A theoretical argument is presented to suggest that engineering curriculum be designed to develop social capital. Additionally, the value of social capital in the retention of students in the College of Engineering, and the development, role, and value of social capital in an electrical engineering laboratory is evaluated. Data collected includes participant observations, informal and formal student interviews, and a researcher-designed survey. Social capital consists of interaction among individuals (networks), social rules that encourage interactions such as trust and reciprocity (norms), and the value of these networks and norms to the individual and the group. A large body of evidence suggests that social capital is valuable in terms of retention and multiple measures of academic achievement. The importance of social capital in retention was verified by students that have left engineering and those that remain, in terms of interactions with peers, teaching assistants, and engineering faculty; and a lack of sense of community in freshman engineering courses. Students that have left engineering differed in their perceptions of social capital from those that remain in their frustrations with teaching methods that encourage little discussion or opportunities to ask questions about assumptions or approaches. The open-ended nature of laboratory assignments, extensive required troubleshooting, and lack of specific directions from the teaching assistants were found to encourage the development of social capital in the laboratory setting. Degree centrality, a network measure of social capital as the number of ties an individual has within a social network, was found to be positively correlated with laboratory grade. Student perceptions of the importance of interactions with other
students on success in the laboratory setting has a negative model effect on academic achievement in the laboratory. In contrast, student perceptions of the quality of interactions with teaching assistants has a positive effect on measures of academic achievement. The results suggest that social capital is more important to some students than others in terms of retention and academic achievement. Recommendations are made to identify students requiring social capital to be successful, and to provide opportunities for these students to develop social capital.
Social Capital in Engineering Education

by
Shane Brown

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Dean of the Graduate School

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Shane Brown, Author
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Chapter 1 - Introduction

Introduction

The intent of this research is to investigate the use of the construct of social capital in engineering education, utilizing multiple data collection techniques and analysis methods, and to develop an understanding of the potential role of social capital in multiple educational outcomes. This dissertation is presented in a manuscript format that includes four separate manuscripts that have either been published or are ready for publication. The first chapter is an introduction to the concept of social capital, its application in engineering education, and an introduction to the included manuscripts. The second through fifth chapters contain each of the manuscripts. The first two manuscripts have been accepted for publication in refereed conference proceedings, and the third and fourth manuscripts will be submitted for publication in refereed engineering education journals. All manuscripts address the common theme of social capital in engineering education and are written to stand on their own. As a result, overlap exists among the manuscripts. The sixth and final chapter summarizes the results from all manuscripts and discusses the implications of these results for further research.

What is Social Capital?

The concept of social capital has gained recognition as a valuable theoretical framework to investigate multiple outcomes in a variety of settings. In general terms, social capital can be considered to be the value (capital) of social networks and the social norms that enhance productive interactions to both the group and individuals. Several individual definitions of social capital have emerged, and the concept has been applied in a variety of settings.

In order to better understand the potential usefulness of social capital as a tool for evaluating multiple outcomes, one first must develop an understanding of the conceptual framework of social capital. To accomplish this task, the concept of physical capital and human capital are addressed followed by an in-depth presentation of social capital.
Physical Capital

Physical capital includes goods that are necessary to sustain livelihood and economic productivity, and consists of capital investments that help people meet their basic needs and to be more productive. The physical capital of a company may consist of items such as machinery, buildings, and office equipment. This equipment allows the company to operate more effectively than it could in the absence of the equipment. The physical capital of an individual refers to their financial resources.

Human Capital

Human capital consists of the skills and knowledge that humans have. Human capital can be in the form of trade skills, education, and technical skills. Similar to physical capital, human capital allows an individual to accomplish tasks in a way that would not be as productive in the absence human capital. For instance, both a beginning and highly skilled woodworker could both build a table. However, the advanced woodworker could perform the task in a more efficient manner and could accomplish specific aspects of the project with greater detail than the beginner due to his/her advanced skills in woodworking.

Social Capital

In a similar fashion, social capital facilitates outcomes that could not be accomplished as efficiently in its absence. Social capital generally refers to the value (capital) of social interactions and the norms that support these interactions. Social capital is not unique to an individual, but is embedded in the interactions that actors have with each other, actors being individuals, social groups, companies, or even countries. For example, a salesman at a particular company may have human capital that consists of the knowledge of products, and social capital, that consists of relationships with employees and, more importantly, customers. If this salesman were to change jobs and move to another town, he would still possess his human capital, but arguably would have lost a majority of his social capital. As a result, the salesman would not be as efficient in his new job until he was able to create social capital. Two important themes exist in this consideration: the absence of social capital has a direct impact on the efficiency of the salesman, and the value of human capital is limited in the absence of social capital.
Credit for the concept of social capital is most often given to Coleman, Bourdieu, Putnam, and/or Fukuyama. Although each of these individuals has proposed social capital in somewhat different terms, and examined the consequences of social capital in different contexts, an understanding of each conceptualization of social capital is critical in any research in this area.

James Coleman has been credited with introducing, defining, and testing the concept of social capital, particularly in the educational context [1, 2]. Coleman provides examples that illustrate the concept of social capital:

- Wholesale diamond markets – Individuals involved in the wholesale diamond market utilize relationships among other actors in the same market to increase the efficiency of doing business. Diamond merchants will provide other merchants with thousands of dollars worth of diamonds for the latter merchant to inspect at his leisure without any formal insurance that the former merchant will substitute an inferior quality diamond for one of the original diamonds. This level of trust, or social capital, is possible due to the tightly knit community of diamond merchants and greatly enhances the efficiency of business transactions of diamond merchants.

- South Korean student activists revealed that study groups are developed based on personal ties from high school, hometown, or church. These groups form to facilitate political opposition. Coleman argues that these students utilize two forms of social capital: the original ties that brought the students together serve as glue for the study groups, and the study groups themselves allow for action that would not be as efficient as individual action.

Coleman proposed that social capital can be used to integrate aspects of two conflicting streams of thought on individual action, social action theory and rational action. Social action theory proposes that people are actors and their actions are governed by social norms, rules and obligations, and is useful in explaining the way that action is redirected, shaped, and constrained by social context. The economic principle of rational action proposes that individuals have goals that are independent of others and their actions are wholly self-interested. In other words, individuals have internal engines
of action that encourage specific behavior. Weaknesses exist in both of these arguments. For example, it is clear that individual behavior is neither wholly explained by either social norms or by individual agendas, but more likely a combination of both.

Coleman argues that a theoretical orientation utilizing aspects of both streams of thought is most appropriate and useful for analysis, and labels this new theoretical orientation social capital. Coleman suggests that social capital consists of several different entities that contain two common elements: social networks and norms. Social capital in the family can be evident in the relationships that parents have with their children, and in the community as relationships that parents have with other children's parents and parent's relations with institutions within the community. Coleman proposes that the presence of social capital in families and in communities has a significant effect on the creation of human capital in the next generation and results in reduced dropout rates of high school students.

Similar to Coleman, Bourdieu has often been credited with introducing and conceptualizing the concept of social capital. Perhaps the most noted of Bourdieu's work is, "The Forms of Capital", in which he discusses three types of capital: economic, cultural, and social [3]. Similar to Coleman, Bourdieu discusses interactions between different forms of capital. In this work, the key theoretical question is, "not how different, and relatively independent, forms of capital interrelate, but how these different appearances of social capital transform themselves into each other in order to maximize accumulation." [4]. Bourdieu provides a succinct definition of social capital, "Social capital is the aggregate of the actual or potential resources which are linked to a durable network of more or less institutionalized relationships of mutual acquaintance and recognition - in other words, to membership in a group -- which provides each of its members with the backing of the collectively owned capital." [3] In this definition, the same implications of economic productivity that Coleman suggested are inferred. Specifically, Bourdieu suggests that the productivity of a group or an individual is tied not only to individual actions and characteristics, but to the social networks and norms that are characteristic of a particular group. Bourdieu also comments on an important aspect of social capital that is addressed in this research, the volume of capital possessed
by the individuals with whom a person is connected. In Bourdieu’s words, “The volume of the social capital possessed by a given agent thus depends on the size of the network of connections he can effectively mobilize and on the volume of the capital possessed in his own right by each of those to whom he is connected.” [3] In summary, social capital consists of networks, “membership in a group,” norms, “institutionalized relationships,” the value of these networks and norms, “actual or potential resources,” and the importance of the capital of those with whom an individual is connected.

Fukuyama utilizes social capital as a framework in explaining the economic productivity of nations [5]. In this work, Fukuyama utilizes trust as a measure of society, and suggests a link between trust and productivity of communities, “The community in each of these cases was...formed not on the basis of explicit rules and regulations but out of a set of ethical habits and reciprocal moral obligations internalized by each of the community’s members. These rules or habits gave members of the community grounds for trusting one another.” Utilizing this framework, he characterizes countries as low-trust or high-trust, and compares these countries’ abilities to develop large scale corporations. High-trust societies, such as Japan and Germany, have more large scale corporations per capita than low-trust societies such as France and China. Fukuyama focuses on the normative aspect of social capital and operationalizes it as ethical habits and reciprocal obligations and identifies the potential economic implications of these norms.

Putnam investigates social capital in the United States in his work “Bowling Alone” [6]. Putnam conceptualizes social capital as, “features of social life - networks, norms, and trust - that enable participants to act together more effectively to pursue shared objectives.” [6]. Putnam measures networks as political, civic, religious, workplace, and informal connections, and social norms as reciprocity, honesty, and trust. Correlations between social capital and low crime levels, productive neighborhoods, and health and happiness are investigated. Similar to Coleman and Bourdieu, Putnam suggests that social capital consists of networks and norms, and the value of these networks and norms to the community.
The common themes present in the definitions of social capital discussed above are networks, norms, and value. Networks were addressed as group membership, civic participation, and parent and child interactions. Norms were presented as institutionalized relationships, trust, reciprocity, and perceptions of supportive interactions. The value component of social capital was presented as creation of human capital, dropout status, productivity of nations, and health and well being. Utilizing various combinations of these three components, social capital has been measured in multiple ways.

Measuring and Operationalizing Social Capital

Social capital has been operationalized in several different ways and multiple research methods have been implemented to measure social capital, ranging from qualitative methods such as observations and interviews to quantitative methods such as surveys and scales. In educational settings, very few research efforts on social capital have been made implementing purely qualitative research methods, while several have utilized surveys to measure social capital. In the following, relevant research efforts are summarized that utilize each of these methods with discussions of how the authors operationalized social capital.

The only paper encountered explicitly investigating social capital using primarily qualitative methods was by Marks [7]. In this study, Marks described the normative and social systems in five high schools that have specific goals of intentionally building social capital in the school. Utilizing descriptions of these systems, Marks identified mechanisms that were utilized to create social capital. Data were collected through extensive observation, informal and formal interviews, and surveys. Additionally, written records from the school were collected and analyzed.

Several authors utilized surveys to measure social capital. Along with his presentation of a theoretical framework for social capital, Coleman investigated the role of social capital in dropout status of high school students utilizing a survey [1]. Coleman attempted to determine if a relationship between a family’s social capital is related to high school dropout rates. Coleman included measures of student interactions with parents and intergenerational closure as indicators of social capital. It was suggested that
number of siblings, mother work status before the child was in school, mother's expectations of children's educational attainment, discussion frequency with parents about personal matters and presence of both parents in the household were indicators of interactions with parents. Intergenerational closure was a measure of the presence of parental relationships with parents of the students friends. The number of changes in schools due to family moves since fifth grade were used as indicators of intergenerational closure. Coleman also suggested that Catholic high schools may have lower drop out rates due to the personal bonds enhanced by the sharing of Catholic values. The type of high school (public, religious and private, non-religious and private) was used as an indicator of outside of family social capital.

Several studies followed Coleman's work, researching links between social capital and both dropout status and academic achievement [8-11]. Each of these studies utilized surveys to measure social capital. In each case, social capital was operationalized as parental support and/or intergenerational closure.

Etcheverry et al. are among a very small group to explicitly investigate social capital in higher education [12]. In their work, social capital is operationalized as consisting of two elements, challenge and support. Challenge is a measure of the cognitive requirements students have encountered in their courses. As an example, students are asked about their perceptions of requirements to recall facts, and organize and develop ideas and arguments based on existing theories. Support is a measure of student perceptions of support from professors and other students and addresses student perceptions of interactions with these two groups. The authors do present a convincing case that student perceptions of challenge may be related to achievement, but not that challenge is a key component of social capital. However, measures of support are consistent with the network and normative aspect of social capital discussed previously.

In summary, much research has been done researching social capital utilizing survey instruments in educational settings. Little work has been done using qualitative research methodology, i.e., interviews and observations.
Research on Social Capital in Education

Existing research on social capital in education is primarily focused on correlations between social capital and retention and academic achievement. Much of the research explicitly utilizes a social capital framework. However, a large amount of research exists investigating components of social capital, such as the value of peer and faculty interactions or trust, without explicitly utilizing a social capital framework.

Coleman suggested that in an educational context social capital is the set of social resources that contribute to the cognitive and personal development of a child [1]. He conducted a study of high school students and found that students with low social capital were more likely to drop out. Following Coleman, several studies were conducted investigating potential relationships between social capital and both dropout status and academic achievement [8-11, 13]. Carbonaro tested Coleman’s hypothesis in a new setting and found that social capital was positively related to dropout status and mathematics achievement test scores [9]. Morgan and Sorensen similarly found that mathematics achievement for 8th graders was positively correlated with density of friendship and parental networks [8]. In a study of university undergraduate students, Etcheverry et al. found that student perceptions of support from other students related positively to student self confidence and grade point average [12].

The relation between social capital, measured as networks and norms, and retention in engineering has not been investigated explicitly. However, several studies propose that social integration and the culture of engineering play important roles in the retention of engineering students. Seymour and Hewitt conducted a study to establish and rank factors that have the greatest influence on students leaving science, mathematics, and engineering majors and found that the competitive culture in engineering prohibited students from forming cooperative study groups and faculty are not supportive in one-on-one interactions during office hours [14]. Tobias reports that teachers discouraged classroom interaction and students found it difficult to interact with their classmates in this didactic environment [15]. From the perspective of Lave and Wenger, students saw no opportunity for legitimate participation in the culture of the discipline to which they aspired, therefore, there was no learning and they dropped out
Tobias found similar results in students who claimed that there was no sense of community in the classroom and that students were not interested in forming study groups due to competitive grading schemes [15]. Astin proposes that students who have contrasting values and beliefs than the peers in their major are likely to leave that peer group in favor of one that has similar values and beliefs [17]. Astin confirmed the importance of the peer group: "the many empirical findings from this study seem to warrant the following general conclusion: the student’s peer group is the single most potent source of influence on growth and development during the undergraduate years.” [17]

The development of social capital may be especially important for minority students in terms of retention. As stated by Chang, “African-Americans, Native American, and Latinos possess strong cultural values of group and community membership that are at odds with the perceived levels of individualism and competition associated with the sciences” [18]. A significant body of evidence exists that suggests social capital is relevant and important for both retention and academic achievement of students at all educational levels.

