	1	6.961	5.406	.021	.021
Immigration Status	6.864	1	6.864	5.330	.022	.020
Group2 * Immigration St.	11.031	1	11.031	8.567	.004	.032
Error	329.657	256	1.288			
Total	3333.000	260				
Corrected Total	361.304	259				

a. R Squared = .088 (Adjusted R Squared = .077)
b. Levene's p = .234, Welch p = .001, Brown-Forsythe p = .001
c. Immigration Status coded as 1 – US citizen and 2 – international student

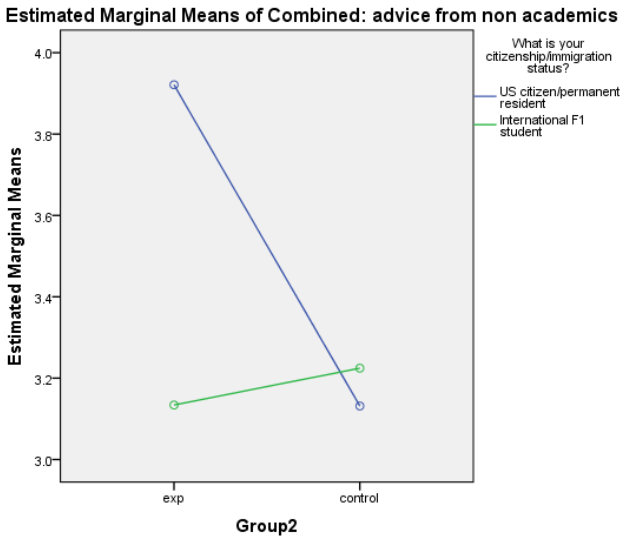

Figure 13. Type of Training Mean Difference of Availability of Advice from Non-academics.

Immigration status was the only significant predictor of the availability of introduction from non-US academics (Table 31, Figure 14). International students reported that they had more confidence in receiving introduction from the non-US academics, $F(1, 256) = 13.036$, $p < .001$, $\eta^2 = .048$, than US citizens regardless of the type of training.

Assumption of equality of variance again was violated because of the large difference in variance between US citizens and international students on the outcome. Three non-parametric one-way ANOVA were used to test whether US citizens and international students differed on the introduction from non-US academics. The tests rejected the null hypothesis, Mann-Whitney U Test $p < .001$, Kolmogorov-Smirnov $p < .001$, and Kruskal-Wallis $p < .001$. International students significantly score higher on the non-US academics introduction than the US citizens and this model explained 6% of variance in the outcome.

Table 31

Tests of Between-Subjects Effects on the Availability of Introduction from non-US academics

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	.022	1	.022	.015	.904	.000
Immigration Status	19.533	1	19.533	13.036	.000	.048
Group2 * Immigration St.	.122	1	.122	.081	.776	.000
Error	383.605	256	1.498			
Total	3318.000	260				
Corrected Total	406.846	259				

a. R Squared = .057 (Adjusted R Squared = .046); b. Levene's p < .001, Welch p < .001, Brown-Forsythe p < .001; c. Immigration Status coded as 1 – US citizen and 2 – international student

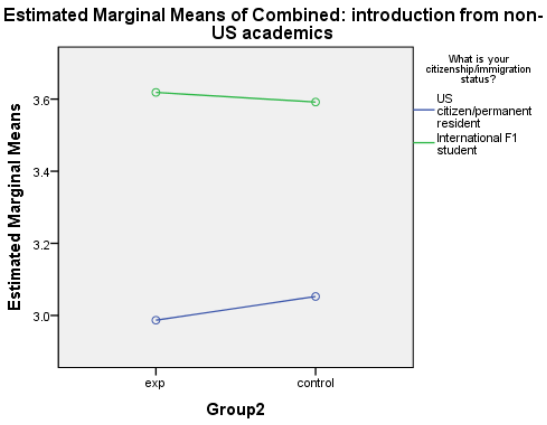

Figure 14. Type of Training Mean Difference of Introduction from non-US Academics.

The last dependent variable that assessed students' bridging PSC was the availability of introduction from non-academics (Table 32). The type of graduate training was a significant predictor of the outcome, where center students showed significantly higher availability of introduction from non-academic professionals, $F(1, 256) = 4.087$, $p < .05$, $\eta^2 = .016$ (Figure 15). Immigration status and interaction of the two predictors were not significant predictors of the availability of introduction from non-academics.

Table 32

Tests of Between-Subjects Effects on the Availability of Introduction from non-academics

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	5.852	1	5.852	4.087	.044	.016
Immigration Status	4.323	1	4.323	3.019	.083	.012
Group2 * Immigration St.	3.430	1	3.430	2.396	.123	.009
Error	366.516	256	1.432			
Total	3554.000	260				
Corrected Total	382.985	259				

a. R Squared = .043 (Adjusted R Squared = .032)
b. Levene's p = .036, Welch p < .060, Brown-Forsythe p < .060
c. Immigration Status coded as 1 – US citizen and 2 – international student

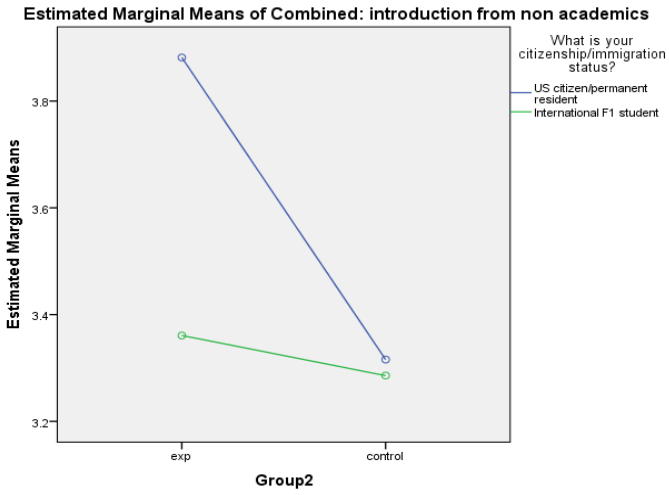

Figure 15. Type of Training Mean Difference of Introduction from Non-academics.

The last two of the total eleven PSC outcomes were the Norms and Values scale (H-1d) and the number of LinkedIn connections (H-1e). Affiliation with the centers significantly predicted higher Norms and Values score, $F(1, 256) = 12.354$, $p = .001$, $\eta^2 = .046$ (Figure 16). The assumption of equality of the variance was violated, so one-way non-parametric ANOVA was performed to see if the center and non-center students differ on this outcome. The tests results rejected the null hypothesis, Mann-Whitney U Test $p < .001$, Kolmogorov-Smirnov $p < .001$, and Kruskal-Wallis $p < .001$. Thus, 6% of variance in the Norms and Values score was explained by the type of graduate training with center students showing higher score.

Table 33

Tests of Between-Subjects Effects on the Norms and Values

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	164.45	1	164.452	12.354	.001	.046
Immigration Status	29.27	1	29.269	2.199	.139	.009
Group2 * Immigration St.	.37	1	.368	.028	.868	.000
Error	3407.91	256	13.312			
Total	323159.00	260				
Corrected Total	3608.14	259				

a. R Squared = .055 (Adjusted R Squared = .044)
b. Levene's p = .025, Welch p < .001, Brown-Forsythe p < .001
c. Immigration Status coded as 1 – US citizen and 2 – international student

Number of LinkedIn connections was approximate measure of the size of students' LinkedIn network as students' actual profiles were not used in this study. The number of LinkedIn connections was significantly predicted by immigration status, $F(1, 224) = 10.475$, $p = .001$, $\eta^2 = .045$ (Table 34). International students regardless of their graduate training demonstrated higher number of LinkedIn connection than US citizens (Figure 17). The model accounted for 5% of variance in the number of LinkedIn connections.

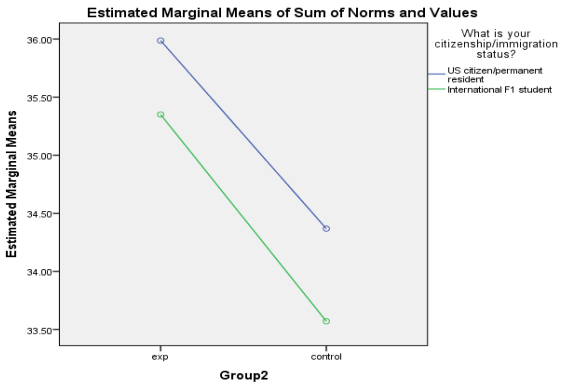

Figure 16. Type of Training Mean Difference of the Norms and Values.

Table 34

Tests of Between-Subjects Effects on the number of LinkedIn connections

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	.60	1	.600	.025	.875	.000
Immigration Status	253.46	1	253.463	10.475	.001	.045
Group2 * Immigration St.	.90	1	.902	.037	.847	.000
Error	5420.28	224	24.198			
Total	15845.00	228				
Corrected Total	5698.33	227				

a. R Squared = .049 (Adjusted R Squared = .036); b. Levene's p = .005, Welch p = .884, Brown-Forsythe p = .884; Immigration Status coded as 1 – US citizen and 2 – international student

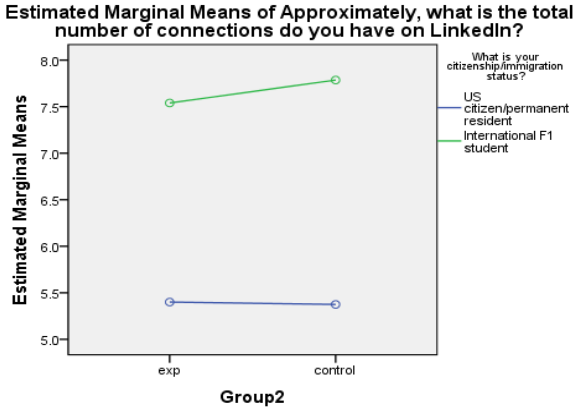

Figure 17. Type of Training Mean Difference of the Number of LinkedIn Connections.

Hypothesis II and Question II

H-2 predicted that the center students will demonstrate higher level of Perceived Career Preparedness than non-center students, $F(1, 256) = 35.507$, $p < .001$, $\eta^2 = .122$ (Table 35, Figure 18). The model explains 12 % of variance in PCP score.

Table 35

Tests of Between-Subjects Effects on the Perceived Career Preparedness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	220.058	1	220.058	35.507	.000	.122
Immigration Status	.563	1	.563	.091	.763	.000
Group2 * Immigration St.	8.101	1	8.101	1.307	.254	.005
Error	1586.584	256	6.198			
Total	70013.000	260				
Corrected Total	1810.996	259				

a. R Squared = .124 (Adjusted R Squared = .114)
b. Levene's p = .629
c. Immigration Status coded as 1 – US citizen and 2 – international student

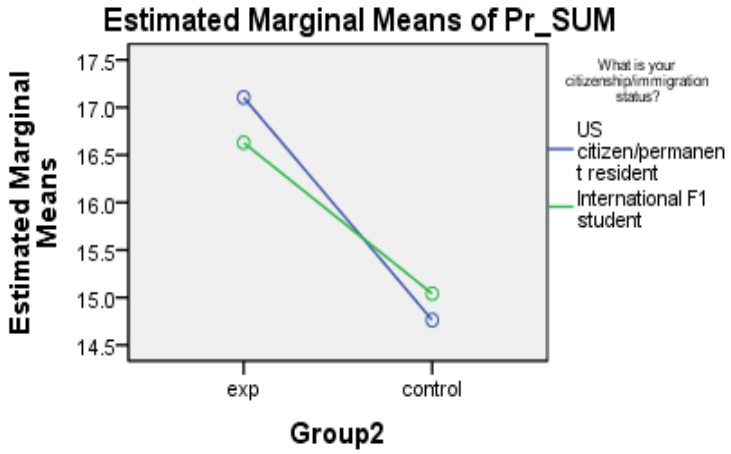

Figure 18. Type of Training Mean Difference of the Perceived Career Preparedness.

Hypothesis III and Question III

Hypothesis 3 predicted that center students are more satisfied with their graduate training than non-center students, $F(1, 256) = 17.217$, $p < .001$, $\eta^2 = .063$ (Table 36). Immigration status did not significantly predict the level of satisfaction of students. Assumption of equality of variance was violated and the non-parametric one-way ANOVA was performed with three significant tests. The three non-parametric tests indicated that the null hypothesis can be rejected, Mann-Whitney U Test $p < .001$, Kolmogorov-Smirnov $p < .001$, and Kruskal-Wallis $p < .001$. Thus, the type of training is a significant predictor of the graduate students' satisfaction (Figure 19). The model explains 7% variance in satisfaction with graduate training.

Center Dosage (I/UCRC Students Only)

This section of the analyses focuses on center students only. This second set of hypothesis examined how different dosage of the center involvement affects the PSC and other outcomes. Previous analysis of the correlations among the three dosage variables demonstrated low to medium significant correlations among: time in month spent at an

Table 36

Tests of Between-Subjects Effects on the Satisfaction with Graduate Training

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group2	7.62	1	7.624	17.217	.000	.063
Immigration Status	.56	1	.556	1.256	.263	.005
Group2 * Immigration St.	.33	1	.332	.749	.388	.003
Error	113.36	256	.443			
Total	1385.00	260				
Corrected Total	122.20	259				

a. R Squared = .072 (Adjusted R Squared = .061)
b. Levene's p = .037, Welch p < .001, Brown-Forsythe p < .001
c. Immigration Status coded as 1 – US citizen and 2 – international student

I/UCRC, percentage of graduate activity spent on the I/UCRC, and whether one's thesis or dissertation is based on the I/UCRC research project. Coefficient alpha were not

large enough to claim these three variables as parts of a single scale. Thus, the three variables were used as separate predictors in Multiple Regressions analysis.

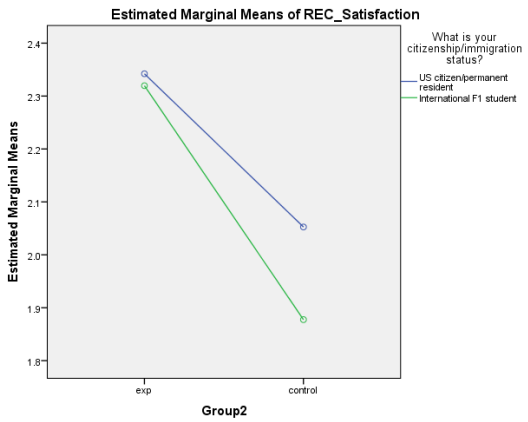

Figure 19. Type of Training Mean Difference of Satisfaction.

One-tailed bivariate correlations were performed on the sample of the I/UCRC students to find any other covariate other than immigration status. Three variables had low to medium significant correlations with multiple study's outcomes: immigration status (1 – US citizen, 2 – international student), time in months spent in graduate school and GPA. These three covariates were entered first into regressions in order to test whether graduate students with a higher dosage of a center involvement will demonstrate larger PSC (Hypothesis 4 (a-e) while controlling for the three demographic covariates. The first set of PSC variables represented the size of students' network s (4a). Table 37 summarizes the results. The results show that the only variable that significantly predicted the size of the students' network was immigration status.

Immigration status was a significant predictor of the size of US academics network, $\beta = -.18$, $p < .05$, and the size of non-academic professionals, $\beta = -0.20$, $p < .05$. US citizens had larger networks of US academics and non-academics. These results explained only a small portion of the variance in the network of US academics, $R^2 = .08$, and network of the

non-US academics, $R^2 = .09$. On the other hand, international students were more likely to have larger network of the academic professionals outside of the US, $\beta = .36$, $p < .001$. In this

Table 37

Summary of Multiple Regression Analysis of Social Network Size

Independent Variable	Count of US academics			Count of non-US academics			Count of non-academics		
	B	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Immigration status	-14.239	6.085	-.182*	12.624	2.648	.355***	-6.110	2.373	-.199*
N of months in grad. school	.804	.626	.116	.022	.272	.007	.394	.244	.146
GPA	7.214	4.310	.129	2.961	1.872	.117	.050	1.678	.002
N of month at I/UCRC	-.667	1.370	-.046	-.001	.595	.000	.315	.533	.056
% activity spent on I/UCRC	-.118	.653	-.015	.010	.284	.003	.038	.255	.012
Project based on I/UCRC	-10.831	7.381	-.122	-4.337	3.204	-.107	3.128	2.872	.090
R^2		.08			.16			.09	
F		2.22*			4.99***			2.61*	

Notes: *p< .05, ** p < .01, p <.001. Immigration status coded as 1 – US citizen, 2 – international student.

case, the regression model predicted 16% of variance in the size of the network of non-US academics.

The second set of outcome variables represented the strength of connection measured as availability of technical advice or input from: US academics, non-US academics and non-academics (H-4b). Table 38 demonstrates the results of multiple regression analysis.

The findings show the same results as the analyses of two-way ANOVA. Immigration status again was significant predictor for two of the three categories. International student status significantly predicted higher availability of advice from academics outside of the US, $\beta = .258$, $p < .01$. US citizen status, on the other hand, significantly predicted higher

availability of advice from non-academic professionals, β = .328, p < .001. Each model predicted only 9% of variance for each of the outcomes.

Table 38

Summary of Multiple Regression Analysis of the Availability of Advice

Independent Variable	Advice from US academics			Advice from non-US academics			Advice from non-academics		
	B	*SE B*	*β*	*B*	*SE B*	*B*	*B*	*SE B*	*β*
Immigration status	-.177	.254	-.054	.636	.186	.258**	-.794	.180	-.328***
N of months in grad. school	-.042	.026	-.144	-.025	.019	-.115	-.008	.019	-.039
GPA	.085	.181	.036	.200	.133	.113	.143	.128	.083
N of month at I/UCRC	-.071	.057	-.119	-.003	.042	-.007	.021	.041	.048
% activity spent on I/UCRC	.018	.027	.057	.009	.020	.036	.024	.019	.098
Project based on I/UCRC	.184	.309	.049*	.214	.226	.076	.205	.219	.074
R^2		.06			.11			.14	
F		1.60			3.47**			4.36***	

Notes: *p< .05, ** p < .01, p <.001. Immigration status coded as 1 – US citizen, 2 – international student.

Regression results for the third measure of SN connections, availability of introduction to other professionals, are provided in the Table 39 (H-4c). International student status significantly predicted higher availability of introduction to other researchers from academics outside of the US, β = .220, p < .01. US citizen status significantly predicted the likelihood of receiving introduction from non-academic professionals, β = -.243, p < .01. Students whose main research project was based on I/UCRC research had higher availability of introduction from non-academics, β = .167, p < .05. Each model explained only 9% of the variance in each of the outcomes with significant predictors.

Results of the remaining two SN measures, Norms and Values scale (4-d) and number of LinkedIn connections (4-e) are summarized in the Table 40. Both regression models were not significant: number of LinkedIn connections, $F(6, 145) = 1.86$, $p = .092$, and Norms and Values scale, $F(6, 164) = 1.91$, $p = .082$. However, there were individual variables that significantly predicted the outcomes. Students' main project that was based on an I/UCRC research (one of the dosage variables) significantly predicted higher score on the Norms and Values scale, $\beta = .180$, $p < .05$. The model explained 7% of variance. International student

Table 39

Summary of Multiple Regression Analysis of the Availability of Introduction

Independent Variable	Introduction from US academics			Introduction from non-US academics			Introduction from non-academics		
	B	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Imm. status	-.340	.266	-.099	.568	.197	.220**	-.612	.192	-.243**
N of months in grad. school	-.030	.028	-.099	-.011	.020	-.049	-.016	.020	-.071
GPA	.321	.189	.131	.268	.140	.145	.216	.137	.120
N of month at I/UCRC	-.067	.060	-.107	.014	.045	.029	.027	.043	.059
% activity spent on I/UCRC	-.008	.028	-.023	.010	.021	.041	-.008	.020	-.034
Project based on I/UCRC	.438	.323	.112	.296	.240	.100	.481	.234	.167*
R^2		.06			.09			.09	
F		1.71			2.79*			2.84*	

Notes: *$p < .05$, ** $p < .01$, $p < .001$. Immigration status coded as 1 – US citizen, 2 – international student.

status was a significant predictor of the larger number of LinkedIn connections, $\beta = .230$, $p < .01$. The model explained 7% of variance in the outcome.

Results of multiple regressions analyses on other outcomes, PCP (H-5) and Satisfaction with graduate training (H-6) after controlling for immigration status, time spent in graduate school and GPA are summarized in Table Y. Two covariates, time spent in graduate school and GPA were significant predictors of satisfaction. More time students

spent in graduate school, the less satisfied they were with their graduate training, β = -.210, p < .05. Students with higher GPA were more satisfied with their training, β = .229, p < .01. The model explained 10% of variance in satisfaction with graduate training.

Table 40

Summary of Multiple Regression Analysis of Norms and Values Scale and Number of LinkedIn Connections

Independent Variable	Norms and Values			N of LinkedIn		
	B	*SE B*	β	*B*	*SE B*	β
Immigration status	-.756	.558	-.105	2.277	.810	.230**
N of months in grad. school	-.093	.058	-.145	-.074	.086	-.084
GPA	-.125	.397	-.024	-.873	.604	-.119
N of month at I/UCRC	-.070	.126	-.053	.195	.196	.102
% activity spent on I/UCRC	-.024	.059	-.034	.014	.089	.014
Project based on I/UCRC	1.477	.678	.180*	.604	.986	.053
R^2		.07			.07	
F		1.91			1.86	

Notes: *p< .05, ** p < .01, p <.001. Immigration status coded as 1 – US citizen, 2 – international student.

Perceived career preparedness was significantly predicted by GPA and whether student's project was based on the I/UCRC research. Students with higher GPA reported higher PCP score, β = .232, p < .01. Students whose main research project was based on I/UCRC research were also more prepared for the future career, β = .177, p < .05. The model explained 16% of variance in the perceived career preparedness.

In summary, the regression analysis with dosage of the center involvement demonstrated the same pattern of results as results of the two-way ANOVA with the type of graduate training. Dosage of the center involvement was not a strong predictor of the study outcomes. Moreover, only one of the three dosage variables was a predictor for some

Table 41

Summary of Multiple Regression Analysis of Satisfaction and Perceived Career Preparedness

Independent Variable	Satisfaction			Career Preparedness		
	B	*SE B*	*β*	*B*	*SE B*	*β*
Immigration status	-.068	.104	-.050	-.563	.361	-.115
N of months in grad. school	-.025	.011	-.210*	-.063	.037	-.144
GPA	.223	.074	.229**	.815	.257	.232**
N of month at I/UCRC	.016	.023	.064	.112	.081	.124
% activity spent on I/UCRC	.005	.011	.038	.074	.038	.153
Project based on I/UCRC	.146	.126	.094	.996	.438	.177*
R^2		.10			.16	
F		3.08**			5.20***	

Notes: *p< .05, ** p < .01, p <.001. Immigration status coded as 1 – US citizen, 2 – international student.

outcomes. Students whose projects is (was or will be) based on the I/UCRC research find themselves more prepared to future career. Immigration status was again a strong predictor. International students showed larger and stronger network with academic professionals outside of the US. On the other hand, US citizens reported larger and stronger networks with non-academic professionals. GPA was a significant predictor for the general graduate training outcomes like satisfaction and PCP, but it did not predict any of the PSC outcomes.

Next section of the analysis focuses on both types of students, center and non-centers, but instead looks at the PSC and other outcomes based on the type of the experiences students receive rather their affiliation with the centers. It seeks to demonstrate whether the type of training or the type of the experience matters more for the PSC and other outcomes.

Multidisciplinary/Teams, Industry and Experiential Experiences

As described in the methods section, we know that there are three distinct types of graduate experiences: experiences in multidisciplinary and team settings, experiences with industry representatives and experiential or "real-world" experiences. Since both, center and non-center, students are exposed to these experiences at different levels they represent a

second characteristic of the graduate training. Here, training is classified in terms of experiences rather than formal affiliation with a center.

Multiple Regression analyses were conducted with each of the study's outcome, three types of experiences as main IVs and immigration status as covariate. Table 42 provides summary of the results.

The results show the same pattern as the two-way ANOVA results. International status is the strongest predictor of the PSC outcomes where international students show larger and stronger networks with non-US academics and larger LinkedIn network and US citizens show larger and stronger networks with other types of professionals. In addition, US citizens demonstrate higher score on the Norms and Values scale than international students, β = -.12, $p < .05$.

While immigration status is definitely an important predictor of the social network outcomes for students, the type of experiences is a strong predictor of students' bonding PSC, Norms and Values score, and non PSC outcomes like satisfaction and PCP. While more exposure to multidisciplinary/team experiences predicts only higher possibility of advice from US academic professionals, β =.30, $p < .001$, industry and experiential experiences each predict 5 study's outcomes.

More exposure to industry experiences predicts higher score on Norms and Values scale, β =.25, $p < .001$, higher score on the perceived Career Preparedness, β = .34, $p < .001$, and higher level of satisfaction, β = .27, $p < .001$. The same predictive power has experiential experiences on the Norms and Values about collaboration, β = .30, $p < .001$, perceived Career Preparedness, β = .25, $p < .001$, and satisfaction, β = .24, $p < .01$. Experiential training also predicts higher possibility of introduction from US academics, β = .17, $p < .05$, and larger network of non-academic professionals, β = .18, $p < .05$. More experience with industry, strangely enough, predicts smaller size of US academics network, β = -.20, $p < .001$

Table 42

Summary of Multiple Regression Analysis of all Study's Outcomes, Immigration Status and Graduate Experiences

Dependent Variable	Immigration Status			Multidisciplinary/ Teams			Industry			Experiential			R^2	F
	B	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*		
N (US acad.)	-9.16	5.26	-.11	.92	.66	.12	-3.87	1.40	-.20**	2.17	1.25	.14	.06	3.92**
N (non-US acad.)	14.18	2.24	.37***	-.05	.28	-.01	-1.25	.60	-.15*	.39	.54	.06	.14	10.57***
N (non-acad.)	-5.23	1.78	-.18**	-.34	.22	-.13	.52	.47	.08	.96	.43	.18*	.06	4.21**
Advice (US acad.)	-.18	.19	-.06	.09	.02	.30***	-.04	.05	-.05	.08	.05	.14	.15	10.96***
Advice (non-US acad.)	.59	.15	.24***	.02	.02	.11	-.04	.04	-.07	.06	.04	.14	.10	6.83***
Advice (non-acad.)	-.55	.15	-.23***	.02	.02	.11	.05	.04	.09	-.00	.04	-.01	.07	4.91**
Intro. (US acad.)	-.03	.21	-.01	.05	.03	.14	-.03	.06	-.04	.11	.05	.17*	.07	4.78**
Intro. (Non-US acad.)	.59	.15	.23***	.02	.02	.06	-.02	.04	-.03	.06	.04	.13	.08	5.81***
Intro. (non-acad.)	-.40	.15	-.17**	.00	.02	.02	.08	.04	.14	.02	.04	.04	.05	3.34*
Norms & Values	-.89	.43	-.12*	-.07	.06	-.10	.43	.12	.25***	.42	.10	.30***	.18	14.00***
LinkedIn	2.34	.67	.23**	-.13	.08	-.38	-.05	.18	-.02	.26	.16	.14	.06	3.81**
PCP	-.50	.28	-.09	.03	.04	.06	.40	.08	.34***	.25	.07	.25***	.30	27.62***
Satisfaction	-.13	.08	-.09	.00	.01	.03	.09	.02	.27***	.06	.02	.24**	.21	17.31***

**p < .05, ** p < .001, *** p < .001. B, unstandardized regression coefficient; SE, unstandardized standard error; β, standardized beta.*

(6% of variance explained), and academics outside of the US, β = -.15, $p < .05$ (14% of variance explained).

Results indicate again that immigration status is an important predictor of at least half of the study's outcomes. However, center experiences seem to explain more variance explained of a given outcome variable.

International Students' Immigration Plans

Separate analyses were done on international students only. They aimed to answer two research questions about international students' intentions to stay in the US (Q4) and to become a US citizen (Q5) and whether they differ by the type of training they receive. The first dependent variable had four categories (Table 43). Results of the multinomial regression analysis demonstrated that international students' intentions to live in the US were not significantly predicted by the type of their graduate training, $X^2 = 5.723$, $p = .126$.

Table 43

Descriptive Summary of the Intentions to Live in the US

Categories		Frequency	Percent	Valid Percent	Cumulative Percent
	Go back to my home country.	15	5.8	10.3	10.3
	Work for some time in the US and return to my home country eventually.	81	31.2	55.5	65.8
	Stay in the US permanently.	34	13.1	23.3	89.0
	Other (Please, explain)	16	6.2	11.0	100.0
	Total	146	56.2	100.0	
	Missing (US citizens)	114	43.8		
Total		260	100.0		

Nevertheless, crosstab analyses demonstrated a pattern where percentage of students who want to live in the US is higher and percentage of students who want to go home is lower for the center type of training (Table 44).

Table 44

Crosstab of Type of Training and Intentions to Live in the US

		Go back to my home country.	Work for some time in the US and return to my home country eventually.	Stay in the US permanently.	Other (Please, explain)	Total
Center	Count	8	54	27	8	97
	% within	8.2%	55.7%	27.8%	8.2%	100.0%
Non-center	Count	7	27	7	8	49
	% within	14.3%	55.1%	14.3%	16.3%	100.0%
Total	Count	15	81	34	16	146
	% within	10.3%	55.5%	23.3%	11.0%	100.0%

The second dependent variable had three ordered categories (Table 45). Results of the ordinal regression analysis demonstrated that international students' intentions to become a US citizen were not predicted by the type of their graduate training. The odds of center students to become a US citizen was 1.386 (95% CI, .713 to 2.696) times that of non-center students, however, the effect was not statistically significant, Wald $X^2(1) = .926$, $p = .336$.

Table 45

Descriptive Summary of the Intentions to Become a US Citizen

		Frequency	Percent	Valid Percent	Cumulative Percent
	No	33	12.7	22.6	22.6
	Undecided	81	31.2	55.5	78.1
	Yes	32	12.3	21.9	100.0
	Total	146	56.2	100.0	
	US citizens	114	43.8		
Total		260	100.0		

Crosstab analyses, however, demonstrated the same pattern where more center students want to become a US citizen than non-center students (Table 46).

Table 46

Crosstab of Type of Training and Intentions to Become a US Citizen

			No	Undecided	Yes	Total
	Center	Count	20	54	23	97
		% within	20.6%	55.7%	23.7%	100.0%
	Non-center	Count	13	27	9	49
		% within	26.5%	55.1%	18.4%	100.0%
Total		Count	33	81	32	146
		% within total	22.6%	55.5%	21.9%	100.0%

Even though crosstab analyses demonstrated a significant pattern in students intentions to live in the US ($X^2 = 5.66$, $p = .129$) and become a US citizen ($X^2 = .929$, $p = .628$) and the type of graduate training, the difference between groups was not significant.

Discussion

Limitations

One of the study's main limitations is that it does not employ pure experimental design, but rather quasi-experimental design. The goal of the study was to assess a very specific population, graduate students in S&E fields, students trained in centers and students trained via a more traditional advisor and committee format, so students in both samples were selected rather than randomly assigned. Obviously, random assignment of students to conditions was not feasible. Individuals in the center condition were identified by their faculty director and about 23% responded to my survey. Traditional students were selected from the same or comparable universities and academic departments and were screened on whether their research project, master's or dissertation, was either one of the two choices: 1. An individual project that is being supervised by my main academic advisor(s) and thesis/dissertation committee"; or 2. Project that is part of a larger team-based project but is still supervised by my main advisor(s) and thesis/dissertation committee." Nevertheless, two groups, center and non-center, have shown not only to be demographically similar, but also be representative of national population of the graduate S&E students in terms of age, gender, immigration status and nationalities (Science and Engineering Indicators). Thus,

there is some degree of confidence that this study's findings can be generalized to the general population of S&E graduate students.