What is missing from existing research?

Research on social capital in education has been done in both K-12 and higher education settings. However, this research on social capital in education is lacking in three main areas relevant to this work: 1) very little research has been done in higher education, and none has been done in engineering education, 2) no research has been done in higher education investigating social capital utilizing qualitative data collection and analysis techniques, and 3) none of the research in higher education addresses a comprehensive definition of social capital including networks, norms, and value.

Description of Research

The overall goal of this research is to develop an understanding of the nature of social capital in engineering education and the relation of social capital with both retention in the college of engineering and student achievement at a classroom level in an engineering laboratory. This research consists of four manuscripts that are presented as individual chapters in this document:
Chapter 2 - An argument that engineering education curriculum should be designed to develop social capital, in addition to human capital, based on an extensive review of the literature on social capital, both inside and outside of higher education;

Chapter 3 - An investigation of the role of social capital in the retention of students in the college of engineering;

Chapter 4 - An investigation of factors that affect the development of social capital in an engineering laboratory and the value of social capital in terms of academic achievement in this setting, and

Chapter 5 - An investigation of the relation between social capital and academic achievement in an engineering laboratory.

This research as a whole begins to fill the components discussed above that are missing in existing research on social capital in education by utilizing qualitative data collection and analysis techniques, and a comprehensive definition of social capital.

Research Setting

All research was conducted within the College of Engineering (COE) at Oregon State University (OSU). OSU is a research-intensive land, sea, and space grant university with a student population of 19,000 located in a rural town with a population of 53,000. The COE consists of seven engineering majors and currently enrolls about 3,000 undergraduate and 500 graduate students annually.

The portion of the research presented in Chapter 3 on retention within the COE, involved student participants from most of the individual engineering disciplines, and was part of a larger effort to improve retention in the COE.

The portions of this research presented in Chapters 4 and 5 were conducted in the School of Electrical Engineering and Computer Science (EECS) and were part of a programmatic effort to understand and improve undergraduate education in this school. The core of this effort lies in the introduction of the TekBot™, a small robot that students utilize as a platform for learning in multiple courses throughout the curriculum [19, 20]. The TekBot™ program is continuously evaluated and improved through a design research approach [21]. As part of this design research approach curricular improvements are
continuously designed, evaluated, and modified. The overarching goals of the research presented herein are to develop an understanding of factors that affect the development and the value of student social capital, and to utilize this information to make curricular changes. Participants in this research were students in “Introduction to Electrical and Computer Engineering Concepts (EECS Concepts)” and “Digital Logic Design Laboratory (Design)”, both lower division undergraduate courses. The EECS Concepts course is the second of a two term freshman introduction to EECS sequence, and is required of all EECS students. In the first course of this sequence, students are introduced to and required to assemble and test the TekBot™. In the second term EECS Concepts course, students are required to program and troubleshoot the TekBot™. In the Design laboratory course, students program the TekBot™ to perform more complex tasks utilizing digital logic programming. The Design course is required of all electrical engineering students. Students enrolled in Design are concurrently enrolled in a companion lecture course focused on digital logic design.

Methodology

Data collection and analysis methods utilized for the research as a whole are discussed including a description of the researcher perspective.

Researcher Perspective

In qualitative research it is important to describe the researcher’s epistemological and ontological perspectives. Epistemology refers to what is considered knowledge and the basis for such knowledge and ontology refers to the nature of reality.

Individual views of the nature of reality can be generally split into the view that one verifiable reality exists or that multiple realities are socially constructed by different individuals. A positivist approach can be described as having one correct answer and one incorrect answer, in contrast to an interpretive perspective, in which a specific situation is interpreted differently by different individuals. In terms of this research, the ontological perspective tends towards an interpretive perspective [22], which involves understanding of individual’s views of their experience in engineering education and their interpretations of that experience. For example, students’ perceptions of support from
teaching assistants in the laboratory setting, as a component of social capital, are likely to differ even though the teaching assistants display only one set of actions.

Other qualitative researchers tend to differentiate research perspectives on a continuum bound on one end by grounded theory and the other by theory testing. Grounded theory is characterized by the theory emerging from the data post hoc. The majority of this research can be considered theory testing. For example, the theory that student's social capital is important in terms of retention is tested. Also, the portion of the research investigating the network aspect of social capital in the laboratory setting can be considered theory testing.

Epistemology is addressed in considering subjectivity and validity for a particular study [22]. In any research, some subjectivity alters or impacts the nature of the study. In qualitative research, subjectivity is addressed in two ways: by describing the researcher's potential sources of bias and by employing strategies to reduce bias. A researcher's biases can be illuminated by introspection of views of reality and what counts as knowledge. As stated above, the perspective of the researcher and of this research specifically is that multiple realities are created by individuals through dynamic interactions with their environment and the perception of these multiple realities will be investigated through qualitative research methodologies. Strategies employed to reduce bias include addressing validity and reliability.

Reliability refers to consistency in the research. In this research, reliability of qualitative data is enhanced through development of a specific protocol for observations or for interviews, or coding and recoding data on multiple separate occasions. Survey reliability is addressed by confirming construct reliability and test-retest reliability.

Addressing internal and external validity is critical to this study. Internal validity refers to the extent that the research answers the question of interest and external validity refers to the ability to generalize the results to the larger population. Construct validity is a form of internal validity and is a vital component in enhancing the robustness of qualitative research [23]. Construct validity refers to whether the study actually portrays and measures the construct being proposed. Construct validity can be enhanced by using multiple sources of evidence and by verifying construct descriptions and measures with
experts in the field. In each phase of the study proposed, multiple sources of evidence are utilized including observations, formal and informal interviews, and surveys. Social capital theories that will be tested in this research are, for the most part, rooted in theories proposed and tested by social capital experts, including Coleman [1], Putnam [6], and Burt [24]. External validity is addressed through careful selection of the participant population.

Specific research methods utilized to address validity and reliability are included in the sections below.

**Qualitative Data Collection and Analysis**

Qualitative data are normally considered to be observations, interviews, or documents [25] and, in this research, data collected includes informal and formal interviews and participant observation. A discussion of the number and selection of participants is not included, as detailed information is available in the individual manuscripts. The focus of this discussion is on the data collection methods and the analysis of the data collected to give the reader an overview of the various methodologies implemented in this research.

Interviews were conducted for the portions of this research presented in Chapters 3 and 4. The portion of the research presented in Chapter 3 was focused on retention in the College of Engineering. In this case, the focus of the student interviews was on student social capital, or students’ networks and engineering norms. Specifically, students were asked about their perceptions of interactions with faculty, peers, teaching assistants, and advisors, and the engineering climate. Interviews can range from very open ended to very focused. For this study, the interviews were on the focused end of the continuum. An interview protocol was developed to ensure consistency and a focus on student social capital in the interviews (Appendix 1). These interviews were conducted in study rooms in the library, a neutral location in which students were comfortable discussing their experiences. The portion of the research presented in Chapter 4 was focused on the development and role of social capital in an engineering laboratory. For this investigation, informal interviews were conducted during the laboratory session and formal interviews were conducted at the end of the term. Interviews during the
laboratory session were very open ended and generally done in response to observing a particular behavior by the student or the teaching assistants. For example, a student may have interacted with a teaching assistant on a particular problem. The researcher may have discussed with the student and/or the teaching assistant the reason or their satisfaction with the interaction. Formal focused interviews were conducted at the end of the term with students selected from two laboratory sections that were observed. Similar to above, the focus of these interviews was on student social capital or student interactions and norms in the laboratory. An interview protocol was developed to ensure focus and consistency in the interviews (Appendix 2). However, in this case, the primary interest was on social capital that was relevant to the laboratory setting. Specifically, the focus of interview questions was on interactions with students and teaching assistants in the laboratory setting, and student perceptions of the laboratory climate. As an example, students were asked about how important it was to work together with students or teaching assistants to be successful. These interviews were also conducted in study rooms in the library.

For the portion of the research presented in Chapter 4, data also were collected in the laboratory setting through participant observation. Laboratory sections were observed every week over the course of an entire term. The overall intent of these observations was to collect data on interactions between students and between students and teaching assistants. Information on both the quantity and the nature of these interactions was collected. An observation protocol was utilized to collect specific data and improve the consistency of data collection (Appendix 3). The observation protocol guides the researcher to record the length and nature of interactions for all students in the laboratory. Students were assigned id numbers by the researcher so that at the end of the term, data could be compiled on all interactions for each individual student. In these observations, it was important to equally observe all portions of the class so that data collected on the quantity of interactions was representative of the entire class and term. The laboratory space was divided into four sections with approximately equal numbers of students in each section. Each section was small enough so that the researcher could capture all of the interactions that occurred within this section. Each section of the
laboratory was observed for equal amounts of time every week. The laboratory sessions were three hours each. However, based on discussions with teaching assistants with experience in this course, most of the students required at least two hours to complete the laboratory, but very few required the entire three hour session. As a result, each section was observed for 30 minutes to ensure that each section was observed while most students were still present. There was concern that the amount and nature of interactions may have changed over the course of a single laboratory period. Consequentially, it was important to observe each section of the class at different times. The order of observation for each week was chosen randomly. Over the course of the term, each section of the laboratory was observed for each of the four time slots at least once.

Teaching assistant meetings were observed for the 3rd portion of the research. Teaching assistant meetings were observed for both EECS Concepts and Design. The intent of these observations was to develop an understanding of the types of teaching assistant behaviors that were encouraged through teaching assistant interactions, and by comments made by the instructor and the researcher. As the researcher was not interested in specific patterns or interactions in this setting, an observation protocol was not utilized for these observations.

Student interview and qualitative observational data from the 2nd and 3rd portions of this research was analyzed to look for emergent themes or patterns in the data. Qualitative observational data refers to notes on the nature of student interactions during the laboratory. The search for themes was facilitated through the use of qualitative data analysis software. Data collected from student interviews in the retention study was analyzed to search for themes on student perceptions of social capital and differences between these perceptions among engineers and students who have left engineering. For example, do students who have left engineering have different perceptions of faculty and teaching support, or the engineering climate than engineers? Interview and observations data collected for the 3rd portion of the research analyzed to search for patterns on student perceptions of the quality and necessity of student and teaching assistant interactions during the laboratory period.
The reliability of qualitative data collection was addressed through the utilization of observation and interview protocols. These researcher-designed tools assisted the researcher in collecting consistent information. The reliability of data analysis was addressed by coding the data multiple times at time intervals that occurred between coding events that were sufficiently large to reduce the ability to simply recode based on memory. For example, interview data for the retention work was coded over the span of a few days. At the conclusion of coding, the data were not investigated for a period of two weeks, at which time it was recoded. The original and final codes were compared to evaluate reliability.

External validity refers to the extent that research results can be generalized to the population and is addressed in each individual manuscript below. Generalization of results requires judgment on the part of the research consumer. In this research descriptions are provided on the research setting that allow the research consumer to evaluate similarities and differences between the research setting and the consumers setting. The ability to generalize results can also be enhanced through careful selection of the participant population. For the research presented in Chapters 3 and 4, purposeful selection of participants based on factors such as gender, minority status, major, and laboratory section allows the results to be generalized to a larger population. Internal validity refers to how well the research answers the question of interest. For this work, each stage involved the conceptualization of social capital. Social capital was defined earlier in this chapter, and this definition was utilized in all stages of the research. As mentioned previously, this definition is based on definitions from social capital experts. In Chapters 3 and 4, social capital was operationalized to develop interview and observation protocol as perceptions of interactions and support with other individuals, and engineering and classroom climate.

Quantitative Data Collection and Analysis

In the research presented in Chapter 4, data collected on the quantity of interactions in the laboratory setting was analyzed using the tools of social network analysis and statistics. Data available for each student include laboratory grade, cumulative grade point average, and the quantity of interactions that each student had
with every other student and teaching assistant in the laboratory over the course of the term. Utilizing the quantitative data on student interactions, measures of social network centrality were calculated. Network centrality refers to the location and number of connections of an individual within a social network. Detailed descriptions of the network measures utilized are included in Chapter 4. Correlations were calculated between these measures of network centrality and laboratory grade to determine if potential value to students existed due to their ties within the laboratory social network.

The research presented in Chapter 5 involved designing and conducting a survey to assess student social capital within a laboratory setting. A survey was designed and conducted in EECS Concepts, Winter term 2004. Utilizing results from this research, a new survey was designed and conducted in EECS Concepts, Winter term 2005. The survey conducted in EECS Concepts operationalized social capital as student and teaching assistant networks, norms, and the value of these norms. Social capital subconstructs were developed for the quantity, quality, and relevance of interactions with both students and teaching assistants. Each of these constructs was evaluated for reliability as discussed below. Correlations were calculated for potential relationships between constructs and between constructs and student achievement in the laboratory. Additionally, linear regression models were developed to investigate the relationship between social capital and academic achievement. Recognizing differences in student performance may be attributed to participating in a particular laboratory setting, variables were created for laboratory section and interactions between social capital and laboratory section. All laboratory section related variables were included in all models to evaluate their significance.

External validity, or generalizability, of the survey results can be enhanced by obtaining a representative sample of the research population. The population in question is students enrolled in EECS Concepts. The goal was to administer the survey to all students in EECS Concepts, facilitating generalization of results.

Construct validity in survey design was addressed by ensuring that the survey in fact measured the construct of social capital. Construct validity was addressed by utilizing accepted definitions of social capital, gained through an extensive review of the
literature of social capital. In this review, several social capital survey instruments were analyzed, and in some cases, revised versions of social capital questions were utilized in the social capital survey instrument utilized in this study.

Two forms of survey reliability are generally critical in survey design, internal reliability, and temporal reliability. Scales were developed to assess student perceptions of sub-constructs of social capital. For example, a three item scale was developed to measure student perceptions of the amount of time spent interacting with students and teaching assistants. The reliability of this scale was evaluated by determining the amount of correlation between the three items, commonly known as the Cronbach alpha reliability coefficient. This reliability analysis was conducted for each scale. Temporal reliability refers to the consistency of responses to the scale over time and can be addressed as test-retest reliability. The survey administered in EECS Concepts was taken by a large percentage of students in the laboratory during week nine of the ten week term. During week ten, the survey was re-administered to a portion of the original target population. Responses to survey questions from students who had taken the survey twice were compared to verify the reliability of the instrument.