The concept of social capital does not have a single measure that academia agrees upon. Also very little measurement work has been done in this area. As a consequence, this study necessarily involved a great deal of psychometric development and use of exploratory measures.

For instance, none of the measures of Professional Social Capital was previously established. In this study, the first task was to develop measures of all different components of PSC in the context of graduate students. Also, the measures had to capture *available* networks and students' view of these collaborations. While still exploratory, principal component factor analysis was used to decide on scale structure and strong factor loadings informed whether measures had one or multiple components. Single items had medium to high factor loadings (> .05). Coefficient alphas demonstrated relatively high reliability. However, the scales were not tested on a separate sample and Confirmatory Factor analyses were not performed. Thus, the measures may need additional psychometrical testing.

Violation of the assumption of normal distribution of variables was another significant limitation of this study. The way measures were constructed resulted in different ways this assumption was violated. For instance, bridging social capital measures of network size was measured on continuous numeric scale. This resulted in many extreme outliers on the higher end of spectrum with many students reporting unusually high number of connections in comparison with the rest of the sample. Another example of skewed distribution with limited variability was some the satisfaction or Likert-type measures of network connections' strength where most students reported higher availability of advice or introduction from professionals in their department or their main advisers. Violation of this assumption may have affected the main results of this study.

Findings

The study's had two main overarching goals: to investigate the concept and measurement of Professional Social Capital of the aspiring scientists and whether it differed by the type of graduate training. As part of the first goal, it was important to investigate

whether PSC represents a measurable concept that can be used to evaluate scientific outcomes from the human capital and process-oriented view of the US innovation policies. In other words, the study attempted to measure PSC and investigate whether it has enough variance in the given sample to be applicable to the evaluation of scientific processes. It is important to emphasize, however, that there is little agreement in the published literature on the definition of social capital, not to even mention its measurement. The same researchers who advocated the Scientific and Technical Human Capital model for evaluating scientific outcomes, Bozeman and his colleagues, failed to provide much guidance on how to operationalize these constructs and put their theory on practice (Bozeman et. al, 2001).

I think the study achieved its two primary goals. The first goal was to summarize the literature on social capital and its measurement and to tailor it to the professional environment of the graduate students in S&E disciplines. As a result, the final measures combined two interrelated aspects of social capital that have often than not been used independently of each other: bridging and bonding. The study's measure also was based on the context of the graduate students and their training. The second goal of the study was to test the measure while comparing the two types of graduate training. This second goal was addressed by testing whether the impacts of university-based Cooperative Research Centers and traditional university training differ on PSC and other measures.

Based on the information available from I/UCRC evaluation on the center students' professional experiences and general knowledge about the graduate training in S&E disciplines in the US, the study had multiple hypotheses and questions. The hypotheses were based on a single assumption that center students receive higher dosage of the Professional Social Capital (all its components) and other outcomes like Satisfaction and Perceived Career Preparedness. Separate hypotheses looked at the impact of type of the training predictors, dosage of the center involvement (center students only) and three types of experiences on these outcomes. Students with higher center dosage were expected to show higher outcomes (H4-6). Students with more of those three experiences were expected to show higher scores on study's outcomes (H7-9).

Since most of the literature on the S&E graduate students in the US does not differentiate the outcomes between US citizens and international students, little was known about whether any of the study's outcomes will differ for more than 50% of its population, international students. Thus, all study's questions asked whether study's outcomes differ based on the immigration status of a student. Finally, the last two questions were different from the rest because they focused exclusively on outcomes relevant to international students: (1) intentions to live in the US; (2) intentions to become a US citizen.

Type of Graduate Training

Hypothesis 1 looked at PSC by the type of training students received during graduate school, center and non-center. These analyses also looked at immigration status. All PSC outcomes were predicted to be higher for center students. The outcomes that center students scored higher were: the size of the non-academic network, the availability of advice from non-academic professionals, and the Norms and Values towards collaborations. The hypothesis, however, were not supported for the effect of type of training on other outcomes. International status, on the other hand, was a significant predictor of: size of the non-US academic network, availability of advice and introduction from non-US academic professionals. This finding demonstrates that international students represent a very distinct category that we need to understand better. For instance, the study could have explained this vast difference in the academic network outside the US if it was controlled by where international students received their undergraduate degree. It seems like, however, that most graduate international students come to the US only for graduate school; otherwise, they would not have such large professional network back home. Significantly high number of LinkedIn connections of international students regardless of their center affiliation may also provide a clue especially if one can know how many of their LinkedIn connections are not from the US or from their home country. They may use LinkedIn to stay in touch with their connections outside of the US.

Other bridging outcomes, size of the US academic network and strength of its connections, were not predicted by the type of training and international status. This is an important finding because center students in most cases are part of multi-university centers.

This may mean that even though a center nominally has university collaborators, center students do not get the chance to be exposed to researchers from other institutions or disciplines. The other explanation could be that since center students do get experiences with professionals from other universities and disciplines, but they may not know faculty from their own department as good as non-center students do.

Even though more than one of two-way ANOVAs had graph that looked like interaction, there was only one significant interaction of the type of training and immigration status. If a student is a US citizen and is affiliated with a center, s/he will have higher availability of advice from their non-academic network. On the other hand, international student in the same center will not report the same benefit from his/her non-academic network. This finding clearly demonstrates the gap between international and US students as they may be exposed to the same experiences, but their outcomes are drastically different. The reason for this finding could be a language or cultural barrier or both, since the non-academic networks may be less tolerant to the non-English speaking collaborators than academia. Students at the centers may well be exposed to the more collaborative opportunities on their main projects, but may be other, personal level characteristics, such as language proficiency and cultural background, may be a factor in students' ability to take a full advantage of this environment. On the other hand, this outcome might be explained by a reluctance of US-based industry members to reach out to students who they are less likely to be able to recruit for a job. Again, finding out whether a graduate international student did his undergrad in the US may also be a good indicator of his English proficiency and the level of adaptation to the US culture.

Hypotheses 2 successfully predicted that center students see themselves as more prepared to their careers. Even though the measure of Perceived Career Preparedness is based on self-perception, this finding leads to an interesting research question: is this difference due to personal characteristics of students, like self-esteem, or it is based on their experiences at the centers. The level of PCP did not differ for international students. Even though international students may have challenges in connecting to professionals outside of the academia, they still feel good about their training. Again, it may be that international students

have different goals from the US students and they do not see non-academic network as a very important factor for themselves. It may also be that benefits other than PSC are driving these reports. This finding also translates into the Hypothesis 3 that stated that center students will be more satisfied with their training. The results showed that center students were more satisfied with their training and that there was no immigration status difference in satisfaction. This finding strengthens the assumption that international students may see their training very positive and useful and that the measures of social networks do not objectively characterize this component very well.

Dosage

The next set of hypotheses that were tested by multiple linear regressions predicted that higher dosage of the center involvement will result in higher scores on the PSC (H4), Perceived Career Preparedness (H5) and Satisfaction (H6). However, not all three dosage variables had an effect on the outcome. The difference in outcomes was shown only when center student' main project was based on I/UCRC research. Availability of advice from US academics, availability of introduction from non-academics, the Norms and Value about collaborations and PCP were higher when a center student' main project was based on I/UCRC research. The other two dosage variables did not affect any of the outcomes. These findings demonstrate that more understanding is required of the settings in which a center student conducts his main project. There may be more collaborators involved or representatives from industry, but there is definitely a component that results in more positive PSC and other outcomes. It is interesting that student whose project is based on the I/UCRC research also report more availability of advice from US academics. May be their advisers and other faculty and their industry representatives are more motivated by the I/UCRC project so that they are better in giving feedback to their students. The results also show that the experience of having main project as a part of a bigger goal, center research, results in more positive Norms and Values about collaborations. Thus, the students' experience must be positive. This "real-world" experience of working on project that has direct practical implications also makes students more confident in their career preparedness.

It is important to emphasize that other types of dosage components, months spent working at I/UCRC and percentage of time spent on IUCRC research, do not predict any of the outcomes. Thus, center involvement may be beneficial to students regardless of how long it lasts. Information about which factors are true indicators of center dosage provides very valuable insight into what makes I/UCRC different from traditional training. This study demonstrates that students' main project and the way it is done may be the key to be able to replicate I/UCRC-type of settings.

Demographic covariates were again strong predictors for many of the study's outcomes. Immigration status was a significant predictor for PSC outcomes showing the same patterns from the earlier results: international students show larger and stronger networks with non-US professionals while the US citizens show larger and stronger networks with non-academic professionals. Other covariates were significant predictors for satisfaction. Students with higher GPA and less time spent in graduate school were more satisfied with their graduate training. Naturally, young professionals who spend many years in graduate school at the time when their peers may be earning a significantly more money, find themselves less satisfied with their training.

Graduate Experiences

Hypothesis 7, 8 and 9 stated that graduate school's multidisciplinary/team-based, industry and experiential experiences will result in higher PSC (H7), PCP (H8) and Satisfaction (H9). The hypotheses were correct mostly for the two types of experiences: industry and experiential. Multidisciplinary and team experiences was associated only with higher availability of advice from US academics. Multidisciplinary and team experiences did not predict any other study's outcomes. This may demonstrate that being part of the multidisciplinary and team-based environment creates stronger connection to the US academic professionals, however, that may not necessarily make your non-academic networks stronger.

Experiences with industry and experiential experiences, however, predicted higher scores for the subjective variables like the Norms and Values about collaborations, Perceived Career Preparedness and Satisfaction. The main implication of these findings is that students

with these experiences have more confidence in their future careers and probably feel comfortable about working with different kinds of professionals. This may not be a very quantifiable outcome such as specific skill students learn, but it demonstrates that these experiences laid down a good base for students' careers that one can build upon.

Interestingly, industry experiences significantly predicted smaller size of the US academic and non-US academic networks which was the opposite prediction of hypothesis 7. This shows that there may be a small trade-off when industry is involved in academia. Industry professionals may bring a different component to academic research, for instance, setting strict deadlines and expecting more communication. Thus, students who have more industry experience may be preoccupied by additional requirements that they would otherwise not face in purely academic settings.

Hypothesis 7 predicted that students who were exposed more to experiential experiences demonstrated larger non-academic network and more availability of the introduction to US academic professionals. Immigration status was again a strong predictor of the PSC outcomes. The same pattern was demonstrated for international students and their larger and stronger networks of the non-US academics and larger LinkedIn network. US citizens seemed to benefit more in all other aspects of the PSC.

It is important to note that percentage of the variance explained in the analyses' were not high for the bridging components of the PSC and in most cases accounted for no more than 10% of the variance explained in an outcome. Variance of the other outcomes, PCP and Satisfaction, however, was explained better by the study's predictors accounting closer to 30%.

Immigration Plans

No significant differences were found between international students with different type of graduate training and their plans to stay in the US and to become a US citizen. However, there were patterns where larger percentage of center students indicated that they want to live in the US and become a US citizen than non-center students. Sample size of the categories in each question may have not been large enough for these results to be significant.

Summary of Findings

The results of this study demonstrate that bridging component of professional social capital, pure social network and its strength, differed by the type of training in case of the non-academic network which is mostly comprised from the industry professionals. Size and strength of the US academics network, however, did not differ by the type of training. This indicates that the type of center studied, I/UCRCs, may not function as true collaborative environment and that industry involvement in the centers does not necessarily results in the academic professionals working together. Immigration status was a strong predictor of the size and strength of the non-US academic network across all the study's analyses. International students consistently have larger and stronger networks non-US academics. Even though this finding may not be very surprising, it demonstrates that international students keep in touch with their networks back at home and that network is still available to them.

Bonding PSC which was represented as the Norms and Values about collaborations was significantly predicted by the type of training, dosage (research project) and type of the graduate experiences (industry and experiential). In each case, students who were involved with the centers, have their project based on IUCRC research (center students only) and are exposed to more industry and experiential experiences demonstrate higher scores on the Norms and Values scale. These results indicate that center involvement definitely makes students view collaborations with different professionals more positively. Availability of such trust in other people makes students more likely to invest in their professional social networks.

Perceived Career Preparedness was a self-reported measure and it was always higher for students trained in the centers, with higher center dosage (research project) and more industry and experiential experiences. Center-like and real-world experiences resulted in more students' confidence in the next step of their careers. Similarly to Schneider study, center students are more satisfied with their graduate training. Thus, the study provides the results consistent with previous research findings (2007).

The study also shows that graduate school experiences represent a different way one can look at graduate training. Instead of focusing on the environmental arrangements, like being part of the research center, one can look at to what extent a student is exposed to a particular type of experiences. In addition, since centers are different in it is important to measure the extent to which these experiences vary by center. Industry and Experiential experiences have also shown to predict study's PSC and other outcomes like satisfaction and perceived career preparedness.

The results about international students' immigration plans have shown some important and intriguing patterns. Students trained in the centers show higher means on the variables of whether they want to live in the US upon their graduation and become a US citizen. Nevertheless, the results were not significant. Larger sample may be needed for comprehensive review of the international students' immigration plans.

Implications for Research

Professional social capital and any type of social capital are underdeveloped concepts in the literature. However, these concepts have been around for as long as society has existed. Who you know and how strong your relationships with that person are important forces that shape the society. In the area of scientific progress and distribution of its discoveries, the strong network of people and willingness of these people work together is an important aspect of how successful any new knowledge is implemented in the real-world situations. Thus, additional research about the measurement and potential usage of professional social capital may help to explain the outcomes of human activity in the realms of scientific discoveries and other frameworks. However, how much impact the larger non-academic social capital networks will have on various scientific outcomes remains to be seen.

First and foremost, this study provided a broadened understanding of social capital and how it can be applied in the context of the S&E higher education. Most of the studies done previously did a very poor job in creating reliable and valid measures of social capital. The measures used in this study were based on theory and subjected to some psychometric evaluation. Nevertheless, since the study was exploratory, these measures require new samples and further psychometric evaluation. Also, additional aspects may be added into

these measures. For instance, there should be more questions about the research project of graduate students since it proved to be a significant indicator of center dosage.

Another measurement issue that should probably be examined more closely is specific characteristics of international students. There were few studies that looked at the both, US and international students, in measuring educational outcomes. It is surprising to see so few of them since international student account for more than half of this population. Moreover, the number of professors in S&E disciplines who are not born in the US are probably also growing. And, these foreign-born nationals not only teach, but also become directors of the CRC like I/UCRCs. Overall, foreign born professionals are becoming a significant part of the US society at the higher rate due to technologies and openness of today's world. Our knowledge about this group of potential immigrants does not keep up with demographic changes that are happening at this moment. Thus, future research should identify things that make international students different and how these differences affect the outcomes of the environment they are exposed to. For instance, it will be informative to know how much time they spent in the US and whether their families are located in the US or at their home countries. Information about the background of students US-based professors may also be informative.

There are different types of graduate training, not simply center and non-center. Knowing more information about how individual outcomes can be improved by the specific training experiences a person is exposed to may provide another area of avenue to research. More importantly, study outcomes also differed by the *experiences* students were exposed to. These experiences may represent explanation of *how* the type of training makes a difference for the PSC and other outcomes.

Besides, possible research direction that comes from this study's experiences, the data collected provide opportunity for additional analysis. Information on students' disciplines, universities and centers was collected that nested students into different groups. This data structure creates an opportunity to use more powerful multivariate analyses on the data that were collected. For instance, one can look more closely on predictors at different levels, such as personal (age, gender etc.) and institutional (center, university or discipline).