Descriptions of research methodology and concerns addressed herein are included in each of the manuscripts below. The previous serves to give an overall description of methodology utilized to assess social capital with multiple data collection and analysis methods (interviews, observations, and surveys), in multiple settings (inside and outside the classroom), and multiple values of social capital (retention and achievement).

Summary

Social capital has been investigated at the nation, community, company, and individual levels, and has been correlated with multiple positive outcomes, such as economic productivity of nations; innovative and productive capabilities of companies; health, well being, and safety of neighborhoods; and retention and achievement of students ranging from kindergarten to college. The intent of this research is to investigate the nature and value of social capital in engineering education. As little work has been done in this specific area, this research serves as a starting point for future research. In the following, four independent manuscripts are presented on social capital in
engineering education. Although each of the manuscripts is presented as an independent piece of work, all fall under the umbrella of social capital in engineering education.
Chapter 2 - Social Capital in Engineering Education

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Abstract

Universities set goals for their graduates to perform in the workplace as well as to be responsible citizens. Students are required to not only develop a mastery of a particular subject, but civic, social and workplace skills as well. Achieving these goals is constrained by time and an academic atmosphere of individualism and competition. Traditional approaches to curriculum designed to develop only subject specific skills are no longer appropriate and adequate to satisfy these criteria. This paper argues that universities must develop student social capital. Social capital consists of social networks, pro-social norms, and the value of these networks and norms. The value of social capital has been investigated in multiple contexts such as business, economics, and sociology and the presence of social capital has been positively correlated with low crime levels, high educational attainment, retention in college and K-12, and perhaps most intriguing for engineering education, innovation and productivity in knowledge-based firms. This work presents a summary of existing literature that is relevant to social capital in engineering education, from both business and academic settings. Utilizing evidence from the literature, it is suggested that engineering education curriculum be designed in terms of developing both human capital and social capital. Several educational methods are discussed that have been shown to increase student social capital, such as cooperative learning and service learning. Additionally, social learning theories are discussed that inform the view that student learning should be centered around active social involvement including pro-social norms such as trust and reciprocity.

Introduction

The preparation of university graduates to perform in the workplace and to be responsible citizens can be a daunting task in the limited tenure of a university student. Students are required to not only develop a mastery of a particular subject but civic, social, and workplace skills as well. University mission statements typically claim to prepare graduates with group skills, tolerance of others, and a sense of civic responsibility. These claims resonate with the image of an ideal graduate; however, the claim of this paper is that the curriculum and social context of the university does not
achieve its stated goals. Oftentimes the goals of preparing students to become knowledgeable in a particular subject and prepare them for social responsibility and civic duty are treated as separate entities. Learning and social involvement can both be achieved as complementary activities when viewed through the lens of social capital.

**Framework – Social Capital**

The concept of social capital serves to provide a framework for understanding, analysis, and improvement of undergraduate education. Social capital has gained much attention in fields ranging from sociology to economics and has proven to be a useful tool in analyzing social systems. Social capital broadly consists of social networks, social norms, and the value of these networks and norms for achieving mutual goals [26].

Social norms can be described as accepted behaviors in a specific social setting. Social norms range from trust and mutual respect to generalized reciprocity. Fukuyama posits that trust plays a vital role in the social and economic productivity of nations [5]. Specifically, Fukuyama indicates that successful communities are “formed out of a set of ethical habits and reciprocal mutual obligations internalized by each of the community’s members”[5]. In terms of economic productivity, Fukuyama claims that a nation’s success is based on the level of trust inherent in the society. Coleman makes a similar claim in terms of group productivity when he claims that “social capital is embodied in the relationships among persons...a group whose members manifest trustworthiness and place extensive trust in one another will be able to accomplish more than a comparable group lacking that trustworthiness and trust.” [27]

The network aspect of social capital refers to “relationships among social entities, and the patterns and implications of these relationships” [28]. Putnam utilizes social connections, or relationships, as indicators of social capital, such as religious and civic participation, connections made in the workplace, and those made through informal community involvement such as in community sports teams [6]. Putnam also considers the normative aspect of social capital, i.e. reciprocity, honesty, and trust, and investigates the correlations between social capital and health, crime and education levels.

In Table 1 below, the concept of social capital is presented as including both norms and networks; any specific community or group of people is only considered to
have high social capital if it is high in trust (norms) and individual associations (networks). As Grootaert and Bastelaer summarize, “Both networks and norms must be assessed to obtain a valid estimate of the aggregate potential for collective action [29].” As an example, a group of people may display a large amount of interaction, but this may not necessarily include a high level of trust and the resulting cooperation that accompanies trust. The literature documents the competitive nature of the first half of the engineering curriculum and its adverse impact on students interest and willingness to form cooperative study groups [14, 15]. Additionally, based on personal observations in laboratories, it has been found that students are unlikely to work together if they can accomplish what they need to without cooperating with other students.

Table 1 - The Normative and Network Aspects of Social Capital

<table>
<thead>
<tr>
<th>Individual associations</th>
<th>High</th>
<th>Low</th>
</tr>
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<tbody>
<tr>
<td>Trust, reciprocity, mutual respect</td>
<td>High</td>
<td>Students work together with minimal barriers.</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>Students work together but are leery due to factors such as competition.</td>
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</table>

Why Social Capital in Engineering Education?

The system of higher education was originally developed to create human capital, or skills and abilities in individuals. The need for universities to develop social capital is highlighted through a discussion of the role of universities in preparing individuals for active citizenship and the workplace; relations between social capital, innovation and productivity in the workplace; teaching standards and learning theories that are aligned with social capital; and the value of social capital in retention and academic achievement.

Higher Education and Civic Engagement

The level of civic engagement of U.S. citizens is in rapid decline [6]. Americans associate less and less with each other through sports leagues, voluntary associations, and community organizations. Americans vote less and participate less in government
activities such as serving on city councils. This is of concern because active citizenship is a hallmark of a healthy democracy [30]. Citizens’ lack of civic engagement is summarized by Putnam, “...Americans have been dropping out in droves, not merely from political life, but from organized community life more generally.” [6]

The ability and the need for the university to prepare students for active citizenship is a well accepted proposition [31, 32]. John Dewey, a twentieth philosopher of democratic education, states that, “Democracy has to be born anew every generation, and education is the midwife.” [33] Schools provide a sheltered opportunity for future citizens to acquire the skills, knowledge, and dispositions necessary for them to be active citizens and contribute to a healthy democracy [34].

**Workplace Readiness**

There is increasing pressure on colleges and universities from corporations to prepare students for the workplace culture. The workplace culture can be characterized as favoring collaboration, group goals, information sharing, strategy, and outcomes while academic culture is characterized by internal competition, independence, reflection, and process [35]. The culture of academia for students is characterized by competition. Students are placed in large classrooms with curved grading systems that discourage collaboration and information sharing [14]. Lecture settings provide little opportunity for student interaction and discussion [36]. Oftentimes, limited community space is allocated for student study groups or more informal social gatherings.

Organizations spend large sums of money to encourage formal and informal networking opportunities. Companies are spending significant portions of money to understand and develop social capital [37]. The ALCOA corporation noticed that employees spent time on the stairwells talking together. As a result, the company created broad stairwell landings with coffee machines and space to visit to encourage more interaction [37]. In the workplace, a new employee learns the ropes of the organization through informal learning characterized as interaction with other employees. An ethnographic report conducted by the US Department of Commerce estimates that 80% of organizational learning is informal [38]. Studies have shown that the primary source of information in technological workplaces is other employees [39]. Specifically, people
were found to be roughly five times more likely to approach friends or colleagues for information than use a database or other repository. Additionally, it was found that 85% of managers at a consulting firm were found to receive knowledge critical to the successful completion of an important project from other people. This contrast in cultures, from academia where students are viewed as receivers of information from faculty and collaboration is discouraged by the competitive culture and few opportunities for formal interaction exist, to corporations where employees utilize each others knowledge base extensively for information, provides insight into the less than optimal educational methods presently implemented in academia.

Innovation, and Productivity

There is good reason that companies spend resources on developing social capital in the workplace. The potential value of social capital in the increased productivity and innovation of engineering firms, large companies, and even nations has been investigated with promising results [40]. Economic productivity in engineering firms is a function of knowledge sharing and creation, “The competitive edge of many firms favors those that can create knowledge faster than their competitors” [40]. Knowledge creation can be in the form of product development, resource management, and production, and occurs as a result of information sharing between firms. Firms that are successful innovators have reciprocal agreements based on trust with other firms. More specifically, individuals in firms have trust-based reciprocal information exchange agreements with individuals from other firms. As stated by Maskell “Social capital enables firms to improve their innovative capability and conduct business transactions without much fuss and has, therefore, substantial implications for economic performance.” [40]

Teaching Standards and Educational Reform

The need and benefits of involving students in the learning process is well documented and supported [41]. The importance of student-generated scientific discourse is central to both national science education reform documents such as Benchmarks for Science Literacy and the National Science Education Standards. Traditional teaching in college consists primarily of the professor talking and the student
listening. A disproportionately small amount of student-student interaction occurs. Lemke conducted extensive analysis of science classrooms and found that teacher asking questions, student responding, and teacher confirming responses, is the dominant form of classroom discourse [36]. Lemke argued further that in order for students to understand science as a body of knowledge based on the processes of scientific inquiry they must learn how to participate in scientific discourse that involves the interaction of diverse and competing points of view. This view is indicative of a large body of research that was used to inform the authors of national teaching standards.

**Learning Theories**

Sociocultural learning theories have also informed contemporary examination of classrooms. The Vygotskian sociocultural theory implies that learners develop cultural knowledge and higher order psychological functions through participating in the communal practices while interacting with the more knowledgeable members of the community [42]. From a Vygotskian perspective, all higher psychic functions are processes that are most commonly mediated through verbal interaction [43]. It is the socially mediating feature of language that guides the learner toward the solution of problems that would be impossible with his/her own unaided efforts. Words and reasoning made over through language reveal both ways of talking about the world and ways of acting in the world. This kind of modeling becomes a powerful tool to a naïve member of a culture to learn procedures and processes for solving problems deemed important within the culture.

Lave and Wenger have emphasized the importance of legitimate participation in culturally embedded activities to support learning [16]. Their view states that learning is a special type of social practice associated with learner participation. It is the opportunities for participation itself that provide access to behaviors not otherwise available that lead the learner to develop skills necessary for solving new problems. Clearly, participation can be more or less purposefully arranged and it is a challenge for a culture to identify the kinds of participation that are most productive for learning. Another challenge is recognizing the importance of participation in skill and knowledge building. Opportunities offered, but not taken, no matter how well conceived by the
more capable in the culture will not result in learning opportunities. These views of sociocultural learning have suggested direct applications to classroom practice. Brown concurs with this approach and suggests that students advance their learning through collaborative social interaction [44]. However the suggested new practices have run counter to the dominant, teacher-directed discourse of contemporary classrooms [36].

The idea that general and scientific knowledge is socially constructed has gathered more and more support during the last 30 years [45]. In science education, this principle of constructed knowledge has resonated with the term “inquiry” as the label for a core principle of science. Simply stated, that principle is that knowledge about the world derives from human efforts to systematically gather and interpret observations that become evidence for or against explanations and theory through collaboration, discussion, and debate. On the basis of this central principle, the National Science Education Standards made “teaching science as inquiry” a core principle for science education.

Retention and Academic Achievement

James Coleman is often credited with introducing the concept of social capital. Coleman suggested that in an educational context social capital is the set of social resources that contribute to the cognitive and personal development of a child [1]. He conducted a study of high school students to investigate the potential relationship between social capital and high school dropout rates. Coleman found that students with low social capital were more likely to drop out. Following Coleman, several studies were conducted investigating potential relationships between social capital and both dropout status and academic achievement [8-11, 13]. Carbonaro tested Coleman’s hypothesis in a new setting and found that social capital was positively related to dropout status and mathematics achievement test scores [9]. Morgan and Sorensen similarly found that mathematics achievement for 8th graders was positively correlated with density of friendship and parental networks [8]. In a study of university undergraduate students, Etcheverry et al. found that student perceptions of support from other students related positively to student self confidence and grade point average [12].
The number of retention studies in college mathematics, science, and engineering is extensive. The relation between social capital, measured as networks and norms, and retention in engineering has not been investigated explicitly. However, several studies propose that social integration and the culture of engineering play important roles in the retention of engineering students. Seymour and Hewitt conducted a study to establish and rank factors that have the greatest influence on students leaving science, mathematics, and engineering majors [14]. One of the most striking differences between students leaving engineering and students leaving mathematics and science was the presence of competitive grading and a “weed out” culture which inhibited students’ abilities to develop collaborative study groups in engineering. Weed out cultures are characterized by student perceptions that a class or curriculum is designed to fail a portion of students who are not academically fit to survive in. From the perspective of Lave and Wenger, students saw no opportunity for legitimate participation in the culture of the discipline to which they aspired, therefore, there was no learning and they dropped out [16]. Tobias found similar results in students who claimed that there was no sense of community in the classroom and that students were not interested in forming study groups due to competitive grading schemes [15]. Astin proposes that students who have contrasting values and beliefs than the peers in their major are likely to leave that peer group in favor of one that has similar values and beliefs [17]. Referring to Table 1, this is an example of a low trust environment that is fostered by the social norms put in place through the competitive structure of the early engineering, science, and mathematics courses. Magnifying this concern are Astin’s findings on the importance of the peer group in college. Astin stated that, “the many empirical findings from this study seem to warrant the following general conclusion: the student’s peer group is the single most potent source of influence on growth and development during the undergraduate years.” [17]

The occurrence of supportive interactions with faculty has been identified as important for both student success and retention. Seymour and Hewitt indicated that faculty are not supportive in one-on-one interactions during office hours or of in-class questions that are not perfectly aligned with the topic of the day [14]. Tobias reports that
teachers discouraged classroom interaction and students found it difficult to interact with their classmates in this didactic environment [15]. This provides further evidence that the development of productive interactions and relationships with faculty is discouraged and may adversely impact retention.

The development of social capital may be especially important for minority students in terms of retention. As stated by Chang, “African-Americans, Native American, and Latinos possess strong cultural values of group and community membership that are at odds with the perceived levels of individualism and competition associated with the sciences” [18]. Additionally, these groups face a lack of participation with fellow students. For example, minority students often express an interest and a need for a cooperative educational culture that is rooted in cultural values and norms. The lack of community in early engineering education may have a potentially adverse effect on retention of minority students.

What can be done?

Higher education has been described as fostering a culture of independence and internal competition which has several potentially adverse consequences:

- Does not prepare individuals for active citizenship;
- Collides with a workplace culture that fosters collaboration and cooperation;
- Does not encourage innovation or productivity;
- Is not in alignment with teaching standards or learning theories, and
- Does little to encourage retention or academic achievement.

Given this description and the dilemma it represents, we are challenged to alter the current practices of teaching and learning at the university. An academic culture as an integrated social learning environment where trust, mutual cooperation, information sharing and respect are fostered is desirable, an environment that promotes the development of social capital. Print and Coleman recommend designing curriculum based on engaging students in active participation to build trust, cooperation, and networking skills [46]. In such an atmosphere, progress can be made towards the daunting task of students developing subject mastery, group learning skills, and active citizenry skills. Several alternatives exist to foster this atmosphere and multiple barriers
exist. Based on existing literature, it is proposed that encouraging the development of social capital can be influenced through student focused academic discourse, group processes in the classroom, cooperative learning, and service learning.

**Academic Discourse**

Research on academic discourse outlines teacher and student behaviors that encourage discourse and describes the personal and learning benefits associated with discourse environments. Discourse is considered verbal interactions among participants and can be thought of as interactive as opposed to traditional didactic lectures. Although no explicit link between social capital and academic discourse was discovered in the literature, it is reasonable that encouraging student-student and student-teacher interactions in the classroom has the potential to encourage the development of student networks and pro-social norms.

Teacher behaviors were found to encourage discourse environments and enhance student learning. Jones indicated that the teacher should guide, but not control the discourse [47]. Similarly, van Zee found that distributing authority, describing to students how to converse, practicing quietness, listening closely, and clarifying student contributions tended to encourage discourse [48, 49]. Jones suggested that higher order questioning was essential to encourage discourse [47], while van Zee utilized questions that developed conceptual student understanding [49].

Students should be required to present new ideas to foster discourse [47], and students were found to engage in discourse when they were able to propose and discuss issues that are relevant to them [47], and with which they were familiar [49]. Each of these behaviors must be conducted in an environment that is both supportive [47] and comfortable [49], in which students can negotiate and compare their understanding with accepted knowledge [47].

**Group Processes in the Classroom**

Collaborative concept mapping has the potential to assist students in the development of technical knowledge and encourage student interaction. It has been argued previously in this paper that knowledge is socially constructed [42, 50, 51]. In
scientific communities of practice, learning occurs through verbal and written interaction, and knowledge is shared and advanced through language, diagrams and images. In the classroom, however, learning is almost never accomplished using these instruments. Roth [52] investigated the social construction of scientific concepts through the use of concept maps. Roth suggested that the use of concept maps in collaborative work will allow the students to practice communicating verbally and with diagrams. Through this research, concept maps were observed to be tools for social thinking. The concept map was seen by students as a shared social space in which all participants could contribute ideas and social knowledge could be generated for the use of all participants. Roth suggested that the process of deriving the concept map as a learning tool was far more valuable than the concept maps themselves.

In alignment with the above proposition of concept maps as tools for social thinking, the author takes an additional step in this direction and propose that the concept maps are conscription devices and they serve as the social glue that holds the group together. This glue facilitates productive student interaction. The visual representations of ideas allowed for a level of complexity in interaction and understanding that would not be possible without a visual representation.

Roth [53] investigated student views of concept mapping to understand student perceptions of their learning and there perspectives on the learning atmosphere. The collaborative concept mapping atmosphere provided a safe atmosphere for the evolution of a community of discourse. Students were able to present and discuss ideas, seek clarifications, and publicly disagree. The dynamics of student-student interactions were found to consist of justifying a claim, explaining what was meant by a proposition, and elaborating on a statement.

Students provided specific reasons why the collaborative concept mapping atmosphere worked for them as a means to develop scientific understandings. These reasons can be broadly sorted into the following categories: students made learning progress by developing and presenting defendable arguments for their positions; students were required to reflect on their own knowledge and understandings; students learned by
integrating alternative views; and the group provided a way for students to receive feedback on their ideas.

*Service Learning and Cooperative Learning*

Both service learning and cooperative learning have been shown to have both positive academic outcomes and contribute to the development of group skills and a sense of civic duty. Both concepts are briefly presented in the following with the intent of providing a description of what each entails and the benefits supported by research.

Service learning is characterized by community service work that is integrated into the curriculum, and is specifically related to learning objectives. The connection between the community service work and the curriculum occurs through written activities and discussions [54]. A growing body of evidence "strongly suggests that when accompanied by proper preparation and adequate academic reflection, service learning can be a potent civic educator." [54] It has been shown that a service learning experience "can achieve the goal of educating young people about their responsibilities in a democratic society, allowing them to think about what it means to be a part of the multiple communities in which they find themselves." [55] Additionally, students involved in service learning have increased comprehension of course material and develop an awareness of their local community [56]. Perhaps the best example of service learning in engineering education is the EPICS (Engineering Projects in Community Service) centered at Purdue University that involves seven universities nationwide. Service learning has tremendous potential to help student develop both subject specific knowledge, group skills, and a sense of civic duty.

Cooperative learning has received significant attention both in practice and in the research and has been implemented and evaluated extensively in the higher education arena. Cooperative learning has been shown to encourage the development of academically and personally supportive relationships that are vital to a number of important processes and outcomes, including pro-social attitudes and behavior patterns, perspective taking abilities, sense of belonging and connectedness with others, achievement and educational aspirations [57]. The concept of social capital focuses on the presence of mutual norms of behavior that allow for productive interaction between
individuals and has been shown to have benefits for both the individual and collective [5, 6].

**Making Sense of it All**

The introduction to this paper suggested that the goal of universities to graduate students who are technically competent in their field, have a sense of civic responsibility, and have skills that allow them to work productively with others is admirable, but not often realized with the methods of teaching and learning used currently. It was suggested that progress towards achieving these lofty goals could be accomplished through a social approach to learning and academic involvement. The concern arises not only from the universities mission statement, but based on clashing workforce and academic cultures and the need to prepare student for the workforce and the presence of respected learning theories that advocate learning as a social process. Social capital was presented as the set of social resources that students have that contribute to both their cognitive and social development. Social capital includes both the value of these social resources and personal behaviors such as trust that support building these resources. Social capital serves as a theoretical framework for analyzing and understanding the benefits of social learning experiences.

The results of multiple articles examining discourse patterns and group activities in the classroom were presented to highlight the potential positive outcomes associated with student centered discourse. Student centered discourse is an important component because it empowers students to participate in their educational experience and involves students developing group skills. Results of these papers indicate that classroom cultures in which students exhibited increased participation were promoted by both teacher and student behaviors.

Collaborative concept mapping was presented as a potential group activity that is representative of authentic scientific discourse and encourages student centered discussions of scientific concepts. Both the student and teacher perceptions of the collaborative concept mapping exercise indicate that students were able to practice communicating both verbally and with diagrams and pictures, both representative of both interaction in the scientific community and the engineering workplace.
Service learning and cooperative learning have been shown to enhance both students technical knowledge, sense of civic responsibility, and group skills and both have an established track record in engineering education.

Each of these implementations involves engaging students in interactive learning environments in which they can develop social capital, and the skills and behaviors necessary to be productive citizens and engineers. Each has the potential to contribute to the development of student social capital, both their resources and connections, and the set of skills and behaviors that contribute to these connections.

The recommendation is not necessarily to implement any of the specific practices described herein, but to view educational innovation through the lens of social learning. Design of educational experiences should focus on empowering students, encouraging and requiring collaboration among students and faculty, encouraging faculty and staff to distribute authority and engage in discourse characterized by mutual respect and trust, and providing students with experiences in the community.
Chapter 3 - Student Social Capital and Retention in the College of Engineering

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Abstract

An investigation of relationships between student social capital and retention in the engineering program and the use of the concept of social capital as a framework to understand the retention of engineering students are discussed. The concept of social capital has been utilized in investigations of economic productivity and innovation of corporations, drop-out rates in high school, and academic performance both in high school and in college. For the purposes of this study, social capital consists of social networks, social norms, and the value of these networks and norms for achieving mutual goals. Previous research suggests that the peer group and faculty support are both important factors in student retention and academic success. It has even been suggested that the peer group is the single most influential factor on personal development in college. Student social capital was assessed in one-on-one and focus group interviews with both students who have left engineering and students who remain. The focus of the interviews was on student interactions with peers, faculty, and teaching assistants, and students’ integration and perception of the engineering culture. Student responses indicate that social capital does play a role in the retention of engineering students. Both students who remain in engineering and those that have left reported that positive interactions with peers, faculty, and advisors were important to retention. Both groups indicated that few opportunities exist in the lecture setting to interact with other students, but the dormitories provide opportunities to develop relationships with other students. Both groups voiced frustration with mostly poor interactions with faculty and advisors. Similarly, both groups indicated that their sense of community in freshman engineering courses is low, and they are frustrated with the competitive norms in engineering. Only those students who left engineering voiced dissatisfaction with teaching methods that encourage “plug-and-chug” problem solving, characterized by little discussion or opportunities to ask questions about assumptions or approaches. Recommendations are made to address student concerns that include active and cooperative learning approaches, and the development of learning communities.[16]
Introduction

In today’s technological society, the need for engineers in the workplace is at an all time high. In the next ten years it is estimated that the United States will need to train an additional 1.9 million workers in the sciences [18], a significant portion of which will need to be engineers. Not only it is important to train larger numbers of engineers, it is also necessary to attract a more prevalent representation of women and minorities in the engineering workforce. Identification of this need is certainly not new or unique to this study, yet simply highlights the need to be interested in the retention of engineering students. Government agencies, universities, and private companies have invested heavily in not only attracting more engineers, but attempting to attract and retain a more diverse workforce in the engineering field.

Purpose of Study

The purpose of this study is to develop an understanding of why students leave engineering at Oregon State University, put forth a theoretical framework for understanding retention issues, and provide recommendations to improve retention.

Literature Review

The need for student academic and social integration into academic settings has been identified as critical to personal and academic success [14, 58]. Student involvement in the total academic environment has been identified as the single most important factor affecting the persistence of students [17]. The three most important forms of involvement turn out to be academic involvement, involvement with faculty, and involvement with student peer groups [59]. Astin further suggests that the single most important factor on student development is the student’s peer group [59]. Specifically, both the characteristics of the student’s peer group and the extent of the student’s interaction with that peer group are correlated with student development. Seymour and Hewitt [14] identify the lack of peer group study support as a relevant factor among students’ reasons for switching from science, mathematics, engineering and technology (SMET) fields.

Tinto developed a longitudinal model of institutional departure that includes academic and social integration as key components [58]. Positive integrative experiences
have been found to reinforce persistence by increasing intentions and commitments both to completion and to the institution [60]. In contrast, negative experiences serve to weaken commitments to the institution [58]. In a description of modes of belonging to communities of practice, Wenger [51] describes some individuals as marginal members, those individuals whose full membership is prohibited due to personal attributes, background, etc. Barriers to belonging exist in engineering communities potentially due to social forces and perceived differences.

It is clear from the literature that social integration into the community, both academic and extracurricular, is vital to both the personal development and retention of students in higher education. The concept of social capital serves to provide a theoretical framework for the nature and the value of this social integration. Tinto’s theory of student departure has gained much recognition from retention experts and universities. The theory of social capital has added value compared to Tinto’s theory in that it is related to innovation and productivity at the engineering workplace, relevant learning theories, and preparing students for a community-oriented workforce, all clearly important factors in engineering education.

**What is Social Capital?**

Social capital has gained much attention in fields ranging from sociology to economics and has proven to be a useful tool in analyzing social systems. Social capital broadly consists of social networks, social norms, and the value of these networks and norms for achieving mutual goals [26].

Social norms can be described as accepted behaviors in a specific social setting. Social norms range from trust and mutual respect to generalized reciprocity. Fukuyama posited that trust plays a vital role in the social and economic productivity of nations [5]. Specifically, Fukuyama indicated that successful communities are “formed out of a set of ethical habits and reciprocal mutual obligations internalized by each of the community’s members” [5]. In terms of economic productivity, Fukuyama claimed that a nation’s success is based on the level of trust inherent in the society. Coleman made a similar claim in terms of group productivity when he claims that “social capital is embodied in the relationships among persons…a group whose members manifest trustworthiness and
place extensive trust in one another will be able to accomplish more than a comparable
group lacking that trustworthiness and trust.” [24]

The network aspect of social capital refers to “relationships among social entities,
and the patterns and implications of these relationships.” [28] Putnam utilizes social
connections, or relationships, as indicators of social capital, such as religious and civic
participation, connections made in the workplace, and those made through informal
community involvement, such as in community sports teams [6]. Putnam also considers
the normative aspect of social capital, i.e. reciprocity, honesty, and trust, and investigates
the correlations between social capital and health, crime, and education levels.

In Table 2 below, social capital can be viewed as including both norms and
networks; any specific community or group of people is only considered to have high
social capital if it is high in trust (norms) and individual associations (networks). Brief
descriptions of situations for each possibility are included. The literature documents the
competitive nature of the first half of the engineering curriculum and its adverse impact
on student interest and willingness to form cooperative study groups [14, 15].
Additionally, based on personal observations in laboratories, it has been found that
students are unlikely to work together if they can accomplish what they need to without
cooperating with other students. As Grootaert and Bastelaer summarize, “Both networks
and norms must be assessed to obtain a valid estimate of the aggregate potential for
collective action.” [29] As an example, a group of people may display a large amount of
interaction, but this may not necessarily include a high level of trust and the resulting
cooperation that accompanies trust.

Social capital can exist and be developed both inside and outside of the classroom
in the form of both networks and norms. As an example, a student’s peer network may
consist of friends outside of their department or classes, through fraternities, military
association, or clubs and organizations, and peers in the classroom. Although there may
be overlap between these two groups, it is not necessarily the case. Similarly, a student
may share specific values with personal groups such as volunteer organizations, and these
values may differ or even be in conflict with values of peers in their class. For example,
a student may have a strong sense of trust and respect with friends in a church or military
group. This sense of trust may not be present in interactions with engineering students, due to an individualistic, competitive climate.

Table 2 - The Normative and Network Aspects of Social Capital

<table>
<thead>
<tr>
<th>Trust, reciprocity, mutual respect</th>
<th>Individual associations</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Students work together with minimal barriers.</td>
</tr>
<tr>
<td>Low</td>
<td>Students work together but are leery due to factors such as competition.</td>
</tr>
</tbody>
</table>

The Value of Social Capital

Social capital has been researched in various settings and it has been found that the value, or capital portion, of the construct is evident. There are two settings that are most relevant for this research: 1) the workplace, specifically consulting and business and the value in innovation and knowledge sharing, and 2) educational settings, including teaching and learning, and retention and achievement.