Implications for Policy and Practice

There are two main policy implications from this study that are related to each other, one is for the US immigration policy and other for the US innovation policy. Immigration in this country is a complex and ongoing issue full of a constant debate. In its best, immigration is a potential for country's economic growth and diversity, and in its worse it may create social injustice and instability. Good immigration policy is priceless. Immigration policy, however, affects immigrant population in different ways because immigrants are very diverse population. Thus, policies must be based on information about different types of immigrants, their immigration trends and possible changes in those trends over time. This study does not look at immigrants; it looks at the international students who have high chance, due to their highly skilled degrees, to eventually immigrate to the US. Thus, informed prediction about what percentage of this population may eventually become US citizens and what factors may affect that decision would be very useful knowledge for policy makers..

Immigration issue is also directly related to the innovation policies in the US. The US is facing higher competition from economically booming Asian Tigers like China, India and South Korea in almost any technology-based sector. At the same time, 60% of its currently trained scientists are from the same region of the world. Thus, the US innovation system, private or public, depends heavily on this workforce and at the same time competes with it. Thus, it is critical to know more about characteristics of this work force.

Since the fame of Silicon Valley, the US has been booming in the number of research hubs, innovative spaces and other environments that are supposed to help innovations. Cooperative centers represent one of these environments and probably the least well known among the general public. This study adds to the growing literature that demonstrates some of the positive impacts of these centers. In this case, my findings demonstrate that I/UCRC students obtain significantly larger and stronger non-academic social capital. Not all of these centers, however, are able to achieve their goal of truly collaborative environment. Therefore, this study provides very useful feedback about what part of the center involvement, dosage, has impact on the professional outcomes such as professional social capital. This study established a starting point indicating that the way the main research project is carried in

graduate school defines how confident students are in their careers and how strong their networks are with non-academic professionals. More information can be gathered about the projects of the graduate students and who have been involved in those projects. Electronic Thesis and Dissertation system that is available in most US universities also provides additional resources that may inform us about this component of graduate training.

Finally, the study bridges the gap between theory and practical implementation of the concept of social capital. This study has demonstrated that professional social capital can be measured systematically if it is done theoretically and psychometrically sound. With the world becoming more educated, there will also be need for characteristics of the workers other than skills and knowledge. Professional social capital should be a part of these characteristics. Due to technological advances, social capital also takes different forms such as digital or virtual in forms of LinkedIn and other social networking sites. Regardless of which type one focuses on, it has proven to be measurable and, thus, has potential to provide useful explanation to various social outcomes.

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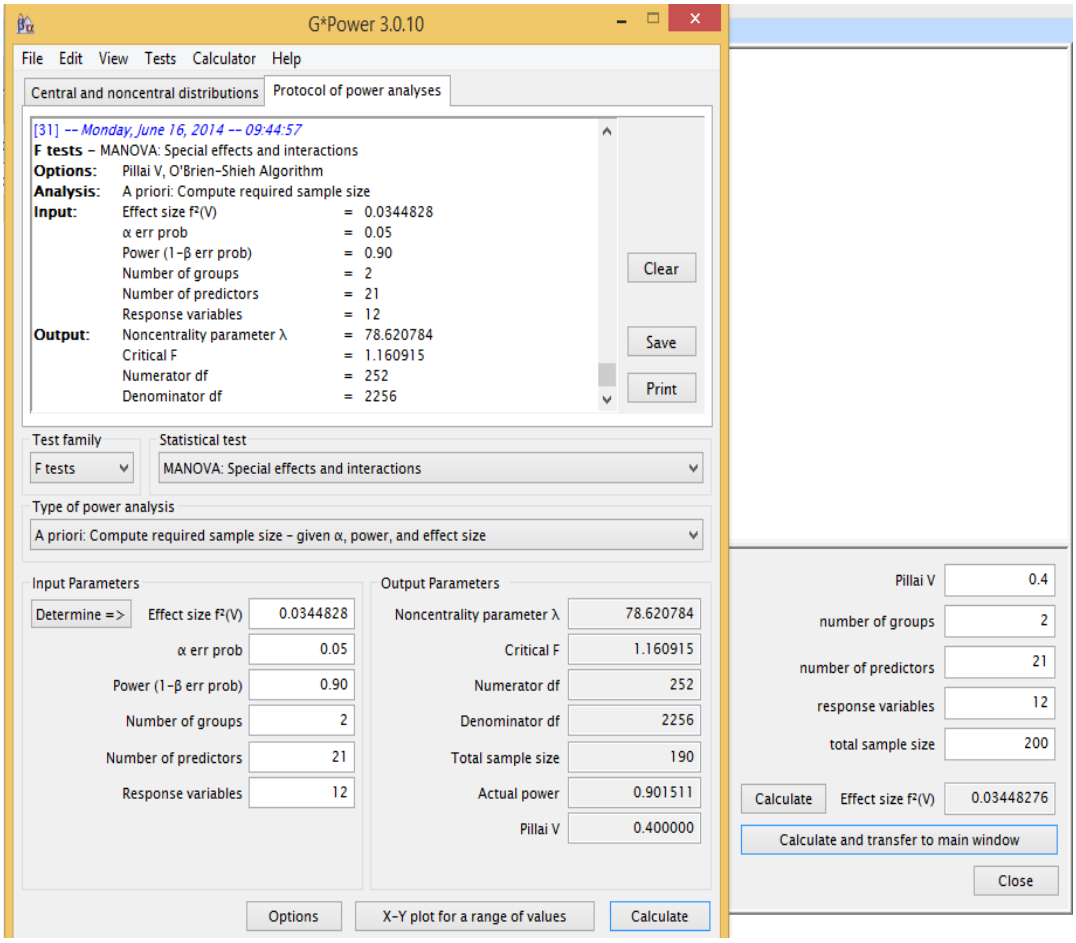
APPENDICES

Appendix A

Snapshot of results of priori power analysis



Appendix B

Empirical Studies that Measured Social Capital

Social Capital Described (1)

Few empirical studies look at SC from the descriptive view point. The study on the entrepreneurs in Argentina is this kind of study that looks at individual SC of entrepreneurs from a stratified sample of 300 start-ups in the Republic of Argentina that started business between 2000 and 2005 (Fornoni, Arribas & Vila, 2010). The data is provided by the Observatory of Small and Medium Enterprises (SME) and the general SME database of Sepyme.

The study has two objectives. First one is based on the authors' belief that one-dimensional approach is not enough to measure SC. The second is the implementation and validation of 3-dimetional tool for measuring SC. The authors define SC from an economic perspective on SC where the potential outcomes are embedded in its definition: "social capital, referring to relations with colleagues, acquaintances or contract which can provide opportunities to access financial and human capital (p. 496). They cite literature on SC's and social networks' outcomes and, thus, fall into the group of researchers who define SC based on its outcomes. This is a common issue on definition of the concept highlighted in the theoretical section of this paper. The authors claim that SC should not be measured in one-dimensional way because SC's different components do not correlate with each other. The authors test this hypothesis by creating and testing the scale of measuring SC based on three distinct components which primarily comes from the work of Batjargal (2003): *structural*, *relational* and *resources* dimensions.

Structural dimension represents more traditional SC and comes from works of pioneers of SC such as Burt and Lin (p. 497). It "depends on the structure of the network and the properties of the position occupied by the agent in the network." Fornoni and others claim that this measure allows one to employ two main ways of measuring individual SC, *position generator* and *name generator*, where first captures more weak ties while second – strong ties. However, the three survey questions representing this dimension are not specific enough to explain a person's social network and do not follow definition of the position and

name generator techniques. For instance, two of the three questions are "yes/no" questions where the first measures self-perceived personal level of contacts and the second - the level of contacts of a person who is identified as *the main contact of the respondent*. *The main contact* is the person who was the most helpful and resourceful for a respondent in his or her entrepreneurial project. However, an entrepreneur may not even have the main contact which makes the second question not relevant. Moreover, "yes/no" response options exclude variance in the social networks of the respondents and do not represent position and name generator techniques.

The second two dimensions, *relational* and *resource*, are even more limited. *Relational* dimension consists of three questions all of which measure strength of the relationships *only* with the main contact: time they know each other, level of confidence in the main contact and nature of relationships. *Resource* dimension consists of two questions: first is asking if the respondent actually used his or her contacts to access a resource and second - if the respondent used the main contact to access an actual resource. Relational dimension is focused only on one contact, which may not even exist in reality and represents too narrow scope to be able to provide the strength of the whole social network of the respondent. Resource dimension, on the other hand, measures the potential outcomes of SC which should not be a part of its definition according to the empirical literature provided in this paper. SC *potentially* can provide a resource through the contacts in the network of an ego. Therefore, the strength of the connection and the characteristics of the people in the network should be measured, not the actual *outcomes* that already took the place.

The authors, nevertheless, proceed with their scale and prove that there is no strong and significant correlation between the different dimensions of SC and conclude that this supports their claim that SC should be measured in a multi-dimensional way where different types of information about an individual are present. While there is value to taking a multi-dimensional perspective to SC, these three dimensions are based on Batjargal's topology and do not reflect commonly accepted types (dimensions) of SC, bonding and bridging, which should have been used as the two different dimensions of the model instead. Overall, the authors ignore extensive theoretical and empirical literature on the commonly accepted

characteristics of SC and rely mainly on their own assumptions. Finally, the dimensions of this model put a different emphasis on the contacts' type, the main contact and general contacts, where one dimension (relational) measured *only* the main contact's characteristics. Therefore, the authors designed this model in such a way that insured the lack of the correlation between the dimensions due to different contacts' being in focus. Further analysis with the three-dimensional scale should not have been conducted due to the poor methodology being used.

Social Capital as Predictor (6)

SC is often taken as a popular predictor of general health and financial stability on individual level. Multiple studies on general health or some of its aspects looked at SC as one of the positive predictors of a good health (Furuta, 2012; Rose, 2000; Rojas & Carlson, 2006). Other types of studies see SC as a positive predictor of individuals' ability to be financially stable, such as repay loans (Dufhues et al., 2011) and avoid bankruptcy (Agarwal et al,2001), and as a predictor of entrepreneurial activity and its development (Davidsson & Honig, 2003).

Health (3)

Social Capital effect on self-rated oral health in Japan

Japanese study on first and second year undergraduate students in Okayama University looked at how SC affects perceived oral health (Furuta, Ekuni, Takao, Suzuki, Morita & Kawachi, 2012). SC, an IV in this study, was measured in the following way: each student was questioned about his/her SC in *family*, *neighborhood* and *high school* during the time they were in high school. One question determined SC in family by asking a student to what extent his/her family was supporting and understanding of the student during the high school years. Two questions measured neighborhood SC: one focused on trust in the neighborhood and the second measured informal social control of adults over young people which is culturally common behavior of adults in Japan. Three questions measured SC in students' high schools: *vertical trust* between teachers and students, *horizontal trust* between students and the level of reciprocity (collaboration) between students.

The results of the study showed that poor self-rated oral health was associated with low level of neighborhood trust, high level of informal social control and low level of vertical trust in students' high schools. Family SC was not significantly associated with self-rated oral health.

The study has many limitations. First, for the measurement of SC, the authors provide very limited description of SC in literature and its measurement. Based on the general social capital theory that trust is an important aspect of SC, they completely ignore the bridging part of social capital which intends to measure the quantity and quality of the social connections of the students. Second, only six questions were designed to measure three different types of SC based on its location: family, neighborhood and high school. It is unreasonable to claim family SC of a student based only on the question of the family support and understanding as we do not know the size of the family (quantity of strong contacts) or the potential resources carried by the family members that embedded in their human capital (education, social status etc.).Conclusively, the authors should have followed literature on measuring SC and designed the questionnaire with more items associated with each type of SC they were looking at.

Social Capital's effect on self-rated physical & emotional health in Russia

Richard Rose looks at SC impact on the health in Russia which has a collective health care system on the contrary to individual such as German or Anglo-American (p. 1421). Data for two IVs (SC and human capital) and DV (self-rated physical and emotional health) come from the nation-wide New Russian Barometer (NRB) survey part which was designed specifically to measure SC. The interview was face-to-face and the sample included 1904 Russians (18 y.o. and over) in 191 dispersed sampling units.

Rose is testing three hypotheses: H1 – Human capital is the primary determinant of individual health; H2 – Social capital is the primary determinant of individual health; H3 – human and social capital are each major determinants of individual health (p. 1423). While HC and self-rated health were measured in a generally-acceptable fashion, SC, for the lack of general measure, was measured by questions that are classified into three categories*: social integration, generic social capital scales* and *health specific social capital*. Social integration

combines indicators on an individual's access to different networks and general trust in his or her surroundings. It contains questions about if 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 (versus city) (p.1429). Generic type social capital 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 socially excluded from these networks. Health-related SC includes 5 questions: three are SC-related (rely on friends & family when ill; paying to doctor; exercising in group) and two are individual-specific (exercising alone & smoking).

In this classification, Rose follows Coleman's theoretical foundation of SC where he claims that SC should not be defined through the norms and attitudes of individuals because one cannot separate these attitudes and beliefs when using SC as a predictor of other variables. Therefore, Rose does not include assessment of norms and beliefs on individuals in his SC scale. While Rose stresses significance of measuring general social integration of an individual, he emphasizes that generic social capital and health specific differ in terms of their outcomes where former "assumes its [SC] utility as generic and diffuse" while later sees its outcomes as sector-specific and makes it impossible to predict individuals' characteristics that are not related to that sector (such as health). Therefore, SC can be looked at from a more general perspective or specific, one where it is defined according to the sector it's being studied (health in this example).

Overall, the OLS multiple regression analysis supports the third hypothesis that both, human and social capital, are stronger predictors of health than they are separate (H1 and H2): "Together, they explain 22.9% of the variance in self-assessed physical health and 19.3% of the variance in emotional health" (p. 1431). To determine the extent to which SC and HC influence on health the unstandardized beta coefficient is used. It shows that the following SC items were significant predictors of the self-rated health: involvement or exclusion from formal and informal networks; friends to rely on when ill; control over one's own life; and trust. All of the HC items were significant, especially, income, but their impact

on health was not as big as of SC. Rose concludes that SC and HC are together significant predictors of health in Russia.

This study stresses the notion that SC influences important aspects of individuals such as health while putting little emphasis on reliability of the concept itself. Similar to many studies on SC where SC is a predictor, Rose does not provide sufficient conceptual validity on what SC is. He again, goes beyond defining SC as is and talks about its potential outcomes: "… social capital is defined instrumentally as the stock of networks that are used to produce goods and services in society, of which health is one example. Networks are relationships between individuals."(1422). Moreover, his rationale on excluding attitudes and norms as part of SC is also based on predictive power of SC simply putting a side a fact that even if some people have access to some networks, depending on their values, they may or may not take advantage of tem.

Many components of the Rose's three-dimensional measure have roots in the literature on SC: access to networks, membership at different organizations, trust in surroundings, and availability of help from others. However, his measure seems to be too complex and large[5] combining all the possible indicators of the SC in the literature. He does not make an attempt to organize his indicators under commonly accepted bridging and bonding types. The health-related social capital part is the most controversial. It combines three questions that can be called network-related, but two other questions are characteristics of individuals (exercising alone and smoking). Therefore, measure of SC in this study may be more appropriate for the scale development of general SC where one could conduct exploratory factor analysis to identify which indicators represent the concept. However, Rose's SC scale is not proven to represent the concept and, thus, cannot be used to predict any, not only, health outcomes.

Social Capital's effect on health in Russia

This study continues to explore the relationship between SC and health in Russia (Rojas & Carlson, 2006). The authors are inspired by Rose's study and want to look at the

[5] Rose does not mention the exact number of questions under Social Capital construct, but the interview is known to last 60 minutes where only 5 generic questions represent human capital and 2 perceived health constructs.

interactions of SC with any other variable that may or may not influence health. They chose the city of Taganrog which used to be known as a typical Russian city in 1980s, however, economic prosperity and standards of living were lower than national overage in 1996 when this study was conducted. People from 1795 households were interviewed by trained female interviewers. The questionnaire contained some items on descriptive statistics (age, marital status, gender), three items that measure SC and educational level as the other predictor of health. SC items measured: participation in union or political organization; membership in any other organization; and frequency of contact with neighbors.