Social Capital and Innovation

Economic productivity in engineering firms is a function of knowledge sharing and creation, “The competitive edge of many firms favors those that can create knowledge faster than their competitors” [40]. Knowledge creation can be in the form of product development, resource management, and production, and occurs as a result of information sharing between firms. Firms that are successful innovators have reciprocal agreements based on trust with other firms. More specifically, individuals in firms have trust-based reciprocal information exchange agreements with individuals from other firms. As stated by Maskell, “Social capital enables firms to improve their innovative capability and conduct business transactions without much fuss and has, therefore, substantial implications for economic performance.” [40]
Social Capital, Teaching, and Learning

The need and benefits of empowering and involving students in the learning process through social interaction is well documented and supported [41]. Teaching standards for K-12 teachers mandate that teaching include practices that engage students in authentic scientific discourse. Additionally, the practice of student-generated scientific discourse is advocated by reform documents such as Benchmarks for Science Literacy and the National Science Education Standards. Traditional teaching in college consists primarily of the professor talking and the student listening. Lemke [36] argues that in order for students to become scientists they must take part in scientific dialogue. Based on extensive analysis of science classrooms, it was found that classroom interactions were controlled by the teacher, and these interactions are not representative of scientific dialogue.

In addition to standards supporting the need for student engagement and community building, sociocultural learning theories are in alignment. The Vygotskian sociocultural perspective suggests that learners develop through interactions with the more knowledgeable members of the community [42]. It has been argued that scientific knowledge is socially constructed and takes on individual meaning for participants in a community of learners. Within such a community learning occurs formally through written records and, informally, through discussion. Brown [44] recommends that in light of this knowledge students advance their learning through collaborative social interaction.

Social Capital, Retention, and Academic Achievement

Coleman [1] conducted a study of high school students to investigate the potential relationship between social capital and high school dropout rates. Coleman found that a lack of student social capital contributed to high school dropout status. Following Coleman, several studies were conducted investigating potential relationships between social capital and both dropout status and academic achievement [8-11, 13]. Carbonaro tested Coleman's hypothesis in a new setting and found that social capital was positively related to dropout status and mathematics achievement test scores [9]. Morgan and Sorensen similarly found that mathematics achievement for 8th graders was positively
correlated with density of friendship and parental networks [8]. In a study of university undergraduate students, Etcheverry et al. found that student perceptions of support from other students related positively to student self confidence and grade point average [12].

The number of retention studies in college mathematics, science, and engineering is extensive. The relation between social capital, measured as networks and norms, and retention in engineering has not been investigated explicitly. However, several studies propose that social integration and the culture of engineering play important roles in the retention of engineering students. Seymour and Hewitt conducted a study to establish and rank factors that have the greatest influence on students leaving science, mathematics, and engineering majors [14]. One of the most striking differences between students leaving engineering and students leaving mathematics and science was the presence of competitive grading and a “weed out” culture in engineering which inhibited students’ abilities to develop collaborative study groups. Weed out cultures are characterized by student perceptions that a class or curriculum is designed to fail a portion of students who are not academically fit to survive. Tobias found similar results from students who claimed that there was no sense of community in the classroom and that students were not interested in forming study groups due to competitive grading schemes [15]. Astin proposes that students who have contrasting values and beliefs than the peers in their major are likely to leave that peer group in favor of one that has similar values and beliefs [17]. Referring to Table 2, this is an example of a low trust environment that is fostered by the social norms put in place through the competitive structure of the early engineering, science, and mathematics courses. Magnifying this concern are Astin’s findings on the importance of the peer group in college. Astin [17] stated that, “the many empirical findings from this study seem to warrant the following general conclusion: the student’s peer group is the single most potent source of influence on growth and development during the undergraduate years.”

The occurrence of supportive interactions with faculty has been identified as important for both student success and retention. Both engineering students and students who have left engineering voiced frustration about poor faculty pedagogy [14, 15]. Seymour and Hewitt indicated that faculty are not supportive in one-on-one interactions
during office hours or of in-class questions that are not perfectly aligned with the topic of
the day [14]. Tobias reports that teachers discouraged classroom interaction and students
found it difficult to interact with their classmates in this didactic environment. This
provides further evidence that the development of productive interactions and
relationships with faculty is discouraged and may adversely impact retention.

Minority students face unique retention issues. As stated by Chang, “African-
Americans, Native American, and Latinos possess strong cultural values of group and
community membership that are at odds with the perceived levels of individualism and
competition associated with the sciences [18].” Additionally, these groups face a lack of
participation with fellow students. For example, minority students often express an
interest and a need for a cooperative educational culture that is rooted in cultural values
and norms. In a report published by the National Science Foundation, minority students
were found to possess strong cultural values of group and community membership that
may conflict with the competitive nature of engineering education [61]. Seymour and
Hewitt found that cultural identities and values can clash with engineering cultures. The
lack of community in early engineering education may have a potentially adverse affect
on retention of minority students.

The value of understanding and encouraging the development of student social
capital extends beyond the retention of engineering students. Student social capital is
related to academic achievement, personal satisfaction, teaching standards, and learning
theories. Additionally, preparation of students for a workforce in which collaboration
and information sharing are vital to the economic success of the companies for whom
they are employed is essential. Although social capital is related to these important
factors, the intent of this study is to investigate the relationship between social capital and
the retention of engineering students. Specifically, the goals of this study are:

- Develop an understanding of why students leave engineering through an
  investigation of student social capital;
- Evaluate similarities and differences between students who have left
  engineering and those that remain of student perceptions of interactions
with engineering peers, faculty, and advising, and the engineering culture, and

- Provide recommendations that have the potential to improve retention that are based on student feedback and the literature.

**Methodology**

The aspects of social capital that are relevant to retention of engineering students consist of relationships (networks) and values (norms). Relationships and interactions that students develop between peers, faculty, and advisors can impact the retention of engineering students. Collecting information on students’ relationships was done through student interviews. The interview protocol was developed to investigate student perceptions of interactions with faculty, teaching assistants, peers, and advisors, and of the engineering culture. The norms and values evident in the college of engineering were investigated in the interviews through questions about experiences in engineering courses and working with peers on engineering assignments.

Both students who are currently in engineering and students who have left engineering were interviewed. First, students were identified that had enrolled in any of the introductory engineering courses in Fall 2001, 2002, and 2003. From this list students who are currently declared as majors other than engineering were identified. This list was further refined by omitting students who had a grade point average below 3.0. This step was taken to ensure that these students would have gained entry into the second half (pro-school portion) of the program and been likely to succeed had they chosen to continue in engineering. This list consisted of approximately 400 students. All students were sent an email from the assistant dean requesting their participation in retention interviews. Approximately 40 students responded to this email.

The number of interviews conducted was chosen based on acquiring representative data. Overall, the intent was to conduct a sufficient number of interviews so that the results can be considered representative of the engineering population at OSU. This was accomplished by conducting interviews until a point at which student responses provide limited new information.
A total of 22 students were interviewed, including both focus group and individual interviews. Several ethnic groups were included in this group including Korean, Chinese, Hispanic, and Brazilian. Ten engineering students were interviewed including individuals from Mechanical, Civil, Industrial, and Electrical Engineering. Of this group of ten students, two groups of three students each were interviewed in focus group interviews, one group of male engineers and one group of female engineers. The remaining four students, two female and two male students, were interviewed individually. Twelve students who have left engineering were interviewed including students who are currently majoring in History, Political Science, Geology, Biology, and Business. In this population of twelve, one focus group interview consisting of five male students was conducted. The remaining seven students, four females and three males, were interviewed individually.

Results
The importance of student social capital in the retention of engineering students was confirmed by student interview responses. As a reminder, social capital consists of both networks and norms. Students reported on both the importance of social networks and norms as factors in retention.

Network Aspect of Social Capital
Students commented that positive interactions with peers, faculty and advisors was critical to staying in engineering. Both students in engineering (engineers) and those that have left (switchers) identified the peer group as essential to success in engineering.

Students made specific comments that it was difficult if not impossible to succeed in engineering without peer group support.

Int (Interviewer): Did you study with people when you were in statics?

Female Business Switcher: Yeah, had to, there was no way I was going to pass without it.

Male Electrical Engineer: You really can't do it (engineering) on your own.

Female Electrical Engineer: Most of the help you get is from other students.
**Int:** How important were your peers in the early years?

*Female Industrial Engineer:* I would say they are very important. Those are the people that I studied with and did homework with and everything else and sat with in class so they were very important.

Although it is clear that peer group support is important to the success of engineering students, evidence exists to suggest that limited opportunities are provided to meet people in engineering courses:

**Int:** Is it easy to meet people in engineering classes if you didn’t know anybody?

*Male Electrical Engineer:* I don’t think so, most of the time you are just head down taking notes.

**Int:** Have they engaged you in any activities that help you meet people or work together with people?

*Male Mechanical Engineer:* No.

*Male Electrical Engineer:* Very seldom.

*Male Civil Engineer:* I’ve met very few people just through class cause you just kind of go in and they start talking and that is pretty much it, there is not much interaction there.

Although lecture appears to provide limited opportunities for meeting people, students commented that they did meet people in laboratory.

*Female Industrial Engineer:* Once I started working in the labs, I got to know the lab people very well, we all started hanging out together.

**Int:** Do you meet people in labs and in recitation?

*Male Civil Engineer:* Yeah, in labs

*Male Mechanical Engineer:* I think labs are big yeah.

**Int:** Was it hard to meet people in the classes where you didn’t know anybody?
Female Industrial Engineer: Not really, because in a lot of the classes we had labs and so you were paired up with some people, and those are the people that I tended to study with so since we were lab partners we would get together and study.

Int: Did the classes that you took in engineering help you get together with people?

Male Geology Switcher: The labs did.

Students also identified the dormitories as a source for social integration.

Male Civil Engineer: I lived in the dorms right across from him so we studied physics together, we were going through it at the same time.

Female Industrial Engineer: I lived in McNary my first year and there were a lot of engineers on my floor and those were the people that I would always study with and had classes with up to my sophomore year. Those are the people that I studied with and did homework with and everything else and sat with in class so they were very important.

Male Wood Science Switcher: Just the dorms, that’s how I met my engineering friends, was from the dorms, and a few from the department.

Int: Seems like a lot of friendships start over in the dorms.

Female Business Switcher: Yeah, it's nice. It's kind of nice and convenient because they're all right there. You just walk down the hall. It's a lot easier than like calling them up and saying hey what's up, you want to hang out.

Both engineers and switchers identified the importance of faculty interactions in retention. Unfortunately both groups also reported that their interactions with faculty were very few, and the interactions they did have were mostly negative. Students made explicit comments about improving retention by getting students more involved with faculty.
Int: If you could improve retention in the college of engineering what would you do?

Male Electrical Engineer: Get the students more involved with faculty.

Male Civil Engineer: Yeah, definitely.

In this particular case, the student identified a faculty member as being the sole reason for remaining in the engineering department.

Female Industrial Engineer: I think interaction with the professors is a big deal, its something that I didn't have and the only reason that I am still in engineering is because of my advisor, and I think at least in the (engineering department) we have incredible faculty, they work so well with the students and if you just get to know them they are incredibly inspiring and I think that interaction is incredibly important and should be encouraged.

Several students reported that they did not have much opportunity to interact with engineering faculty. It is important to note that both engineering students and students who have left engineering had similar reports with engineering faculty.

Int: During your freshman and sophomore years how much interaction did you have with engineering faculty?

Female Industrial Engineer: Hardly any.

Female Industrial Engineer: None unless you went out of your way.

When students did get an opportunity to interact with faculty they reported that faculty were annoyed when students had questions during office hours and more generally that interactions with faculty were poor.

Male Civil Engineer: Sometimes they are pretty good, other times it's kind of irritating. I find a lot of times, even if it is during their office hours that some professors are irritated that you are using their time.
Male Mechanical Engineer: There's a big separation between the teacher student integration. There have been instances where I have gone in and talked with the teachers in their office hours and they were, it seemed like they were rather irritated that I even had a question, or why didn't I understand this when I was in the classroom and why are you coming in and talking to me about it now. Type of thing where they just hurried you along so they could get back to whatever they were doing.

Male Biophysics Switcher: I'd say seventy percent of the reason I transferred out of engineering was overall interaction with faculty... it was just they had zero time for the students.

Female Civil Engineer: My friend and I took (engineering course) at the same time and she went to talk to the professor and he basically said that she should drop engineering right away because she was female and she wouldn't make it through the rest of the program. That was my first impression of engineering professors so I didn't go talk to them until my junior year. It turned me off enough to not talk to any of them. It was four years ago.

Although the majority of comments about the quality of faculty interaction were negative, in several cases, one specific faculty member was identified as having a very positive influence on students' experiences in engineering.

Male Biophysics Switcher: Well, I'd say one of the greatest experiences I had was actually (engineering course) with (engineering professor). He was a great professor and really a refreshing change to the whole department that I had seen up to that point. He was there for the students, which he's the only professor in engineering that I ever found that knew what the students' names were.

Students did not report as many concerns about the importance of interactions with advisors on retention. However, some still felt these interactions were important.
Male Biophysics Switcher: I think I was assigned two different advisors then had to talk to another one or two for different stuff and no one was ever very encouraging of taking anything except for what they told me to take, and so advising was a big issue for me.

Similar to experiences with faculty during office hours, students reported both positive and negative experiences with advisors. It appears that early in the students’ careers they had poor experiences with their advisors, but as time wore on the experiences improved.

Male Political Science Switcher: I was having some problems freshman term and I went in and talked with him and thought he was really helpful giving me advice.

Male Mechanical Engineer: I’ve had a horrible experience with counselors until right now. This last counselor visit was the first time the counselor was nice to me and actually cared that I was there. Before that it was like yeah, take those classes, I don't care, now get out of here.

Male Electrical Engineer: My advisor had been pretty decent. It took me a while to get to the position I am in with her. She was just like with all the other teachers, like hurry up, get in and get out, let me get back to whatever I am doing, but I’ve worked with her for two and a half years now, so she kind of has a basic idea of who I am and I think that I have a decent rapport with her.

Students voiced some frustration with the large advising sessions.

Male Geology Switcher: And in engineering they see you once every three months and there are 500 people they see and its just did you meet this, did you meet this, did you meet this.

In general, it appears that students have some frustration with faculty in both academic office hour sessions and advising sessions. In both cases students are frustrated because faculty do not appear to have the time to answer students’ questions and rush
them out of their office. Helping the students with coursework or with advising does not appear to be a priority on the part of the faculty. Although some students reported positive experiences with faculty outside of class, these reports were about isolated individuals. As an example, several students reported very positive interactions with two specific faculty, but overall students reported poor interactions with most faculty.

The importance of positive interactions with peers, faculty, and advisors to retention was consistent. Perhaps the most important pattern was that no significant differences in perceptions exist between engineers and switchers in terms of the importance of networking to retention.

Normative Aspect of Social Capital

Students also commented on norms in engineering that prohibited students from working together. The norms enforced and encouraged in the College of Engineering are not conducive to student involvement in learning and forming cooperative study groups. As reported previously, students recognized the need to work together in groups, but as noted by one student the difficulty of the program appears to be the only factor that brings students together.