Using multiple regression approach, the authors conducted 5 models where different predictors were eliminated accordingly and interactions of different predictors were addressed. The results show the following. All variables except for marital status and contact with neighbors are significantly associated with health. Higher educational level controlling for three indicators of SC is associated with better health. Membership with any other organization is a health predictor only for people with higher education. Similarly, membership with political organization is a small positive predictor of health for higher educational group. Total household income is used as economic capital predictor. 4 out of 5 models control for this predictor which makes interactions between education and SC components significant. When economic capital is not a control variable, it is a significant predictor for health.

In this study, works of Bourdieu is used as a theoretical foundation. The authors follow his definition of SC: "Social capital is acquired through membership of a group and is understood as effective possession of durable networks or relationships capable of being mobilized or at least manifested" (Bourdieu, 1986, 1990). Based on Bourdieu's work, the authors conclude that they provide empirical evidence that SC should not be looked at in vacuum and that is a common mistake other studies have made. Nevertheless, three questions that measure SC do not combine into a sufficient measure of SC. Rojas and Carlson, similarly to Rose, rely on favorite scholars on SC and simply ignore works of most other influential authors on SC such as Burt, Putman, Lin etc.

Moreover, literature on SC emphasizes the lack of agreement on what SC is and how it should be measured. Instead, these three authors skip this important conceptual problem and focus mainly on looking at SC predictive nature in the relationships with other forms of capital (human and economic). Here is how Rojas and Carlson describe the literature: "…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." However, one of the critical components in the literature for measuring SC is not only the quantity of connections (networks), but also their *quality* which is often measured by contacts' social status or economic level that authors exclude. Rojas and Carlson are also mistaken about the fact that SC does not include the socio-political and cultural differences. These tend to be part of bonding SC, socio-political and cultural characteristics that tend to unite people are associated with strong, bonding connections. In conclusion, these two studies provide some good insights that SC alone probably cannot be a single predictor of health. However, in terms of conceptual value, these studies have little to contribute to further research in terms of a valid measure of SC or at least its main components.

Financial stability (3)

Social Capital's effect on bankruptcy or default

The authors justify their decision to look at SC as IV using the literature that indicates that SC inspires socioeconomic outcomes such as higher economic growth and lower level of corruption in the communities (Agarwal et al. 2001, p. 632). They use socioeconomic characteristics of the credit card owners as the proxies for SC formation (p. 633) (age, marital status, homeownership). The authors look at the SC at two levels of analysis. At the individual level, they measure SC using cardholder's age, marital status, how close she/he lives to the home state and homeownership at the time they open the credit card account. The authors assume that married individuals who live close or in the state they grew up and who own a house have higher SC. Based on the literature they cite, need for acquisition of SC increases but then declines with age. At the state level of SC where individual resides currently, Putman's Social Capital State Index is compared with states' level of filing for

bankruptcy. At both levels, larger amount of SC was associated with smaller percentage of individuals filing for bankruptcy or developing the risk of default.

Even though it was a clever economic study with some interesting findings, the measurement of individual SC comes mainly from the authors' assumptions rather than the literature on SC. Even though they provide reasons for why age, location, marital status and homeownership define the level of SC, the studies they site reflect not what SC is, but rather what affects SC. For instance, the authors provide example of the study that shows that SC tends to be higher in the rural communities (Alesina & LaFerrara, 2000). Based on this, the authors claim that rural cardholders have higher SC than urban. However, it is not clear if they focus on how the location of an individual influences SC or on the fact that people in the rural communities tend to file less for bankruptcy because of the social stigma attached to it which is possible *outcome* of SC. Either way, the authors do not provide any substantial literature on any of the measures of SC they use. Moreover, it seems that authors chose some of the measures based on their effect on the level on bankruptcy rather than its role in the SC concept and based on the information available from the banks on credit cards accounts rather than valid characteristics of SC such as personal networks and trust in others.

Social Capital's effect on loan repayment

Thomas Dufhues and others look at the effect of SC on the individuals' loan repayment performance in rural Thailand (2011). Two hundred fourteen bank credits out of 346 were selected from 50 % of the villages of the Chiang Dao district, Chiang Mai province to measure these relationships. After the data was cleaned and missing data was removed, the total of 3621 respondents combined the study sample. The authors use the name and position generator techniques of social network analysis to create a measure of SC.

The name generator technique typically captures strong ties of a person. A respondent is asked to identify a name of a contact, contact's characteristics and the strength of connections between the two. The lengthy process tends to produce limited number of connections that are only part of the person's network ignoring connections to people who respondent would not interact often or be in a close relationship with (Laumann, 1966) It is a popular approach for ego-centric measures, but it is limited to strong ties with people who

tend to have close relationships with a respondent (ego) (Burt, 1984; Lin, Dean & Ensel, 1986). In order to prevent this bias to one type of ties in people's network, the author use the second, position generator, technique which tends to capture more weak ties. Position generator technique proposed by Lin (Lin & Dumin, 1986) provides a respondent with a list of occupations and structural positions people may have in society and ask him to identify number of people in each category he or she knows. This technique allows to measure "(1) *range* of accessibility to different hierarchical positions in the society (e.g., the distance between the highest and lower accessed positions); (2) *extensity* of heterogeneity of accessibility to different positions (e.g., number of positions accessed); (3) *upper reachability* of accessed social capital (e.g., prestige or status of the highest position accessed)" (Lin, Fu & Hsung, 2001).

Cluster analysis (k-means) on the data obtained from the personal networks in order to measure the strength of the ties in network which differentiate bonding (strong tie) and bridging (weak tie) SC. The second cluster analysis was performed to differentiate linking SC or social distance which compares respondents' social status to his/her contacts using individual occupation. The following four items were used in the cluster analysis of strength of a tie: "role relationship (core family, other family, friend, and acquaintance), frequency of contact per month, duration of relationships in years, and closeness" (p. 1203). Two clusters were defined: weak ties and strong ties.

The following items were used to cluster responses in terms of *social distance* which is "social distance between the respondent and his/her personal network member" using occupations of both. The Standard International Occupation Prestige Scale (SIOPS) is used to cluster responses into clusters based on social distance or *linking* SC (continuous measure). Approximately, half of the responses fall under strong ties (N=1773) and half under weak (N=1848). In terms of linking SC, responses fall under cluster of positive social distance (N=1120) and a cluster that represent small social distance (N=1112) or no social distance/link (N=1389). Based on these clusters, SC was classified into four types: bridging, bonding, $\text{bridging}_{\text{link}}$ (linking SC connected via weak tie), and $\text{bonding}_{\text{link}}$ (linking SC connected via strong tie).

Binary probit regression was used to estimate the relationship between SC (IV) and loan repayment performance (DV) that was assessed with this question: "Have you always paid the principal or interest on time and/or are you able to pay the loan back on time?" (p. 1207). The results of the regression analysis suggest that strong ties, or bonding SC, had a significant and positive effect on repayment performance (p. 1212).

This study used a more comprehensive measurement of SC than most studies reviewed in the literature. Similarly to the theoretical literature, it differentiates SC into different types that tend to capture different types of connections: weak and strong. Linking SC captures social differences between an individual (ego) and the people (alters) he or she is connected in the network. It is assumed that an ego has richer SC if he or she is connected to people who are higher in the social hierarchy since they tend to possess more resources. However, this type of SC has its limitations because it relies on ego's and alters' difference in occupational prestige which may not be applicable in measuring a specific, not general, SC.

Social Capital's effect on nascent status & gestation activity of entrepreneurs

Davidson and Honig look at the effect of SC, along with human capital, on nascent entrepreneur status and the gestation activity during the first 18 months of a start-up (2003). First, 35,971 random people in Sweden were identified to conduct a telephone screening interview which identified 961 people being qualified as nascent entrepreneurs. After the loss of some of the participants due to different reasons, the experimental group accounted total 380 participants. The control group of N=608 was randomly selected from the rest of the screened participants. SC was originally classified into bonding and bridging SC based on the types of connections, strong and weak, in the individuals' networks where four items measured bonding SC and three bridging. *Bonding* SC items included question on: 1. If a parent owned a business before; 2. If close friends and neighbors run their own business; 3. If family or close friends encouraged a respondent to start a business; 4. If a respondent lives with a spouse or a partner. *Bridging* SC included: 1. If respondent was involved in any business network; 2. If respondent had a contact with organization that gives business advice in Sweden; 3. If a respondent was a part of a start-up team or a solo entrepreneur. Since the

bridging SC was only applicable to experimental group, only bonding SC was used in the analysis.

Logistic regression and OLS regression were used to test the relationship between IVs and DV. The effects of bonding SC played an important role in starting a business such as family members' own businesses or encouragement. Bridging SC, on the other hand, was more influential in the later process of starting a business where control group was no longer applicable: business network connections significantly increase business growth of a start-up while connection to planning organization did not have effect at this stage. Finally, closer to the outcome time of a start-up, both bridging and bonding SC had smaller effect on the development of a start-up.

Even though this study differentiate SC between bonding and bridging, only bonding SC is used to compare control and experimental groups at the beginning stage of a start-up – the decision to start a company. Therefore, at this stage of the study SC is not measured in its complete form. Nevertheless, the authors provide comprehensive explanation to the SC typology and design SC measure that is based on both, theoretical literature on measurement and specific population being measured, entrepreneurs. The questions reflect typical entrepreneurs' challenges in starting and developing a business and the role SC can play with its close and weak connection in these two processes. Therefore, this study contributes to the literature knowledge on how to design SC measure for population of entrepreneurs.

Social Capital as Outcome (2)

Welfare state's effect on Social Capital

This study looks at how welfare state (national level) affects individual SC (individual level) (Gelissen, Van Oorschot & Finsveen, 2012). The sample comes from Eurobarometer 62.2 survey in 2004 of 27 the EU states which a total N of individuals is 25,467. Since DV, welfare state, is a variable on the macro level and IV, SC, is looked at individual micro-level, the authors assume that they can see any relationships between two if they take "resources, attitudes, and behavior of individuals that are conductive to their [individuals'] social capital." DV, SC, is measures by "access to informal help from network members outside the family." Eight hypothetical situations were presented and availability of

help was assessed by "yes/no" answers: 1. Help with household tasks, shopping, gardening, etc.; 2. Occasional care for a dependent member of your household (child, elderly, disable, etc.); 3. Personal care including washing, dressing, eating, etc.; 4. Help with paperwork for getting social benefits, prepare tax returns, getting a phone or another service, etc.; 5. Discuss personal problems; 6. Borrow money; 7. Borrow valuable goods (car, use of house, lawn mower, electric drill, etc.); and 8. Help in case you were threatened, harassed or assaulted.

The authors' goal was to assess mechanisms through which welfare state influences individual SC. Explanatory variables included: first order factors (participation in formal/informal networks, help given) and second order (resources, interpersonal trust, and social responsibility) which influence SC directly and indirectly respectively.

Multi-level modeling techniques, ordinal logistic and ordinal least squires, were used to assess how welfare state influence SC and how much variance in SC is explained by explanatory variables. The results showed that there is positive bivariate relationship between welfare spending (ordinal DV) and SC (dichotomous IV), the effect was significant but not large with unstandardized coefficient of 0.073. With first and second order predictors added to the equation the models showed slight decrease – 0.066 and 0.060 respectively. This may indicate that explanatory variables represent correctly the relationships between IV and DV. All the explanatory variables had positive and significant regression coefficient where only one factor had a negative relationship with SC, number of active membership. Interestingly enough, "help of the ego," help respondent gives to others, had the largest explanatory power in comparison with other predictors with unstandardized coefficient of 0.663 and 0.658 in the model with second order predictors.

The relationships of all variables were summarized in the path model described by unstandardized regression coefficient. They concluded that the explanatory mechanisms behind the relationship between welfare state and SC are still not as clear.

This study's overall methodology was strong. However, the measurement of SC again still leaves some doubts. Even though the authors mention theoretical foundations of SC and its forms, bonding and bridging, the actual measurement is based on the access of help outside of family networks in different situations. First, the measurement does not include

bonding SC as it excluded connections outside the family and also because it does not measure "bonding" characteristics of the relationships such as trust and common values. Second, eight different situations provided may not reflect all the possible areas of life of an individual where higher SC may be used for help. Most items reflect some kind of assistance with every day things that some people who are young, single and economically independent may not even need. At the same time, this set of situations may not include areas where particular individuals might actually need help such as starting a business. Therefore, the construct validity is under question.

The Internet and graduate training's effect on Social Capital

This study focuses on the role of internet access and utilization and graduate training composition in professional social capital of scientists in governmental research institutes and state universities in two different locations in the Philippines (Ynalvez & Shrum, 2008). In 2005, face-to-face interview was conducted with 312 scientists working full time in Los Banos, Laguna (N=180) and Munoz, Nueva Esija (N=132). The interview consisted of 200 questions "on socio-demographic characteristics, professional activities, personal networks, collaborative behavior, research productivity, access to communication technologies, and Internet utilization" (p. 349). According to graduate training composition (IV), scientists also have been classified in terms of their degree (Masters or PhD) and where they obtained it (the US, Japan, Australia or the Philippines).

Ynalvez and Shrum provide a comprehensive literature review on social capital and networks in the context of science by stating that:

> Science is organized by areas and structured around network of scientists, who interact through conferences, publications, and seminars … . They also engage in other types of relationships: informal discussions, collaborations, and student-professor mentoring. (p. 345)

In addition, they emphasize the importance of the communication technologies in the era of information age and that it should be a part of analysis of scientists' networks: "Within this transnational network resides the social network of scientists, scientific communities, and state agencies, as well as the technical network of computers, telephone hubs and communication satellites" (p. 346).

In this study, professional SC of scientists was measured using ego-centric social network analysis approach, particularly, name generator where each scientists could name up to 12 contacts and answer additional questions about their contacts and relationships with them. Network size and composition in terms of gender and location of their contacts were measured. Since DV was either binary-nominal or interval-ration in scale, the authors performed logistic and a normal error regression approach to look at the relationships between two IVs and DV.

The results suggested that almost half of scientists' contacts are domestic which means they are in the same location as a respondent. Due to the lack of stable internet access and its successful utilization, most scientists preferred face-to-face or phone communication. Those scientists, who have more regular access to internet and use it for more than just email, tend to have larger networks. Scientists who obtained their degrees in "the research core" places (the US, Japan, Australia) tend to have more contacts from those countries. Interestingly enough, scientists who received their degrees in Japan, which is particularly characterized by close and very frequent relationships of students with their mentors, tend to have largest percentage of contacts from the research core locations.

The authors assume that training in the research core places exposes future scientists to more tacit knowledge which helps students to improve their formal and informal communication, including utilization of the internet that leads to more network connection in their future careers.

This study provides a solid methodology in measuring professional social capital of scientists, it is not overly complicated, but at the same time, it includes components that are important in the scientific world: graduate degree, country where one went to school, current location, characteristics of current location (no stable internet location, government institutes or state universities etc.), gender of respondent and his or her contacts. The face-to-face interview was also probably the right choice of the instrument as the authors were able to understand cultural and geographical characteristics of the two locations in the Philippines that were important part of the context of the scientists. Nevertheless, name generator technique and limit of the number of connections to 12 may have excluded some ties of the

scientists that could be taken into account. As the author noted, almost a half of contacts scientists reported were from the same geographical location in the Philippines as the authors. However, since name generator tends to capture more strong ties and since scientists could name only up to 12 connections, they may have focused naturally more on their colleagues in the closest surrounding excluding their loose connections may be with scientists from the other island or from the research core countries. As it is demonstrated in the literature review, individual social capital should capture both ties of ties, weak and strong, in order to provide a complete picture of one's network.

Appendix C

Empirical Studies of the Center Students

ERC (3)

Two studies were conducted on experiences of the former ERC students while another study was sponsored by NSF to evaluate industry members and their interactions with students during and after students' university training.