Recent studies have reported the competitive weed out culture and its adverse impact on student retention [14, 15]. Similar results were found in this study. Students reported that engineering students were pleased to outperform their fellow students to the point of annoyance and discouraging collaboration, and that the goal of early engineering classes was to weed out a large portion of the students. Referring back to the discussion of social norms, this is an example where social capital is low due to factors such as low trust and lack of support that discourage student collaboration. These comments were consistent from both engineers and switchers.

Female Business Switcher: But then it was just kind of weird because she would always be like what'd you get, what'd you get, what'd you get and I'm like why do you want to know so badly? Does it really matter? But then she'd be like all excited when she did better than me, she wouldn't really be that
happy when I did better than her, and I'd be like what's going on, I don't like this.

Male Biology Switcher: It was kind of discouraging. Why am I going to take this class where they want to fail me?

Female Civil Engineer: Who could handle the most BS, busy work and I don't think they cared about us at all, it was like you have to do this stuff and sit there and take it and if you pass you get to keep going.

Male Political Science Switcher: I sort of get the impression that they don't care if they retain a lot of their students, that they want to get rid of them. I don't know exactly what the philosophy behind that is.

Students also indicated that there was no sense of community or connection in engineering, which has been verified in other retention studies [15].

Female Industrial Engineer: It wasn't personal, it felt like they really didn't care about you, can you pass it, can you make it through, that type of thing.

Male Geology Switcher: There's no sense of community between engineers either, especially the first 2 years.

Female Electrical Engineer: Engineering is kind of like swim or die. It's like nobody cares if you don't, if you have 300 people whose going to notice that the one person dropped out.

Male Biology Switcher: You don't feel any connections with your department at all.

Male Political Science Switcher: Not only that there were like 300 people in the class, you could pick out faces but there was, just like he said, no community.

Students' lack of a sense of support and a sense of community were consistent among both engineers and switchers. A non-caring impersonal climate does little to encourage collaboration and cooperation.
In Tobias's investigation of student retention in science, students reported that early science courses are taught in a fashion in which information is presented as here it is and there is only one way to think about it [15]. Additionally she found that discussion was not encouraged in the classroom environment. Knowledge was presented as “plug-and-chug”, i.e. here is the equation, here is the situation, now plug in the numbers and get an answer. Students in this study reported similar results.

*Female Business Switcher:* I found more in engineering classes it was more like this is what it is and you write it down.

*Male Political Science Switcher:* It was a lot of the plug and chug teaching method and that just kind of turned me off.

*Male Biology Switcher:* You go to the next class and they say just do it and not why. I mean there's no explanation of what you are doing, why you are doing it or where you are going, its just do it.

*Male Biophysics Switcher:* It was very this is how you do things I don't want to talk about why, I don't want to talk about how, I don't want to talk about this, it's do it and that's it.

It would be inappropriate for faculty to suggest to students that engineering knowledge is absolute fact and that there is no time for questions. Engineering knowledge is certainly not static; if it were research universities would not provide value to society. Students have reported interest in the source of knowledge, assumptions, limitations of equations presented, and why something might be done in a certain way. If the norm in the classroom is to not ask questions about methods or concepts, minimal opportunities are provided for students to interact and discuss material. Most importantly, this runs contrary to teaching standards and learning theories discussed previously.

Both switchers and engineers commented on the competitive weed out culture and the lack of a sense of community. However, only switchers were frustrated with the “plug-and-chug” teaching methods.
Summary

Students perceive that social capital, in the form of networking with peers, faculty, and advisors, and pro-social norms, encouraging collaboration and trust among students, are important to student retention and success in the College of Engineering. Unfortunately, the evidence suggests that little is done to encourage the development of social capital. Classroom environments are seen as unfriendly, lacking a sense of community, and not conducive to discuss subject matter. Students feel that the purpose of the early years is simply to weed students out. Several engineering students reported that the early years were just to see who could handle the difficult environment with little support from faculty. Students are interested in acquiring a more in depth understanding of subject matter, an ideal situation, but questions are not encouraged either in or out of class. Although students made multiple positive comments about experiences in specific classes and with certain faculty, the consensus was consistent among both engineers and switchers that overall interaction with faculty was poor.

Perceptions of social networking and norms in engineering were consistent among both engineering and switchers. The only difference between the two groups was switcher’s frustration with the “plug-and-chug” teaching method. Based on the extensive similarities between the groups, it could be concluded that social capital is a concern for these students, but does not play a role in retention. A question that arises is, “what differences exist between switchers and engineers that allow them to cope with this chilly climate?” It is likely that social capital is more important to some individuals than others, and it would be a mistake to assume that the chilly climate in engineering is conducive to keeping only the best engineers. The lack of frustration of engineers with the “plug-and-chug” teaching method is alarming. There are few that would argue that we want engineers that are inquisitive and question the source of knowledge and the assumptions of certain approaches. Two themes emerge: what are differences between engineers and switchers that result in differences in retention, and what can be done to change the chilly climate in engineering? The first question is a topic for future research, and the second is addressed below.
Recommendations

As it has been established that social capital is important to the retention of engineering students and that opportunities for students to develop social capital are minimal in the early engineering curriculum, the following recommendations will focus on successfully implemented practices that have been shown to increase several positive outcomes, most notable for this study, retention of engineering students, student social capital, perceived satisfaction with the program, and academic achievement. The number of available programs and practices found to increase student retention, in addition to the outcomes mentioned above, is immense. The descriptions of programs and practices below serve to provide an overview of potential programmatic changes. Described below are both in-class and out-of-class opportunities.

It is important to note that not all of these practices have been proven to improve retention. This may seem problematic at first. However, each of these practices, as mentioned above, is related to multiple positive educational outcomes and to increasing student interaction and student social capital. Also important to note is that the ability to positively link a specific program or practice with increased retention is very difficult in a complex social setting like higher education. Some programs have been shown to increase retention including those at Purdue and Carnegie Mellon Universities. In both of these cases the changes made were expansive and multifaceted, and determining which aspects of specific changes actually increased retention would be difficult. The lesson to be observed is that to improve retention multiple changes must be made with each change having the potential to impact a variety of students and each having the potential to have multiple positive outcomes.

In-Class Practices

Active and cooperative learning have been shown to have both positive academic outcomes and contribute to the development of group skills. Both concepts are briefly presented in the following with the intent of providing a description of what each entails and the benefits supported by research. Following the discussion of active and cooperative learning is a summary of research of teacher and student discourse in the classroom including practical suggestions for increasing student learning and
involvement in the classroom. In this discussion several recommendations for in-class practices are included, some of which have limited descriptions of specifics of implementation. However, references are provided for the reader to investigate these practices in more detail.

Active learning is characterized by a student’s direct involvement in the learning process [62]. In active learning, students are seen as active constructors of knowledge as opposed to passive receivers of information. Learning theories and learning experts have reached some consensus that students actively construct new knowledge based on previous understandings and experiences [63, 64]. A subset of active learning is cooperative learning. Cooperative learning has received significant attention both in practice and in the research, and is best understood when compared with two alternate modes of learning, competitive and individualistic. It is important to note that cooperative learning is not simply putting students together in a group to work together. Specific characteristics of the group work must be present for it to be successful: positive interdependence of the group members; promotion of face-to-face interaction; individual accountability and responsibility to groups goals; use of relevant personal and small group skills; and group evaluation of group processing to increase the group’s effectiveness [65]. Cooperative learning has been implemented and evaluated extensively in the higher education arena. Perhaps the best example in engineering education is the Foundation Coalition, a group of six universities that have implemented innovative educational practices into the engineering curriculum. Cooperative learning has been shown to encourage the development of academically and personally supportive relationships that are vital to a number of important processes and outcomes including pro-social attitudes and behavior patterns, perspective taking abilities, sense of belonging and connectedness with others, achievement, and educational aspirations [57].

Faculty can increase student interaction in the classroom through active learning exercises. Active learning exercises encourage discourse among students in the classroom. The role of student discourse in the classroom has been investigated extensively. Jones argues that within the framework of interactive teaching exists several teaching components and strategies that have been shown to positively impact learning of
mathematics, including higher-order questioning, student presentation and discussion of mathematical ideas, and reflective discourse [47]. In addition, each of these strategies needs to be conducted in a supportive classroom culture in which students and teachers can negotiate mathematical understanding and students can compare their conceptual understandings with accepted understandings. Additionally, the classroom culture allows students to propose and discuss mathematical issues and situations that are important to them. A barrier to the described culture is the power differential between teacher and learner. This barrier can be minimized through teacher behavior that guides, not controls, the discourse. Specifically, teachers can encourage student reflective discourse on relevant topics.

Van Zee [48] conducted an investigation of student centered discussions. The author concludes that two aspects of her practice tend to encourage discussion, distributed authority and quietness, and suggests that these practices may be used in classrooms to encourage discourse on inquiry. In a second article by van Zee [49], multiple case studies were conducted by a group of educators from grade school through college. The intent of the case studies was to investigate methods of speaking by teachers and students that encourages students to formulate insightful questions about science topics and share their own ideas during science discussions. The authors identified common aspects of both student and teacher questioning. Student questions were found to occur under four conditions: 1) when discourse structures were set up that explicitly elicited questions, 2) when students were engaged in conversations about contexts of which they are familiar and had made observations for a long period of time, 3) when discourse environments were comfortable and students tried to understand each others thinking, and 4) when small groups of students were collaborating with each other. Comfortable discourse environments were found to be created by appointing students to facilitator roles, describing to students how to converse, listening closely to what they said, and clarifying student contributions. Teacher questioning was characterized by eliciting student questions that developed conceptual understanding, and asking students to clarify meanings, explore various viewpoints, and monitor their own thinking.
Teachers were found to encourage discourse by practicing quietness and reflective questioning.

In the above, descriptions of educational practices focused at getting students more involved in the classroom learning experience were provided. In order to implement these practices, faculty must be willing to adopt changes in their teaching and be provided with the resources and training to do so effectively.

**Out-of-Class Practices**

Out of class experiences include service learning, learning communities, and a variety of out-of-class programs and experiences. As noted previously, providing a detailed description of all available programs is not within the scope of this project. However multiple resources are available. Most notable are the retention efforts undertaken by Purdue University, which are based on Tinto’s model of retention [58], and focus on increasing students social and academic integration and commitment to the college.

Service learning is characterized by community service work that is integrated into the curriculum, and is specifically related to learning objectives. The connection between the community service work and the curriculum occurs through written activities and discussions. Service learning has been shown to be correlated with student’s social involvement during and after graduating from college. A growing body of evidence “strongly suggests that when accompanied by proper preparation and adequate academic reflection, service learning can be a potent civic educator.” [54] It has been shown that a service learning experience “can achieve the goal of educating young people about their responsibilities in a democratic society, allowing them to think about what it means to be a part of the multiple communities in which they find themselves.” [55] Additionally, students involved in service learning have increased comprehension of course material and develop an awareness of their local community [56]. Perhaps the best example of service learning in engineering education is the EPICS (Engineering Projects in Community Service) centered at Purdue University that involves seven universities nationwide. Service learning has tremendous potential to help students develop subject specific knowledge, group skills, and a sense of civic duty.
Learning communities are established as part of efforts undertaken by the Foundation Coalition. Learning communities are established by placing small groups of students together in several pre-engineering classes during their first two years of school. These students then have the opportunity to meet people early in their academic career. These peers provide social support and study partners, both of which are essential for survival in the engineering curriculum.

The above described methods for encouraging the development of student social capital are just the tip of the iceberg for educational opportunities. They have been selected based on the extensive research done indicating that they can increase student academic socialization and achievement, both of which are related to retention.

Summary

The most important consideration in improving student retention in engineering is that a single change in practice is unlikely to have a substantial impact on the retention of engineering students. Changes must be multifaceted and targeted at multiple groups. Both in-class and out-of-class positive experiences must be available. While this report has provided some recommendations on improving retention, the most valuable aspects are utilizing social capital as a framework for understanding and improving retention and developing an understanding of why students leave engineering. Improving student social capital, i.e. increasing opportunities for networking and social integration and enhancing pro-social norms such as trust and mutual respect, has the potential to not only improve retention, but to increase academic achievement, perceived satisfaction, and perhaps most importantly to prepare students to be active democratic citizens and cooperative and innovative engineers.
Chapter 4 - An Investigation of the Development and Role of Social Capital in an Electrical Engineering laboratory

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Abstract

An investigation of social capital in an electrical and computer engineering laboratory was conducted. Factors that affected the development and the value of social capital were researched. Social capital consists of interactions among individuals (networks), social rules that encourage these interactions (norms), and the value of these networks and norms. Data were collected through participant observation over the course of a term, interviews with students, participation in teaching assistant meetings, and a survey. A total of 30 students were observed in two laboratory sessions. Interview and observational data were analyzed to determine themes or patterns in behaviors and actions that affected the development of social capital and the value of social capital in this setting. The open endedness of the laboratory assignments, requirement for extensive troubleshooting, and teaching assistant behaviors encouraging students to work on their own appear to encourage the development of social capital. Social network analysis was used to investigate correlations between social capital, in this case measures of network centrality, and academic achievement. Degree centrality, the connections that an individual has in a social network, was found to be positively and significantly correlated with laboratory grades, while there was no significant correlation between closeness centrality (the minimum number of ties necessary for an individual to reach all other members of the network) and laboratory grades. The multiple methods of data collection and analysis appear to validate the result that social capital is developed in this laboratory and that social capital is positively correlated with academic achievement.

Introduction

The purpose of this research is to investigate factors that impact the development of social capital in an engineering laboratory setting and potential correlations between individual student social capital and achievement. The concept of social capital is introduced, including a definition of social capital and a summary of existing research correlating social capital with positive group and individual outcomes. An argument is presented that the presence of individual social capital in an academic setting may be associated with access to information and, therefore, academic achievement. Based on
this argument the research questions and a description of the qualitative and quantitative research methodologies are presented, followed by the results of this study. Concluding statements are then made concerning the applicability of these results to other settings and implications for further research.

**What is Social Capital?**

Social capital has been researched in multiple fields, including economics, business, and sociology, and has been shown to be positively correlated with economic productivity of nations [5], health and well being of individuals [6], innovation [40, 66], productivity [67], and academic achievement [12]. With the use of the concept in such varying fields, numerous definitions and applications of social capital have emerged, leaving the researcher with the task of choosing a definition that is appropriate for their context. Generally, social capital is seen as a set of social resources that consists of interactions among individuals (networks), that are enabled through social norms such as trust and reciprocity, and that allow for an outcome that would not be possible in its absence.