ERC Industry Members (Ailes, Roessner, & Feller, 1997)

Ailes, Roessner and Feller's study with the 337 members in ERC demonstrate that industry members are involved with students in three different ways: mentoring students, sharing research projects with student and hiring students. The type of communication is one of the major measures used to assess member-student interaction. In the last year, majority of the industry members communicated on the research objectives with a student (66%) via phone or email. Most members had face-to-face interaction (73%). Nevertheless, only a few members had a more frequent communication with 5 or more communication session during last year via email or phone (15.7%). Only a few members said that they were actually supervising a current or former (working for the company now) ERC student (17.5%). These results demonstrate that on average there was little direct communication of student with industry either for the purpose of their common research projects or mentoring students.

40% of members reported to recruit former ERC students and big majority of them rated students very high on their skills, particularly their ability to work and understand industry' needs. Another important finding was that industry members rated access to ERC students as potential hires as the biggest value of their membership. Therefore, exposure to students as part of being an ERC member was very beneficial for businesses and students' careers. The study, however, focuses mainly on particular firms' benefits without providing information on a bigger impact on students' complete set of networks and social capital that they carry on into the working world. The results are not sufficient enough to draw definite conclusions about ERC students' outcomes because there was no control group of non-ERC students to see if their experiences and potential hiring opportunities differ from ERC students. Also, the industry members surveyed in this study vary greatly in their years of

involvement with ERC which may or may not account on some variation of finding. Finally, the study was conducted more than 15 years ago and does not reflect conditions of current market and rapidly changing industry demands.

ERC Student Alumni and their Current Employers (Scott & Schaad,1992)

This study was developed as a pilot study to identify the best way to measure effectiveness of ERC program for the kind of skills students acquire during their training (Scott, 1992). From the total sample of 217 former students in ERCs, 81% agreed to give interview. Students identified their current supervisors who were given a telephone interview that asked them how employees with ERC training experience were different from employees without such training. Unfortunately, even though 99% of employees agreed to do the interview (N=101, Response rate = 62%), half of them were not very informed about ERC program in general and a third could not differentiate a former ERC employee from non-ERC employee (Scott, 1992). It is hard to draw strong conclusion from this study. Analysis on students' responses was not supported methodologically and the author used these responses mainly to make a proposition on when and how to collect the data in order to evaluate students' outcomes. With the little understanding of the ERCs and background of their employees, employers could not provide useful answers to the ERC effectiveness in forms of students as S&E workforce.

ERC Student Alumni vs. Peers (Parker, 1997)

Another study done by Parker also looked at the former ERC students in the workforce and how their performance was different from their colleagues with no ERC experience (Parker, 1997). Parker surveyed 433 (response rate 60%) former ERC students with masters and PhD degrees via mail. Contact information of their current employers identified in the survey was used to telephone interviews 477 of industry employers (87%).

The first part of the students' survey was to create a list of ERC-specific experiences that were the most helpful for their following career. The two activities that were rated highest by students were real-world experiences (31%) and internships with industry (31%). ERC courses (23%), exposure to different disciplines (21%), high quality equipment or facilities (19%), work in teams (16%), networking (12%), and communication skills (7%)

followed the two. These findings show that students rate the highest activities that are associated with soft skills and opportunity to network and be exposed to other professionals which are directly connected to their social capital.

Students' responses about their performance at current job revealed that ERC alumni who had more significant involvement with ERC-related activities during their training, were significantly more likely to rate themselves higher on variety of skills. ERC alumni who took a sponsored course rated themselves higher on communication and leadership skills; ERC alumni with doctorates who took ERC courses rated themselves significantly higher on interdisciplinary teamwork; ERC alumni who did prototyping were significantly more likely to rate themselves higher on technical knowledge and ability to carry out job responsibility. When alumni had to compare which experiences, ERC or non-ERC, were more helpful, they rated ERC experiences higher, particularly, in interdisciplinary teamwork, networking and relationships with customers (Parker, 1997; Schneider, 2007). This demonstrates that ERC experiences provide more opportunities for and learning from interaction with professionals and also customers in their field.

Supervisors' interview showed that majority of ERC alumni' employers rated former ERC students "somewhat better" or "much better" than other workers. These results indicate that outcomes of the industry collaboration with university students in the form of ERC resulted in higher performance outcomes of the ERC alumni in comparison with their coworkers. Nevertheless, this study has a number of limitations. It was contracted with outside firm to produce report on the former ERC students' effectiveness at the workforce and the final and complete report was obtained only by ERCs. The shortened version of the report that was available for this study does not contain statistical evidence for the study's findings. There was also no control group or a pre-test which are the threats to internal validity, particularly, maturation, history and response bias (Schneider, 2007). Therefore, no conclusion can be drawn on the basis of this study due to a low reliability of its findings.

IUCRC (4)

Most recent and comprehensive research on the S&T students who received their training in the I-U cooperatives was done on students at I/UCRCs.

IUCRC Student Alumni (Scott, Schaad & Brock, 1991)

Scott et al. conducted a follow-up study of the former IUCRCs (10 of the 13 randomly contacted, 83% response rate) Master and PhD graduate students (N=98, 88% response rate) and graduate students at same institutions without IUCRC training to see how IUCRC students perceive their training in comparison with control group (N=70, 51% response rate) (Scott, Schaad & Brock, 1991). Group of I/UCRC students had to be involved at least 18 month with the program to participate in the study.

In all significant differences between two groups I/UCRC students scored higher on their satisfaction with graduate training. Total 14 of significant interactions out of 17 were in favor of the I/UCRC group in their overall satisfaction level with their training. The Professional Participation Composites Score, in particular, showed some social capital impacts where IUCRC 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 (Scott, Schaad & Brock, 1991).

The results of the study however, have some limitations and make any confident conclusions about I/UCRC students having higher satisfaction with their training than departmental students tentative. In evaluating the study's methodology for her thesis, Schneider states that MANOVA would be more appropriate statistical analysis than t-test to evaluate interaction between multiple independent and dependent variables (2007).[6] Also, it is unknown whether there was selection or self-selection bias towards only the best students since IUCRC students were going to receive more funding. Significantly higher response rate for I/UCRC group than for control group may resulted in selection bias of participants. Finally, participants surveyed assessed the program's experiences after they had them and may rely more on their impressions than the details of their experiences that may have been lost by then.

[6] Results from the MANOVA would most likely be significant as 14 out of 17 interactions were found significant.

This study's results indicate that I/UCRC students' outcome – *satisfaction* with their training – was higher than traditional students in their opportunities to do applied work and to be exposed to different professionals. However, these results alone cannot be used alone to support this statement due to methodological limitations.

Unintended Consequences (Behrens & Gray, 2001)

Study of the I/UCRC students by Behrens and Gray had significantly stronger methodological reliability which makes it possible to draw some general conclusions from its findings. The study's goal was to measure if industry funding in CRCs had any "unintended consequences" for students who are involved in the centers' research (Behrens & Gray, 2001).

Six I/UCRC centers at universities with departments in chemical and electrical engineering were selected to represent three different groups of funding each consisting of two centers: low, moderate and high levels. For the first time in the literature, students (N=824, 43% response rate) were characterized by their level of funding: by industry (I/UCRC, single company, and non-university based consortium) (45%), government (34%), and by other university funds or no funding (21%). The results did not support hypothesis that industry funding hinder students' outcomes and researchers concluded that the outcomes of the I-U cooperation on graduate students are still not very well known. The only two significant relationships related to the sources of funding were: an I-U consortium funded student were more likely to do master degree than single-company funded student or student with no funding; while a non-funded student was more likely to do a small research project which consequently could not be a major work such as theses or dissertation that could have been published (Behrens & Gray, 2001).

In general, majority of students' *interaction* (experiences) and *outcomes* were not significantly different by type of funding they received with an exception of students with no external funding who had more struggles with finding funding for their master or PhD research and, as a consequence, had fewer chances to publish their work. Students with governmental funding were more likely to work with a full time professor (65.4%) than students with industry funding (51.8%) or no sponsor (48%).

The findings of this study did not support assumption made in other research that industry funding undermines academic freedom and career choices of the students. Students' career choices were not influenced by industry funding. Regarding of the source of funding, majority of students were more likely to go to industry (66.9%) than academia (28.9%). Almost all I/UCRC students did their thesis or dissertation on the topic of research they were working at the center as a part of their research assistantship. But, even though 21% of these students reported that they were assigned to do this research, students indicated that they had the biggest say in their research (Behrens & Gray, 2001). There was no evidence found that students had less academic freedom to choose and conduct research they were interested in when they received industry funding. This study provided little information, however, on either industry- or academia-oriented students' social capital that they could draw upon by the end of their training.

Academic Capitalism (Mendoza, 2007)

Another study was conducted with I/UCRC students. Pilar Mendoza, the author, does not say which center was used for confidentiality purposes (Mendoza, 2007). He looked at how academic capitalism, in other words, involvement with industry, affects students' socialization. Particularly, he wants to see if students start thinking in a different ways when they work with industry citing that industry has a different ideological goal to bring profit rather than do research for good of society.

Mendoza decides to do a case study of students from one center and the academic department where center resides. The center is successful in having more than 30 industry members that fund its activities, primarily, graduate students. According to Tinto stage of students' socialization (Tinto, 1993),10 students were selected to represent adaptation stage of socialization, first 2 years in the program, and another 10 represented advanced stage of socialization in academia. Ethnographical interviews were conducted for 1-1.5 hour long (Mendoza, 2007).

Students were asked to evaluate organizational culture, particularly, industry involvement which can be seen as bonding aspect of SC. All the students perceived industry in academia in a positive light and many of them did not have anything negative to say about

it. There was no instance of "exploitation" of "cheap labor" by industry. On the contrary, they saw themselves receiving a high value from this interaction particularly in forms of funding, job opportunities, networking, and learning about industry before graduating from academia. Finally, students did not see industry being more prestigious future than academia. On the contrary, they considered the two as complementing each other saying that it is good to have a couple of years of experience in industry before going to academia. Their reasons for going to academia followed the culture of freedom of research and were not diminished by industry's ideology of applied research.

When advanced group was compared to beginning group, advanced students thought that publications are the primary goal of their work while beginning students, overwhelmed with industry presence in the department, thought that patents were natural results of their work.

There were also differences between students who were exposed to industry on different levels or were not exposed to it at all. Students with no industry exposure perceived more time pressure to deliver the findings for industry research and less freedom for faculty to choose research they like. While students who had industry interaction had more positive remarks about the industry and did not see time constraints or less freedom with industry. This difference may also indicate different beliefs that students may develop towards industry depending on the kind of training they are exposed to. Differences were identified in how students describes the way research topic were chosen. Students without industry involvement thought that faculty's seniority defines who makes those decisions, while students working with industry thought that younger faculty has to go with research that is dictated by market/industry and after some years of experience receiving more freedom on topic selection.

There were no difference in socialization experiences found for students of different race, gender age and ethnicity. It is important to acknowledge, however, that this was not a research question of this study. Slight difference was between US and non-US students where non-US students had more struggle in communicating with industry and rating wealth of the department as a high priority for their research.

Overall results suggest that academic capitalism or industry in academia does not change the value system of academia using mechanism of socialization of students with industry. Moreover, it provides many positive benefits making students very satisfied with their experiences. These findings have implications that students who acquire more SC may be more satisfied with their graduate training and in general view . The study results should not be generalized to all the I/UCRC centers as they are hosted at different universities and represent different disciplines.

Graduate Students' Perceptions (Schneider, 2007)

Schneider conducted a cross-sectional predictive analysis of I/UCRC graduate students to identify if their demographics and training experiences at the centers predict outcomes for students (Schneider, 2007). In 2006-2006 fiscal year, 39 I/UCRC and one ERC were contacted by researchers to provide their students' contact information. With the 87% center response rate, Schneider received 528 addresses from 34 centers. She measured satisfaction of students with their training, self-reported skills, organizational commitment with the center, perceived competitive advantage in comparison with non-center students, scholarly achievement and career goals.

One of the findings of the study was the description of students' experiences at the centers. Most students had their thesis/dissertation link to the center research with majority of students having multidisciplinary committee for their research.

The students in the sample were involved in the centers at different lengths of time. One-fifth of the students had 6 or more people on their projects while two quarters of students had either two or three people working on their project in the team. Two main factors were identified through exploratory factor analysis: experiential experiences (hands-on) and multidisciplinary experiences with industry and professionals from other disciplines.

Schneider also measured students' involvement in the centers' typical activities. In the scale from 1 to 5 where 1 is "not involved at all" and 5 – "extremely involved", these were the activities and means of the students' involvement: regular meeting with the project team (Mean=3.6, *N*=177); regular meetings with the entire center team (Mean=2.78, *N*=165); periodic center IAB meetings (Mean=3.05, N=133); scientific/technical seminars with

external speakers (Mean=2.32, *N*=164); co-op or internship placements (Mean=1.84, *N*=68); workshop on "soft skills" or non-technical topics (Mean=2.63, N=27); mentoring and educational interventions with youth (Mean=2.56, N=27 and Mean=2.30, N=27 respectively) (Schneider, 2007). As numbers demonstrate, not all students in the centers receive the same opportunities due to differences among centers and mechanisms they offer.

Multiple regression analysis was used to identify significant predictors of the dependent variables: satisfaction with the training, perceived soft and technical skills, the level of organizational commitment, academic achievements such as publications and technical reports and career goals.

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 had more interaction with their committee and industry members. Also, U.S. students and students who spent more time in the program were more likely to rate higher the level of soft skills they gain. Controlling for the number of years in graduate school, students with more multidisciplinary experience, involved in more technical aspects of the projects and who interacted more often with committee members perceived as having higher advanced technical skills.

The level of organizational commitment was predicted by two factors: extent to which students had experiential experiences and extent to which they had multidisciplinary interactions. Perceived competitive advantage was predicted by the level of experiential learning students experience at the centers with more "hands-on experience, students believe they have more competitive advantage over their peers. More publications were produced by the students who were more involved with the variety of centers' mechanisms and were communicating more often with committee members. Students who interacted more with committee members also were more likely to produce more technical reports. Surprisingly, GPA in this prediction had a negative effect on the students' production of the technical reports.

Finally, there was a significant difference for gender and citizenship status in satisfaction. The more experiential training students receive, the more males and non-U.S.

students were satisfied with their training when females and U.S. citizens were highly satisfied no matter of the experiential component in their training.

In the qualitative analysis of the open-ended questions, three main groups of the skills that 30 students identified three main types of skills on which they want the centers to put more emphasis on: technical (26.7%), communication (20.0%) and soft skills (20.0%). Fifty eight students gave comments on the question of the strength and weaknesses of receiving training at a center where two main strengths were general collaborations (19.0%) and interactions with industry (17.2%) which directly related to SC. Two main weaknesses were operations/administration (12.1%) and time allocation/workload (10.3%). Finally, 39 students identified three major areas they think the centers should be improved: courses/curriculum (28.2%), seminars/meetings (25.6%) and training & involvement (23.1%).

Schneider provided comprehensive information about students' satisfaction and perceived outcomes in CRCs. She showed that satisfaction with graduate training depend on different experiences and is not the same for male and female students. Nevertheless, it is hard to conclude anything about students' social capital based on the study's results. The study also has its limits. Even though centers' experiences were positive in nature, the lack of comparison group from more traditional academic settings puts restrictions on concluding on the effectiveness of their training without inclusion of other students in the analysis.

Overseas I-U Graduate Students

In the late 2000s, other developed countries than the U.S. demonstrated a particular interest in increasing industry involvement on university campus and how it affects doctorate students who represent the main working force of the research produced in these I-U collaborations. Two countries in particular, produce research that investigates students' experiences in the context of the I-U: Norway and Australia. The I-U link in these counties similarly to the U.S. takes different forms where Norway has more diverse relationships with industry involving individual contracts and grants and Australia has a large population of students from the government-sponsored program of Cooperative Research Centers that started in 1990.

I-U links and doctorate students in Norway (Thune, 2010)

In Norway, industry is actively involved in academic research in material sciences, engineering, business economics and information and communication technology. Thune conducted qualitative study with 25 doctorate students in the three out of four academic departments concentrated in the fields of engineering, sciences and business. Half of the students were funded by combination of university and governmental research grants and industry (N=13) and another half had a full industrial funding (N=12) (Thune, 2010). It is important to note however that two out of 12 students funded fully by industry were funded by a consortium of firms and 10 were funded by an individual company.