The consensus of most researchers involved in social capital work is that Pierre Bourdieu originally introduced the concept to analyze economic theory [3]. Bourdieu criticized economic theory in its narrow focus on economic capital and suggested that social capital must be considered as an asset in economic theory. Bourdieu put forth a definition of social capital:

"...the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition-or in other words, to membership in a group-which provides each of its members with the backing of a collectively owned capital..."

For the current study, social capital is viewed as social resources that are available through institutionalized relationships. The term "relationships" refers to the network aspect and the term "institutionalized" alludes to the presence of a set of social rules within a particular group that encourage specific behaviors (social norms). The value of
the relationships and social norms, an essential feature of social capital, is asserted by the final phrase, "collectively owned capital".

Social capital consists of networks and norms. However, research approaches tend to focus on either networks or norms with very little work being done that includes both. Fukuyama focused on trust as a social norm and proposed that social trust is an indicator of social capital [5]. Putnam incorporated both social relationships and norms as measures of social capital [6]. Grootaert and Bastelaer suggested that it is essential to measure both the network and normative aspects of social capital [29]. As an example, a group may have a high level of interactions, but these interactions may have little or no value due to the absence of trust. Alternately, a group may display a high level of trust but have few interactions.

Social capital can be both a collective and individual resource. Both Putnam and Fukuyama utilize a collective resource approach in their work. Putnam investigated the level of social capital at a state level and presents positive correlations between social capital and such factors as health, low crime levels, and economic prosperity [6]. Fukuyama suggested that high trust countries are more capable of fostering the development of large corporations and are more economically prosperous [5]. However, significant research exists analyzing individual social capital. Research in both K-12 and higher education has found that individual student social capital is positively correlated with academic achievement and retention [1, 8-13]. Measures of social capital in these works are primarily students' perceptions of social capital, i.e. perceptions of peer and faculty support.

Social capital consists of both networks and norms, and allows for outcomes that would not be possible in its absence. The research reported here investigated both the normative and network aspects of social capital, and assessed the value of social capital to the individual. The normative aspect is examined as the presence of social norms and factors that affect the development of these norms. The network aspect is examined as both perceived support from individuals, and as position and degree of connections within a social network. The value of social capital to the individual is evaluated by looking at potential correlations between academic achievement and their position and
degree of connection within a social network. It is hypothesized in the following that the presence of social capital is essential to increasing access to information from other individuals in both business and academic settings and this access to information is positively correlated to achievement in an academic setting.

**Social Capital, Access to Information, and Achievement**

Social capital has been shown to play a vital role in people's access to information. An individual can access information utilizing both human and non-human resources. Significant evidence exists to suggest that in business people use other people more than other sources to acquire information. An ethnographic report conducted by the U.S. Department of Commerce estimates that 80% of organizational learning is informal [38]. Studies have shown that the primary source of information in technological workplaces is other employees [39]. Specifically people were found to be roughly five times more likely to approach friends or colleagues for information than use a database or other repository. Additionally, it was found that 85% of managers studied at a consulting firm were found to receive knowledge critical to the successful completion of an important project from other people. A study investigating the economic prosperity of Silicon Valley suggested that information sharing, encouraged by the presence of social capital, was a factor in its success as compared to other high tech regional centers [66]. In another work, Maskell [40] stated that:

"Social capital enables firms to improve their innovative capability and conduct business transactions without much fuss and huss and has, therefore, substantial implications for economic performance."

Greve concluded that social capital, “is as important as human capital in determining productivity”, and further that, “social capital contributes to productivity because individuals use their personal contacts for getting advice, solving problems, and obtaining complementary resources [67].” Consistent evidence suggests that both individuals and businesses with high social capital have greater access to information. Although the business and academic settings are different, this evidence suggests that
social capital may be positively tied to access to information, and consequently, could also affect achievement in an academic setting.

In an academic setting, students' access to information is vital to their success. Students' social sources of information include faculty, teaching assistants, and peers. A significant body of research has investigated correlations between social capital and academic achievement. Students' perceptions of social capital were found to have effects on educational achievement in a higher education setting [12]. Carbonaro found that social capital was positively related to dropout status and mathematics achievement test scores [9]. Morgan and Sorensen similarly found that mathematics achievement for 8th graders was positively correlated with density of friendship and parental networks [8]. In a study of university undergraduate students, Etcheverry et al. found that student perceptions of support from other students related positively to student self confidence and grade point average [12]. Social support has been shown to be a key factor in student success in college [17, 68]. Each of these studies utilizes survey data to measure social capital.

Evidence suggests that a strong link between social capital and academic achievement exists. It is argued that social capital and the corresponding benefit of access to information is important to academic achievement in higher education in general. The current study will build on this work by examining how social capital works at a more fine grain level in an electrical engineering laboratory. The research includes several aspects that have not been addressed in the existing literature on social capital in education: social capital is measured as both networks and norms, the presence of social capital is evaluated through extensive participant observation and informal interviews, and the value of social capital is evaluated as the correlation between the role and degree of interactions of the student in a social network and academic achievement within that network.

**Proposed Research and Methodology**

The intent of this research is to investigate social capital in an undergraduate engineering laboratory. The specific research questions are:
What factors encourage and/or discourage the formation of social capital in the laboratory setting, and
Is individual social capital positively correlated with academic performance in the laboratory setting?

The definition of social capital utilized for this research is reiterated as follows:

- Social capital is a set of social resources that consist of interactions among individuals (networks), that are enforced through social norms, and that allow for an outcome that would not be possible in its absence (achievement and productivity).

The following is a description of the research setting, and data collection and analysis procedures that were used to address each of these research questions. The data collected served to answer both research questions and is described first. Methods of data analysis utilized to address each research question differ significantly and are described individually.

**Research Setting**

This research is situated within a larger programmatic effort designed to understand and improve undergraduate education in the Electrical Engineering and Computer Science Department (EECS) at Oregon State University (OSU). The core of this effort lies in the introduction of the TekBots™ platform, a small robot that students utilize as a platform for learning™ in multiple courses throughout the curriculum [19, 20]. The TekBots™ program is continuously evaluated and improved through a design research approach [21]. As part of this design research approach, curricular improvements are continuously designed, evaluated, and modified. The overarching goals of this specific effort are to develop an understanding of factors that affect the development of student social capital and to utilize this information to make curricular changes.

Participants in this research were students in “Introduction to Electrical and Computer Engineering Concepts (EECS Concepts)” and “Digital Logic Design Laboratory (Design)”, both lower division undergraduate courses required of all ECE
students. TekBots™ are used in these courses and laboratory assignments have been designed for students to program and troubleshoot the TekBot™.

**Data Collection**

The role of social capital in student success in a particular laboratory was assessed by interviewing students about the role of working together with other students in laboratory and collection and analysis of student and teaching assistant (TA) interactions by direct observations in the laboratory and weekly TA meetings.

Observations were made in the Design laboratory setting, and in the weekly TA meetings for both the EECS Concepts and Design courses. A total of 7 laboratory sections were offered for Design. Data were collected for students in two 3-hour laboratory sections over the course of the entire term, 22 students were present in the first laboratory section and 8 were present in the second laboratory section. The second laboratory section was held in the evening, where traditionally evening laboratories have fewer students. These 2 laboratory sections were representative of all 7 laboratory sections in terms of time offered (day or evening), number of students, and representation of women and minority students. Although students were not assigned to the laboratory sections randomly, the results of this study can be generalized to the entire population of design students for the Fall term. As there are no obvious unique attributes of the students or the laboratory sections offered Spring term, it is reasonable that the results can be generalized to future laboratory sections of this course.

Data collected includes:

- Student survey administered in EECS Concepts, Winter term 2004;
- Observations and informal student interviews in two 3-hour laboratory periods in Design, Spring term 2004;
- Formal interviews with students from Design laboratory sections; and
- Observations of weekly TA meetings for both EECS Concepts and Design.

The development of social capital in the laboratory setting can occur through interactions between and among students, and between students and teaching assistants. The intent was to collect data on the student interactions and classroom norms that may impact both the nature and extent of these interactions. The most appropriate way to
collect data on interactions is through firsthand participant observation. The value of observation is that it allows the researcher to observe the interactions firsthand and, "use his or her own knowledge and experience in interpreting what is observed" and "observation makes it possible to record behavior as it is happening" [69]. An observation protocol was developed to capture who students interact with, the nature of their interactions, and the time they spend interacting. The observation protocol serves to increase the reliability and consistency of data collected in the laboratory. Informal interviews were also conducted during observation to understand why a student carried out a specific action or why they asked a certain question.

Formal interviews were conducted with nine students selected from laboratory sections that were observed. The number of interviews conducted resulted in students providing consistency in their responses to interview questions. The interviews were conducted outside of the class in a neutral setting during the last week of the term. Students were purposefully selected based on gender, minority status, laboratory section, and working location in the laboratory to represent all laboratory students. An interview protocol was developed to question students about their interactions with students and the perceived need to interact with other students to successfully complete the laboratory assignments. These interviews were audio taped and transcribed.

Teaching assistants held weekly meetings to discuss the laboratory for the week. The researcher attended these meetings and either notes and/or an audio recording of the conversations was taken. Teaching assistants discussed topics such as potential student difficulties in the laboratory, student progress in understanding and completing the laboratory, and teaching strategies to encourage student success and collaboration.

Data Analysis

The analysis of data was different for each of the two research questions. The first research question concerning what factors impact the development of social capital in the laboratory setting was addressed utilizing an interpretive perspective [22]. This perspective is appropriate when analyzing observational and interview data, and is based on the premise that individuals view the same social setting in very different ways. These views are created by individuals through dynamic interactions with their surroundings.
An interpretive analysis allows the researcher to understand an individual’s views of their experience and of their interpretations of that experience. Analysis of the data was done utilizing data analysis software, which facilitates the coding and interpretation of qualitative data. Data were coded and recoded at separate times to enhance the validity of the results.

The second research question was addressed using the tools of social network analysis. Social network analysis (SNA) was utilized to examine relationships between students’ ties in social networks and their academic success in laboratory. The focus of social network analysis is on the “relationships among social entities, and on the patterns and implications of these relationships” [28]. Social network analysis provides a systematic means of assessing informal networks by mapping and analyzing relationships among people. In this case, the relationships refer to personal interaction occurring during laboratory and the potential implication of the relationship is academic achievement in laboratory, measured as the laboratory grade. Multiple measures are utilized in social network analysis to identify the amount of interaction or number of ties and to assess individuals’ strategic locations within the network. Measures of centrality are appropriate as social capital indicators in instances when the individual is the unit of analysis and complete network data are available [70]. An individual is central to a network if he or she has a proportionally large number of ties in the network meaning they are “in the thick of things.” The two most common measures of centrality are degree and closeness. Degree is calculated as the total number of ties in the network, and closeness refers to the total number of links to reach all members of the network. Social network analysis software [71] was utilized to calculate measures of centrality and statistical analyses were performed to investigate potential correlations between the measures of centrality and academic achievement in the laboratory.

Factors Affecting the Development of Social Capital

A survey was conducted in EECS Concepts in Winter term 2004 to assess students’ willingness to help other students and their perceptions of how much time they spend helping other students. Students’ perceptions of a supportive environment in the EECS Concepts class appear to be positive. Responses to three questions are provided in
Figure 1 below. 86% of students responded either strongly disagree or moderately disagree to the question, "I have asked for help from other students and been turned down." Students responded 84% with either "strongly agree" or "moderately agree" to the question, "I am willing to help other students in this laboratory even if they don’t help me." However, data suggest that although students are willing to help others, they do not spend significant amount of time engaged helping other students. 56% of students only "slightly agree" or "disagree" with the statement, "I spend time helping others in lab." Together this evidence suggests that students in the EECS Concepts class are willing to help each other, but do not spend much time engaged in this activity.

![Bar Chart](image)

**Figure 1 - Responses to Select Survey Questions from Winter 2004 Community Survey Administered in EECS Concepts**

Observations and interviews conducted in Design suggest that three main factors may influence the quality and amount of interactions: the need for extensive troubleshooting, the nature of the laboratory assignments, and teaching assistant behaviors.

The inherent complexity of the TekBot™ and the laboratory assignments associated with the TekBot™ appear to encourage students to cooperate in the laboratory setting. Students are introduced to the TekBot™ in EECS Concepts and are required to completely assemble a kit, while performing numerous laboratory experiments. Students
spend approximately 30 hours assembling their TekBot™, which includes hundreds of connections. Although the physical components and functionality of the TekBot™ are relatively simple compared to most electronic devices, the level of complexity is significant for students at this stage in their career. As a result, students spent a significant amount of time troubleshooting in the subsequent Design laboratory, where they are required to utilize the functionality of the TekBot™ to perform given tasks. Students commented on how much time they spent troubleshooting in interviews:

Student 1 - The whole class spent a lot of time troubleshooting, every class, probably two out of three hours.

This level of complexity requires the students to rely on one another to be successful in the laboratory. For example, students who were observed to work in relative isolation in the laboratory were observed spending several hours troubleshooting a problem that was the result of a loose connection or a poor quality solder joint. In contrast, students who spent relatively large amounts of time interacting with other students, were able to find solutions in far less time when faced with a similar problem with their TekBot™. Multiple incidents were observed where students who worked in isolation struggled for large periods of time with troubleshooting, while students who were not isolated were able to solve complex problems in a timely manner. These students became frustrated, and these incidents seemed to detract from the laboratory experience. Student responses to interview questions provide further evidence of the perceived value of social interaction and success in troubleshooting:

Student 2 - yes, same kind of thing, you are coming from different viewpoints so its easier to figure it out.

Student 3 - yeh, definitely, when you work on something and you wire something up you think that you have it right and you look at the same things over and over again, its like writing a paper and reading it yourself, you have to have somebody else read it to see the things that your mind just glosses over.
The laboratory assignments are characterized as being open ended and providing minimal specific directions for the students to complete the laboratory. Additionally, most laboratory assignments can be completed using multiple strategies. Although this aspect of the laboratory reportedly has been a source of frustration for most students, it has resulted in students not only recognizing the need to work together, but seeking out help from other students. Teaching assistants also encouraged collaboration among students by being somewhat vague in their responses to student questions. This behavior and its impact on student cooperation will be discussed later in this paper. Students reported that they were given little direction in the laboratory and that this lack of direction encouraged cooperation and interaction among students:

Student 1 - The difficulty and especially in this lab it is so vague we really have no idea what we have to do.

Student 4 - We were given a problem and we weren't told how to fix it, how to do it and we had to use our own ideas and our knowledge from the class to actually implement the design rather than be given it.