The exploratory analysis of the face-to-face interviews revealed a great deal of variation among students' individual responses and among three groups that represented different disciplines. First, decisions to be involved in collaborative projects with industry (either full sponsorship or partial) vary with two reasons being the most popular: to work with industry (most students demonstrated desire to work in private sector) and simply to receive funding for their research. Second, surprisingly to some of the previous results on the students' experiences, students who had full industry funding had more freedom to choose the research topic and manage it more freely than students who worked under grant obligations where government was one of the funders. Some responses indicate however, that the nature of the research project may have bigger influence on the students' freedom to decide on management and direction of their research.

Interaction with industry has more homogeneous character. Most students reported that at the initial stage of the collaboration, they had meaningful interaction with an industry member (Thune, 2010). However, with time, frequencies of this interaction declined often as a result of leaving of "the contact person" in that firm. While some research argues that students may be pushed by the industry to the direction industry is primarily interested in, students, in contrast, describe that they do not have as much interaction with industry as they wish. Finally, academic advisors play an important role in this interaction: they require students to interact with industry as long as it is a concern of their thesis or dissertation. Therefore, with an exception of the 5 business students in this sample who provide additional

consulting services to their firms, the rest of the students work with industry only on their main academic project. Based on the 25 interviews with students, Thune provides three conclusions on Triple Helix students. First, she states that the industry included in this sample had a good understanding of R&D process and academic demands. Therefore, they know what they can or cannot ask students to do. Second, she concludes that academic professors are very experienced dealing with industry-sponsored research and manage the collaborative process successfully that does not undermines students' traditional educational outcomes such as process towards their degrees and publications. And, lastly, the companies that get involved in the cooperative research do not have high stakes in these projects which often prevents legal or other difficulties in managing research in a collaborative fashion.

This study provides some useful insights about students' experiences in Triple Helix collaborations. It can be concluded that students' experiences with industry are very diverse depending on their personal preferences and their field of studying. Moreover, there are probably differences between these collaborations among different countries such as Norway and the US. The findings did not seem to show any negative attitude of students towards industry. On the contrary, they seem to seek industry as professional leaning experience and as additional source of funding. Choice of topic and academic freedom does not seem to suffer from industry involvement as well. Nevertheless, the findings should be interpreted with caution. First, the study was conducted in Norway where demands of the companies and university structure can substantially different from the US. Second, the findings cannot be generalizable because of the different disciplines having different needs for cooperative research process. Third, none of the statistical data was provided to support of the findings besides describing the groupings of common themes in students' responses. Therefore, similarly to most other studies on this topic, these findings cannot be used to promote further recommendations.

CRCs and doctorate students in Australia (Harman, 2008)

In 1990s, Australia experienced an intensive growth in number of research institutions and in awarded PhDs (Evans et al., 2003; Kemp, 2004). With the growth of doctorates and more opportunities to conduct research, industry and government became

more involved in universities one of the outcomes of which was creation of CRCs. Naturally, the question came up on which type of training, traditional or cooperative, is more effective in satisfying needs of society in terms of the set of skills young professionals acquire in their training.

The goal of the current study was to investigate how training experiences of the CRC students differ from non-CRC students and if CRC students acquire more skills required by today's scientific demands (Harman, 2008). The author provides two types of educational models that have different "modes of knowledge production." "Mode 1" (non-CRC) is characterized by academia as the main player in production of knowledge and new generation of scientists. "Mode 2 " (CRC), on the other hand, is characterized by active involvement of industry, research parks and think tanks that bring additional expertise and market understanding to the university research and education of the future scientists mentored by professionals from multiple disciplines and private sector.

Social survey administered in 2000 to 3725 doctorate students in Australia tried to find if there are differences between groups. With the response of 42.02%, 1549 responses were received. The focus of the study was to look at the students in engineering and sciences because industry tends to be particularly interested in R&D. Also, the researcher particularly focused on students who are full-time students because the students with part-time employment were perceived to already have some employment opportunities upon completion of their studies.

Results suggest that CRC students rated industry involvement significantly higher than non-CRC students on many items. More CRC students (68.5%) liked the idea of working with industry than non-CRC students (58.4%). CRC students (74%) rate possibility of working in industry higher than non-CRC (62.5%). Both groups rated very high their future career prospects as a result of the industry involvement: 86.3% for CRC and 84.9% for non-CRC student. Finally, more CRC students (74.0%) were optimistic about their professional career after graduation than non-CRC students (62.0%). In addition, smaller number of CRC students stated that I-U links represent a threat to academic values: CRC (23.3%) and Mode 1 non-CRC (27.3%).

The author concludes that findings demonstrate the changing nature of the knowledge production in S&E and that CRC model of external players, particularly, industry, not only helps to produce better knowledge, but also a new generation of scientists who are more "industry-ready" to satisfy social demands of today's world. Nevertheless, Harman's findings do not prove that industry involvement provides significantly higher outcomes. First of all, she only measured students' perception of their training. While students may be more satisfied with industry, it does not mean it provides better outcomes for them. Also, the changes in students' perception on the industry involvement may also indicate that presence of industry changes students' values which may be viewed as a negative outcome. The context of the survey, students' perceptions about industry links, is not a valid indicator for the effectiveness of the "mode 2" knowledge production. Therefore, the results of the survey provide more information about the students' experiences, but they do not represent strong evidence that I-U links provide better prepared doctorates than more traditional university settings.

Appendix D

Graduate Schools of the Center and non-Center Groups' Students

Graduate School Name		Group		Total
		Center	Non-Center	
Arizona State University	Count	12	2	14
	% within Group2	6.9%	2.3%	5.4%
Boston University	Count	0	1	1
	% within Group2	0.0%	1.1%	0.4%
Brigham Young University	Count	3	0	3
	% within Group2	1.7%	0.0%	1.2%
Clemson University	Count	2	0	2
	% within Group2	1.2%	0.0%	0.8%
Colorado School of Mines	Count	4	0	4
	% within Group2	2.3%	0.0%	1.5%
Colorado State University	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
Drexel University	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
Georgia Institute of Technology	Count	4	0	4
	% within Group2	2.3%	0.0%	1.5%
Iowa State University	Count	3	0	3
	% within Group2	1.7%	0.0%	1.2%
Leigh University	Count	2	0	2
	% within Group2	1.2%	0.0%	0.8%
Marquette University	Count	2	0	2
	% within Group2	1.2%	0.0%	0.8%
Mississippi State University	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
Missouri University of Science & Tech.	Count	10	0	10
	% within Group2	5.8%	0.0%	3.8%
New Jersey Institute of Technology	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
North Carolina State University	Count	3	53	56
	% within Group2	1.7%	60.9%	21.5%
Northeastern University	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
Ohio State University	Count	24	5	29
	% within Group2	13.9%	5.7%	11.2%
Pennsylvania State University	Count	3	0	3
	% within Group2	1.7%	0.0%	1.2%
Purdue University	Count	14	18	32
	% within Group2	8.1%	20.7%	12.3%
Rutgers University	Count	2	0	2
	% within Group2	1.2%	0.0%	0.8%
Southern Methodist University	Count	3	0	3
	% within Group2	1.7%	0.0%	1.2%
State University of New York	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%

University of Arkansas	Count	7	0	7
	% within Group2	4.0%	0.0%	2.7%
University of California, Berkeley	Count	16	0	16
	% within Group2	9.2%	0.0%	6.2%
University of California, Davis	Count	2	0	2
	% within Group2	1.2%	0.0%	0.8%
University of Colorado at Boulder	Count	4	0	4
	% within Group2	2.3%	0.0%	1.5%
University of Florida	Count	3	0	3
	% within Group2	1.7%	0.0%	1.2%
University of Hawaii	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
University of Illinois, Urbana-Champagne	Count	2	0	2
	% within Group2	1.2%	0.0%	0.8%
University of Kentucky	Count	5	0	5
	% within Group2	2.9%	0.0%	1.9%
University of Massachusetts	Count	2	0	2
	% within Group2	1.2%	0.0%	0.8%
University of Miami	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
University of Missouri Columbia	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
University of North Carolina, Charlotte	Count	5	0	5
	% within Group2	2.9%	0.0%	1.9%
University of North Texas	Count	3	0	3
	% within Group2	1.7%	0.0%	1.2%
University of South Carolina	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
University of Texas, Austin	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
University of Texas, Dallas	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
University of Wisconsin-Madison	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
University of Wisconsin-Milwaukee	Count	4	0	4
	% within Group2	2.3%	0.0%	1.5%
West Virginia University	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
Other	Count	2	2	4
	% within Group2	1.2%	2.3%	1.5%
University of Louisiana at Lafayette	Count	4	0	4
	% within Group2	2.3%	0.0%	1.5%
George Mason University	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
Arenberg Doctoral School (KU Leuven)	Count	1	0	1
	% within Group2	0.6%	0.0%	0.4%
Virginia Tech	Count	7	0	7
	% within Group2	4.0%	0.0%	2.7%
California Institute of Technology	Count	0	2	2
	% within Group2	0.0%	2.3%	0.8%
Virginia Commonwealth University	Count	0	4	4
	% within Group2	0.0%	4.6%	1.5%

Appendix E

Descriptive Summary of Social Network Size Measures with Outliers

Variable	N	Mean	SD	S	SE
Academic advisers who are directing/supervising you with your thesis or dissertation.	262	2.54	1.603	1.022	.150
Faculty from your department.	261	9.07	7.067	2.304	.151
Other graduate students or post-docs from your department.	261	22.54	23.839	4.544	.151
Faculty from other disciplines/departments from your university.	260	4.75	5.911	3.378	.151
Faculty from other universities in the United States.	260	5.59	8.018	4.503	.151
Graduate students or post-docs outside of your department at your university.	260	9.54	12.663	3.600	.151
Graduate students or post-docs from other universities.	260	10.28	18.267	5.785	.151
Representatives of large privately owned companies (e.g. Google, Microsoft, Boeing etc.)	260	5.53	9.917	4.973	.151
Representatives of small private companies (1 - 500 employees)	260	4.50	8.528	6.621	.151
Representatives of the United States Federal, State or Local government.	260	1.54	4.188	7.613	.151
Representatives of non-profit organizations, associations or foundations.	260	1.30	2.951	4.212	.151
Entrepreneurs (start-ups' representatives)	259	1.21	2.143	2.746	.151
Faculty from universities outside of the United States.	259	4.73	7.896	2.921	.151
Graduate students or post-docs outside of the United States.	260	8.95	26.281	7.313	.151

Descriptive Summary of Social Network Size Measures after Recoding Outliers

Variable	N	Mean	SD	Skewness	
Academic advisers who are directing/supervising you with your thesis or dissertation.	259	2.53	1.566	.844	.151
Faculty from your department.	258	8.86	6.308	1.369	.152
Other graduate students or post-docs from your department.	258	21.33	17.398	1.402	.152
Faculty from other disciplines/departments from your university.	257	4.47	4.699	1.850	.152
Faculty from other universities in the United States.	257	5.16	5.846	1.791	.152
Graduate students or post-docs outside of your department at your university.	257	9.07	10.194	1.513	.152
Graduate students or post-docs from other universities.	257	9.19	11.912	2.187	.152
Representatives of large privately owned companies (e.g. Google, Microsoft, Boeing etc.)	257	4.81	6.513	2.155	.152
Representatives of small private companies (1 - 500 employees)	257	4.11	5.778	2.483	.152
Representatives of the United States Federal, State or Local government.	257	1.28	2.325	2.272	.152
Representatives of non-profit organizations, associations or foundations.	257	1.16	2.253	2.504	.152
Entrepreneurs (start-ups' representatives)	256	1.18	2.041	2.348	.152
Faculty from universities outside of the United States.	256	4.63	7.681	2.793	.152
Graduate students or post-docs outside of the United States.	257	6.70	12.493	2.918	.152

Descriptive Summary of Social Network Strength in form of Advice and Introduction

Variable	Mean	SD	S	SE
Technical advice and input: Other academic professionals (faculty, graduate students and post-docs) from my department.	4.19	.866	-1.065	.151
Technical advice and input:.-Academic professionals (faculty, graduate students and post-docs) from other U.S. universities or disciplines.	3.77	.990	-.182	.151
Technical advice and input: Academic professionals (faculty, graduate students and post-docs) outside of the United States.	3.65	1.251	.147	.151
Technical advice and input: -Non-academic professionals.	3.61	1.182	-.029	.151
Technical advice and input:.-Your academic adviser(s).	4.63	.796	-2.805	.151
Introduction: Other academic professionals (faculty, graduate students and post-docs) from my department.	4.22	.829	-1.159	.151
Introduction: Academic professionals (faculty, graduate students and post-docs) from other U.S. universities or disciplines.	3.85	1.024	-.469	.151
Introduction: Academic professionals (faculty, graduate students and post-docs) outside of the United States.	3.69	1.248	-.144	.151
Introduction: Non-academic professionals.	3.70	1.199	-.333	.151
Introduction: Your academic adviser(s).	4.54	.826	-2.293	.151

Appendix F

Table X

Means and Standard Deviations across experimental and control groups for all study outcomes

Dependent Variable	Experimental			Control		
	Mean	SD	N	Mean	SD	N
Number of the US academics	56.05	38.98	170	61.90	48.24	87
Number of the non-US academics	10.25	17.68	169	13.46	21.08	87
Number of non-academics	14.15	15.31	169	9.38	11.62	87
Advice from the US academics	7.88	1.61	173	7.72	1.54	87
Advice from the non-US academics	3.14	1.23	173	3.28	1.20	87
Advice from non-academics	3.48	1.20	173	3.18	1.13	87
Introduction from the US academics	8.01	1.70	173	7.82	1.72	87
Introduction from the non-US academics	3.34	1.28	173	3.36	1.20	87
Introduction from non-academics	3.59	1.25	173	3.30	1.12	87
Norms & Values	35.63	3.58	173	33.92	3.59	87
Number of LinkedIn connections	6.64	4.89	154	6.74	5.28	74
Multidisciplinary and Teams experience	20.00	5.49	173	19.46	5.096	87
Industry experience	9.66	1.97	173	7.93	2.20	87
Experiential experience	14.73	2.67	173	13.79	2.76	87
Career Preparedness	16.84	2.43	173	14.92	2.60	87
Satisfaction	2.33	0.67	173	1.95	0.65	87

Table X

Means and Standard Deviations across US citizens and international students for all study outcomes

Dependent Variable	US citizen			International		
	Mean	SD	N	Mean	SD	N
Number of the US academics	63.71	40.67	114	53.50	43.29	143
Number of the non-US academics	3.79	6.68	113	17.31	22.95	143
Number of non-academics	15.45	16.04	113	10.22	12.38	143
Advice from the US academics	7.89	1.62	114	7.79	1.56	146
Advice from the non-US academics	2.85	1.29	114	3.45	1.10	146
Advice from non-academics	3.66	1.17	114	3.16	1.15	146
Introduction from the US academics	7.94	1.93	114	7.95	1.52	146
Introduction from the non-US academics	3.01	1.45	114	3.61	1.01	146
Introduction from non-academics	3.69	1.21	114	3.34	1.12	146
Norms & Values	35.45	3.47	114	34.75	3.91	146
Number of LinkedIn connections	5.39	3.80	97	7.62	5.57	131
Multidisciplinary and teams	19.22	5.43	114	20.29	5.27	146
Industry	8.78	2.39	114	9.32	2.03	146
Experiential	14.37	2.67	114	14.45	2.79	146
Career Preparedness	16.32	2.86	114	16.10	2.47	146
Satisfaction	2.25	0.69	114	2.17	0.68	146

Appendix G

One-tailed bivariate correlations of the main independent variables, the type of training and immigration status, with the Social Capital outcomes

	Group	Imm. status	Academics in US	Non-US acad.	Non-acad.	Advice acad. in US	Advice non-US acad.	Advice non-acad.	Intro. Acad. in US	Intro. non-US acad.	Intro. non-acad.	Norms & Values
Group	1	.002	.066	.080	-.158**	-.048	.053	-.118*	-.054	.006	-.113*	-.217**
		.485	.148	.100	.006	.222	.197	.028	.192	.463	.034	.000
Immigration status?	.002	1	-.120*	.356**	-.182**	-.031	.242**	-.208**	.004	.238**	-.146**	-.092
	.485		.027	.000	.002	.311	.000	.000	.475	.000	.009	.069
Academics in US	.066	-.120*	1	.473**	.387**	.121*	.096	.029	.071	.122*	.059	.098
	.148	.027		.000	.000	.027	.063	.324	.127	.026	.173	.059
Non-US academics	.080	.356**	.473**	1	.109*	.116*	.196**	-.065	-.002	.182**	-.024	-.085
	.100	.000	.000		.040	.032	.001	.151	.485	.002	.350	.088
Non-academics	-.158**	-.182**	.387**	.109*	1	.095	.088	.230**	.156**	.112*	.283**	.166**
	.006	.002	.000	.040		.065	.081	.000	.006	.037	.000	.004
Advice from academics in US	-.048	-.031	.121*	.116*	.095	1	.453**	.378**	.566**	.350**	.311**	.215**
	.222	.311	.027	.032	.065		.000	.000	.000	.000	.000	.000
Advice from non-US academics	.053	.242**	.096	.196**	.088	.453**	1	.286**	.268**	.615**	.264**	.072
	.197	.000	.063	.001	.081	.000		.000	.000	.000	.000	.123
Advice from non-academics	-.118*	-.208**	.029	-.065	.230**	.378**	.286**	1	.246**	.187**	.646**	.064
	.028	.000	.324	.151	.000	.000	.000		.000	.001	.000	.151
Intro. from	-.054	.004	.071	-.002	.156**	.566**	.268**	.246**	1	.542**	.502**	.116*

academics in US	.192	.475	.127	.485	.006	.000	.000	.000		.000	.000	.031
Intro. from non-US academics	.006	.238**	.122*	.182**	.112*	.350**	.615**	.187**	.542**	1	.445**	.086
	.463	.000	.026	.002	.037	.000	.000	.001	.000		.000	.084
Intro. from non-academics	-.113*	-.146**	.059	-.024	.283**	.311**	.264**	.646**	.502**	.445**	1	.108*
	.034	.009	.173	.350	.000	.000	.000	.000	.000	.000		.042
Norms and Values	-.217**	-.092	.098	-.085	.166**	.215**	.072	.064	.116*	.086	.108*	1
	.000	.069	.059	.088	.004	.000	.123	.151	.031	.084	.042	

One-tailed bivariate correlations of the main independent variables and other study outcomes

		Group2	Immigration status	N of LinkedIn connections	Experiences: multidiscipline, team	Experiences: industry	Experiences: experiential
Group	R	1	.002	.010	-.048	-.372**	-.162**
Immigration status	R	.002	1	.220**	.099	.122*	.015
N of LinkedIn connections	R	.010	.220**	1	-.040	.009	.055
Experiences: multidisciplinary and team	R	-.048	.099	-.040	1	.515**	.637**
Experiences: industry	R	-.372**	.122*	.009	.515**	1	.464**
Experiences: experiential	R	-.162**	.015	.055	.637**	.464**	1

Appendix H

Professional Social Capital of S&E graduate students

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)
- City University of New York, City College (7)
- Clarkson University (8)
- Clemson University (9)
- Colorado School of Mines (10)
- Colorado State University (11)
- Columbia University (12)
- Cornell University (13)
- Drexel University (14)
- Florida Atlantic University (15)
- Florida International University (16)
- George Washington University (17)
- Georgia Institute of Technology (18)
- Howard University (19)
- Iowa State University (20)
- Leigh University (21)
- Marquette University (22)
- Mississippi State University (23)

- Missouri University of Science & Technology (24)
- New Jersey Institute of Technology (25)
- North Carolina State University (26)
- Northeastern University (27)
- Ohio State University (28)
- Oregon State University (29)
- Pennsylvania State University (30)
- Polytechnic Institute of New York University (31)
- Purdue University (32)
- Rensselaer Polytechnic Institute (33)
- Rutgers University (34)
- South Dakota School of Mines and Technology (35)
- Southern Illinois University Carbondale (36)
- Southern Methodist University (37)
- State University of New York (38)
- Temple University (39)
- Texas A&M (40)
- University of Maryland Baltimore County (41)
- University of Arizona (42)
- University of Arkansas (43)
- University of Buffalo (44)
- University of California, Berkeley (45)
- University of California, Davis (46)
- University of California, San Diego (47)
- University of Cincinnati (48)
- University of Colorado at Boulder (49)
- University of Denver (50)
- University of Florida (51)
- University of Georgia (52)
- University of Hawaii (53)
- University of Houston (54)
- University of Idaho (55)
- University of Illinois (56)
- University of Illinois, Urbana-Champagne (57)
- University of Kentucky (58)
- University of Maine (59)
- University of Massachusetts (60)
- University of Miami (61)
- University of Michigan (62)
- University of Minnesota (63)
- University of Missouri Columbia (64)

- ❍ University of North Carolina, Charlotte (65)
- ❍ University of North Texas (66)
- ❍ University of Oklahoma (67)
- ❍ University of Pennsylvania (68)
- ❍ University of South Carolina (69)
- ❍ University of Texas, Austin (70)
- ❍ University of Texas, Dallas (71)
- ❍ University of Virginia (72)
- ❍ University of Washington (73)
- ❍ University of Wisconsin (74)
- ❍ University of Wisconsin-Madison (75)
- ❍ University of Wisconsin-Milwaukee (76)
- ❍ Washington State University (77)
- ❍ West Virginia University (78)
- ❍ Wichita State University (79)
- ❍ Worcester Polytechnic Institute (80)
- ❍ Wright State University (81)
- ❍ Other (82)

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

Q3a: If Other, please, indicate the name of your graduate school.

(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)
- ❍ Advanced Processing & Packaging Studies (4)
- ❍ Advanced Vehicle and Extreme Environment Electronics (5)
- ❍ Agricultural, Biomedical, and Pharmaceutical Nanotechnology (6)
- ❍ Arthropod Management Technologies (7)
- ❍ Berkeley Sensor & Actuator Center (8)
- ❍ Bioenergy Research and Development (9)
- ❍ Biophotonics Sensors and Systems (10)
- ❍ Broadband Wireless Access and Applications (11)
- ❍ Ceramics Composites and Optical Materials Center (12)
- ❍ Child Injury Prevention Studies (13)
- ❍ Communications Circuits & Systems/ Connection One (14)
- ❍ Compact High-Performance Cooling Technologies (15)
- ❍ Configuration Analytics and Automation (16)
- ❍ Cyber-Physical Systems for the Hospital Operating Room (17)
- ❍ Design of Analog Digital Integrated Circuits (18)
- ❍ Dynamic Data Analysis (19)
- ❍ E-Design (20)
- ❍ Electric Vehicles: Transportation and Electricity Convergence (21)
- ❍ Electromagnetic Compatibility (22)
- ❍ Embedded Systems (23)
- ❍ Energy Harvesting Materials & Systems (24)
- ❍ Energy Smart Electronic Systems (25)
- ❍ Excellence in Logistics and Distribution (CELDI) (26)
- ❍ Experimental Research in Computer Systems (27)
- ❍ Freeform Optics (28)
- ❍ Friction Stir Processing (29)
- ❍ Fuel Cell Center (30)
- ❍ Grid-Connected Advanced Power Electronic Systems (31)
- ❍ Health Organization Transformation (32)
- ❍ High-Performance Reconfigurable Computing (33)
- ❍ Hybrid Multicore Productivity Research (34)
- ❍ Identification Technology Research (35)
- ❍ Integration of Composites into Infrastructure (36)
- ❍ Integrative Joining of Materials for Energy Applications (37)
- ❍ Intelligent Maintenance Systems (38)
- ❍ Membrane Science, Engineering and Technology (39)

- ❍ Metamaterials (40)
- ❍ Net-Centric Systems (41)
- ❍ Next Generation Photovoltaics (42)
- ❍ Nondestructive Evaluation (43)
- ❍ Optical Wireless Applications (44)
- ❍ Particulate and Surfactant Systems (45)
- ❍ Pharmaceutical Development (46)
- ❍ Plasmas & Lasers in Advanced Manufacturing (47)
- ❍ Power Systems Engineering Research Center (48)
- ❍ Research in Intelligent Storage (49)
- ❍ Research in Storage Systems (50)
- ❍ Resource Recovery & Recycling (51)
- ❍ Safety, Security, Rescue Research Center (52)
- ❍ Science Center for Marine Fisheries (53)
- ❍ Security & Software Engineering Research Center (54)
- ❍ Silicon Solar Consortium (55)
- ❍ Smart Vehicle Concepts (56)
- ❍ Spatiotemporal Thinking, Computing and Application (57)
- ❍ Surveillance Research (58)
- ❍ Sustainably Integrated Buildings and Sites (59)
- ❍ Tire Research (60)
- ❍ Unmanned Aircraft Systems (61)
- ❍ Visual and Decision Informatics (62)
- ❍ Water and Environmental Technology (63)
- ❍ Water Equipment & Policy (64)
- ❍ Wheat Genetics (65)
- ❍ Wood-Based Composites/ Sustainable Biomaterials (66)
- ❍ Other (67)

Q5a: If Other, please provide the name of the I/UCRC you are/were affiliated with.*(Center students only*)

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)
- ❍ 13-18 (4)
- ❍ 19-24 (5)
- ❍ 25-30 (6)
- ❍ 31-36 (7)
- ❍ 37-42 (8)
- ❍ 43-48 (9)
- ❍ 49-54 (10)
- ❍ 55-60 (11)
- ❍ 61-66 (12)
- ❍ 67-72 (13)
- ❍ 73-78 (14)
- ❍ 79-84 (15)
- ❍ 85-90 (16)
- ❍ 91-96 (17)
- ❍ 97-102 (18)
- ❍ 103-108 (19)
- ❍ 109-114 (20)
- ❍ 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)
- ❍ 11-15% (4)
- ❍ 16-20% (5)
- ❍ 21-25% (6)
- ❍ 26-30% (7)
- ❍ 31-35% (8)
- ❍ 36-40% (9)
- ❍ 41-45% (10)
- ❍ 46-50% (11)
- ❍ 51-55% (12)
- ❍ 56-60% (13)
- ❍ 61-65% (14)
- ❍ 66-70% (15)
- ❍ 71-75% (16)

- ❍ 76-80% (17)
- ❍ 81-85% (18)
- ❍ 86-90% (19)
- ❍ 91-95% (20)
- ❍ 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/Moderately (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)
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)	❍	❍	❍	❍	❍

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)
1. I believe that science benefits from involvement of different sectors such as private businesses, government and academia. (1)	❍	❍	❍	❍	❍
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)	❍	❍	❍	❍	❍
3. I view collaborations between industry and academia as positive despite differences in the ways they operate and things they value. (3)	❍	❍	❍	❍	❍
4. I like working with researchers from different disciplines as I can use their knowledge in my area of work. (4)	❍	❍	❍	❍	❍
5. I believe that any contemporary scientist must have strong communication skills in	❍	❍	❍	❍	❍

order to be able to solve today's problems. (5)					
6. Despite extra time and resources spent on communication, I still think 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)
- ❍ 51-75 (4)
- ❍ 76-100 (5)
- ❍ 101-125 (6)
- ❍ 126-150 (7)
- ❍ 151-175 (8)
- ❍ 176-200 (9)
- ❍ 201-225 (10)
- ❍ 226-250 (11)
- ❍ 251-275 (12)
- ❍ 276-300 (13)
- ❍ 301-325 (14)
- ❍ 326-350 (15)
- ❍ 351-375 (16)
- ❍ 376-400 (17)
- ❍ 401-425 (18)
- ❍ 426-450 (19)
- ❍ 451-475 (20)
- ❍ 476-500 (21)
- ❍ 501-525 (22)
- ❍ 526-550 (23)
- ❍ 551-575 (24)
- ❍ 576-600 (25)
- ❍ 601-625 (26)
- ❍ 626-650 (27)

- ❍ 651-675 (28)
- ❍ 676-700 (29)
- ❍ 701-725 (30)
- ❍ 726-750 (31)
- ❍ 751-775 (32)
- ❍ 776-800 (33)
- ❍ 801-825 (34)
- ❍ 826-850 (35)
- ❍ 851-875 (36)
- ❍ 876-900 (37)
- ❍ 901-925 (38)
- ❍ 926-950 (39)
- ❍ 951-975 (40)
- ❍ 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)
- ❍ 18 (3)
- ❍ 19 (4)
- ❍ 20 (5)
- ❍ 21 (6)
- ❍ 22 (7)
- ❍ 23 (8)
- ❍ 24 (9)
- ❍ 25 (10)
- ❍ 26 (11)
- ❍ 27 (12)
- ❍ 28 (13)
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- 80 (65)

- ❍ 81 (66)
- ❍ 82 (67)
- ❍ 83 (68)
- ❍ 84 (69)
- ❍ 85 (70)
- ❍ 86 (71)
- ❍ 87 (72)
- ❍ 88 (73)
- ❍ 89 (74)
- ❍ 90 (75)
- ❍ 91 (76)
- ❍ 92 (77)
- ❍ 93 (78)
- ❍ 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)
- Austrian (3)
- Belgian (4)
- Bolivian (5)
- Brazilian (6)
- Cambodian (7)
- Cameroonian (8)
- Canadian (9)
- Chilean (10)
- Chinese (11)
- Colombian (12)
- Costa Rican (13)

- Cuban (14)
- Danish (Dane) (15)
- Dominican (16)
- Ecuadorian (17)
- Egyptian (18)
- English (19)
- Estonian (20)
- Ethiopian (21)
- Finnish (22)
- French (23)
- German (24)
- Ghanaian (25)
- Greek (26)
- Guatemalan (27)
- Haitian (28)
- Honduran (29)
- Indian (30)
- Indonesian (31)
- Iranian (32)
- Iraqi (33)
- Irish (34)
- Israeli (35)
- Italian (36)
- Japanese (37)
- Jordanian (38)
- Kenyan (39)
- Korean (40)
- Laotian (41)
- Latvian (42)
- Lithuanian (43)
- Malaysian (44)
- Mexican (45)
- Mongolian (46)
- Moroccan (47)
- Dutch (48)
- Nepalese (49)
- New Zealander (50)
- Nicaraguan (51)
- Norwegian (52)
- Pakistanian (53)
- Panamanian (54)

- Paraguayan (55)
- Peruvian (56)
- Filipino (57)
- Polish (58)
- Portuguese (59)
- Puerto Rican (60)
- Romanian (61)
- Russian (62)
- Salvadorian (63)
- Saudi (64)
- Serbian (65)
- Scot (66)
- Spanish (67)
- Swedish (68)
- Swiss (69)
- Taiwanese (70)
- Tajik (71)
- Thai (72)
- Turkish (73)
- Ukrainian (74)
- Uruguayan (75)
- 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)
- 7-9 (3)
- 10-12 (4)
- 13-15 (5)
- 16-18 (6)
- 19-21 (7)
- 22-24 (8)
- 25-27 (9)
- 28-30 (10)
- 31-33 (11)
- 34-36 (12)
- 37-39 (13)
- 40-42 (14)
- 43-45 (15)
- 46-48 (16)
- 49-51 (17)
- 52-54 (18)
- 55-57 (19)
- 58-60 (20)
- 61-63 (21)
- 64-66 (22)
- 67-69 (23)
- 70-72 (24)
- 73-75 (25)
- 76-78 (26)
- 79-81 (27)
- 82-84 (28)
- 85-87 (29)
- 88-90 (30)
- 91-93 (31)
- 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 (I/UCRC) (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.