Teaching assistant behaviors in the laboratory appear to have an impact on students interacting with each other to accomplish the laboratory task. Teaching assistant meetings were held on a weekly basis to discuss the laboratory assignment and to share techniques utilized in laboratory that appeared be helpful promoting student success. The researcher was present during these meetings and the teaching assistants were aware of this research project. The teaching assistants were encouraged to implement specific behaviors that would encourage students to work together and to look to one another for assistance in completing the laboratory. For example, teaching assistants were encouraged by the researcher to not provide direct and specific answers to student questions, but to guide the students in finding answers to their questions. Over the course of the term, not a single incident was observed in which the teaching assistant provided a direct answer to the student or performed a laboratory task for the student. Although students voiced some frustration over this practice they recognized that some value existed in students being required to be independent.
Student 5 - Well, the TA's were important but they were encouraging more independence so a lot of the times they wouldn't directly answer my question.

Student 4 - In this lab they (TA's) basically just shooed you off with a vague answer. Towards the end it was encouraging to figure stuff out on your own, and actually get it done, which we actually started doing. I didn't like that at first but ended up appreciating it.

Students agreed that it was important to work together to be successful in the laboratory.

Student 3 - It's definitely a lot better to be able to bounce ideas off of somebody else.

Student 1 - I had problems with constraint editing. At first I had a problem with that, but my friends came and helped me and that was cool. They went out of their way to help me.

Student 1 - Definitely, you need ideas, especially now that we are starting all this lab tekbots stuff. A lot of problems might come in like for troubleshooting. They say three hints are better than one. It helps to be a team.

As a result of these TA behaviors a norm was developed in the classroom that students were more likely to look for help from other students than from the TA's. This behavior was observed with increasing regularity as the term progressed.

Both observational data and interview responses indicate that due to the open ended nature of the assignments, TA's providing vague answers to student questions, and the need to troubleshoot, students must collaborate to be successful in this laboratory setting. Students recognized the value of interacting with other students i.e. social capital, to be successful in the laboratory.

Social Capital and Achievement

Correlations between measures of students' network centrality and their academic success in laboratory were examined. This analysis was performed using data from only
the first laboratory period with 22 students. Of the 8 students in the second laboratory, 4 students received a grade of 100, and 4 students received a grade of 93. Due to the overall high level of achievement of the students in the second laboratory period, investigating correlations of grades and network centrality measures would have little value.

Both degree and closeness centrality measures were investigated. In Figure 2 below, a sample network of 5 students is displayed. Degree centrality is a measure of the connections that an individual has within a specified network, and can be calculated as simply the number of ties. For example, student 2 has a tie to all four other students, therefore has a degree of centrality of 4. Student 1, on the other hand, has ties only to Student 2 and therefore has a degree of centrality of 1. Degree centrality can also be weighted based on the strength of the ties of an individual. The labels on the links indicate arbitrary tie strengths. Student 1 has ties only to one other student, but the strength of the tie is 4, resulting in a weighted degree centrality of 4. Student 2 however, has connections to 4 other students. Taking into account the strength of the ties results in a weighted degree centrality of 7.

Closeness centrality is a measure of the minimum number of ties necessary for an individual to reach all other members of the network, and does not take into account the strength of the ties. Student 2 is directly linked to all students and requires one tie to reach all students, resulting in a closeness centrality value of 4. In contrast, Student 1 requires one tie to reach Student 2, and a minimum of two ties each to reach Students 3,4, and 5. Student 1 has a closeness centrality of 7 (1+2+2+2).

Measures of degree centrality were weighted based on the time spent with other students and the academic ability of the students being interacted with. Normally in network analyses, firsthand data are not available on the actual quantity of time that individuals spend together. In this study, however, direct observation over the course of the term allowed estimates of the time that each student spent with all other students in the laboratory. Student interview responses indicate that interactions with high ability students were more valuable than interactions with students of low ability. Bourdieu
confirms this and suggests that not only the number of interactions but the capital of those who an individual interacts with are important [3].

“The volume of the social capital possessed by a given agent thus depends on the size of the network of connections he can effectively mobilize and on the volume of capital possessed in his own right by each of those to whom he is connected.”

Cumulative grade point average was used as a measure of academic ability of students. Two measures of weighted degree centrality were calculated, the first was weighted based on the total amount of time spent with other students, and the second was weighted based on time spent and the grade point average of the individual with whom the interactions took place.

In summary, three centrality measures were calculated:

- Degree centrality weighted by time spent together, labeled degree centrality;
- Degree centrality weighted by both time spent together and the cumulative OSU GPA of the individual that time was spent with, labeled GPA degree centrality, and
- Closeness centrality.

The potential correlation between both calculated measures of degree centrality and laboratory grade was investigated. None of these measures are normally distributed and social network measures are not independent, thus necessitating the use of the Spearman non-parametric correlation. Correlation coefficients and significance levels are shown in Table 3. A strong positive correlation exists between degree centrality and
laboratory grade (0.407) that is significant at the 0.10 level, but a stronger correlation exists between GPA degree centrality and laboratory grade (0.466) that is significant at the 0.05 level. This suggests that the correlation is strengthened when accounting for the ability of the students who an individual interacts with, supporting the general proposition proposed by Bourdieau [3].

Closeness centrality is a measure of the total distance between a particular individual within a network and all of the other actors. In this setting it has been shown that access to information is important to student success in the laboratory and access to information can be measured as closeness centrality. The small correlation (-0.065) and the lack of significance indicate that, in fact, a correlation between closeness centrality and laboratory grade does not exist. This is somewhat surprising based on the strong correlation between degree centrality and laboratory grade. However, degree centrality accounts for not only the number of connections, but the total time spent with each of the actors interacted with, and is weighted based on the GPA of the individual being interacted with. Closeness centrality only measures the existence of a connection, but does not weight the connections based on time spent or GPA.

Table 3 - Correlation Between Laboratory Grade and Measures of Network Centrality

<table>
<thead>
<tr>
<th>Laboratory Grade</th>
<th>Degree Centrality</th>
<th>GPA Degree Centrality</th>
<th>Closeness Centrality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \rho_{(1)} = 0.407 )</td>
<td>( \rho = 0.466 )</td>
<td>( \rho = -0.065 )</td>
</tr>
<tr>
<td></td>
<td>( \text{Sig}_{(2)} = 0.060 )</td>
<td>( \text{Sig} = 0.029 )</td>
<td>( \text{Sig} = 0.779 )</td>
</tr>
</tbody>
</table>

(1) - \( \rho \) is Spearman’s Rho Correlation Coefficient
(2) – Significance is two tailed.

This result suggests that the strong correlation between degree centrality and laboratory grade is strongly dependent on the time spent with other actors and the ability of these actors in the social network. This is logical as a relationship between two actors in which the actors spent several hours working together is clearly more valuable than one in which the actors spend just a few minutes interacting, in a setting in which access to information is critical. Recall that isolated students were observed spending several hours troubleshooting what turned out to be a relatively simple problem while students
who consistently worked closely with several students were observed solving relatively complex problems in little time.

Conclusions

Both observational and social network measures indicate that social capital is correlated with student success in the laboratory setting studied, specifically the network aspect of social capital. Students reported that the open-endedness, level of difficulty, and the necessity to troubleshoot required that they work together in the laboratory to be successful. The correlation analysis additionally confirmed that students who spent more time working with other students performed better in this laboratory course.

The combined use of participant observation and interview data enhance the validity of the findings. Observational data were consistent with student reports during interviews. While we can generalize these findings to ECE students taking the Design course, it is more difficult, and inappropriate, to argue that social capital is valuable in any engineering laboratory setting. As noted above, evidence suggests that specific characteristics of this laboratory setting necessitated collaboration among students to be successful in terms of academic achievement. The characteristics discussed above are however, not unique to this setting. Many engineering laboratories are open-ended and are characterized as having a high level of difficulty. It would be expected and is confirmed by this research, that the student collaboration is valuable in a setting characterized in this way.

The question that arises is, what are the practical implications of these results? Or, more specifically, should laboratories be designed to encourage the development of social capital? There are inherent dangers in designing laboratories in this way. Confirmed by this analysis is the proposition that students who do not engage with their TA’s and peers in this type of setting will be less likely to achieve academically. If the learning atmosphere is designed to necessitate interaction, the responsibility to encourage interaction among students who are isolated falls in the hands of the instructors.
Chapter 5 - Social Capital and Academic Achievement in an Electrical Engineering laboratory

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Abstract

The relation between student social capital and academic achievement in an electrical engineering laboratory was investigated utilizing a researcher-designed survey instrument. Student social capital in the laboratory setting consists of interactions with both students and teaching assistants. It is proposed that the quantity, quality, and relevance of these interactions are included in the construct of social capital. Academic achievement includes laboratory grade, the number of extra credit assignments the student was able to complete, and self-concept of ability. Utilizing data from a focus group pilot of the survey and a full scale implementation, some survey questions were discarded from use in the final analysis of social capital and academic achievement. Survey results indicate that the effects of social capital on academic achievement vary from strongly negative to strongly positive. The quantity of student-student and student-teaching assistant interactions appear to have no significant relation to any measures of achievement in this laboratory. The relevance of student-student interactions to the laboratory assignment has a negative effect on laboratory grade, and the quality of student-teaching assistant interactions has a positive effect. The relevance of student-student interactions to the laboratory assignment, and the quality and relevance of student-teaching assistant are the only significant social capital variables in predicting the number of extra credit exercises completed. The relevance of student-student interactions has a negative effect, the quality of student-teaching assistant interactions has a positive effect, and the relevance of student-teaching assistant interactions has a negative effect. Three social capital variables are significant with both positive and negative effects on self-concept of ability, quality of student-student interactions, relevance of student-student interactions, and quality of student-teaching assistant of interactions. These results may indicate that relatively low achieving students in this setting rely more on student and teaching assistant interaction than high achieving students.

Introduction

Social capital theory is gaining recognition as a valuable theoretical framework for investigating multiple positive outcomes associated with interaction among
individuals. The construct of social capital has been examined in multiple settings, including business, education, neighborhoods, and countries. It has been found to be associated with reduced crime rates, enhanced productivity, innovative capability, retention, and academic achievement. The fact that the theory of social capital has been used as a framework in such diverse settings and as a predictor variable for multiple positive outcomes is an indication of the research potential of this construct. This study applies the construct of social capital to academic achievement in an electrical engineering laboratory setting in a research extensive university.

The higher education setting is a social enterprise in which students’ abilities, behaviors, and attitudes change as a result of interactions with peers, professors, and teaching assistants (TA) [17, 68]. Universities were originally established to develop human capital, or skills and knowledge that increase the value of students to society. The importance of social capital in developing human capital has been argued extensively [1, 3, 72]. In order for students to develop human capital, the university setting must provide a supportive atmosphere where students can “develop networks of interaction, based on trust, so that norms, obligations, and expectations for scholarly achievement are increased, information channels are expanded, and the conceptions of individuals change from the I to the we.” [72] Astin confirms the importance of student interactions and suggests that a student’s peer group is the single most influential factor in their development [17].

Although several definitions of social capital have emerged, nearly all definitions encountered include three components that address both the social and the capital components of the construct. Two components deal with the social component, networks and norms, and one deals with the capital component, value. Networks are interactions among individuals based on relationships and can be a valuable source of information. In the workplace, a new employee learns the ropes of the organization through informal learning. An ethnographic report conducted by the US Department of Commerce estimates that 80% of organizational learning is informal [38]. Studies have shown that the primary source of information in technological workplaces is other employees [39]. Specifically, people were found to be roughly five times more likely to approach friends
or colleagues for information than use a database or other repository. Additionally, it was found that 85% of managers at a consulting firm were found to receive knowledge critical to the successful completion of an important project from other people. In a higher education setting interacting with other students, faculty members, and TA's has been found to be critical to success in terms of retention [14, 58] and academic achievement [8-10].

Norms are people's beliefs and perceptions about normal and accepted ways of behaving within a specific social setting. Norms can either be behaviors that are perceived to be accepted by other people, or perceptions of how other people are behaving. Our perception of norms can influence our behavior, even if our perceptions are incorrect. Fukuyama posits that trust, a social norm, plays a vital role in the social and economic productivity of nations [5]. Specifically, Fukuyama indicates that successful communities are “formed out of a set of ethical habits and reciprocal mutual obligations internalized by each of the community’s members” [5]. In terms of economic productivity, Fukuyama claims that a nation’s success is based on the level of trust inherent in the society. Coleman makes a similar claim in terms of group productivity when he claims that “social capital is embodied in the relationships among persons...a group whose members manifest trustworthiness and place extensive trust in one another will be able to accomplish more than a comparable group lacking that trustworthiness and trust.” [27] Johnson found that the development of social norms in the classroom is influenced by teacher behaviors, teaching structures, and students actions [73]. In this setting, students were required to provide evidence for their assertions and were required to defend their physics models in terms of evidence that was acceptable to other classmates. In other research, it was found that classroom norms can have an affect on student learning opportunities, as norms influence the nature of discussions in the classroom, students’ abilities to participate in classroom discussions, and teachers’ abilities to track student understanding [74]. As an example, a norm in the classroom was the negotiation of mathematical meaning between the student and the teacher, as compared to the teacher telling the students about canonical meanings of mathematical
concepts. The relevance of these norms to this study is that classroom-specific factors can affect the quality and quantity of interactions that occur among students.

The value component indicates that the presence of networks and norms allows for an outcome that would not be possible to the extent observed in their absence. The value of social networks and norms ranges from economic productivity of nations [5]; healthy neighborhoods with low crime levels [6]; retention of science, mathematics, and engineering students [14]; and academic achievement of both K-12 students [9, 10] and college students [12]. For this research the value measured is academic achievement in an engineering laboratory.

The Problem

Various researchers have found correlations between social capital and academic achievement across a variety of settings. Coleman [1] conducted a study of high school students to investigate the potential relationship between social capital and high school dropout rates. Although this work did not investigate correlations between social capital and academic achievement, several studies followed Coleman’s lead and tested this relationship [8-11, 13]. Each of these studies utilized survey data from the National Education Longitudinal Study of 1988 (NELS:1988). Sun found that community-based social capital was positively associated with academic performance, even after controlling for family-based social capital and demographic factors [10]. Carbonaro tested Coleman’s hypothesis in a new setting and found that social capital was positively related to mathematics achievement test scores [9]. Morgan and Sorensen similarly found that mathematics achievement for 8th graders was positively correlated with density of friendship and parental networks [8]. Although these studies are relevant, in that they found positive correlations between social capital and achievement, all were conducted in a K-12 setting. This study makes the assumption that social capital is a relevant variable in achievement at the college level. This assumption has been productively made about other research on K-12 classrooms, most notably the application of National Science Education Standards [75] to collegiate teaching [76].

In a study of university undergraduate students, Etcheverry et al. found that student perceptions of support from other students related positively to student self
concept of ability and grade point average (GPA) [12]. Social capital is conceptualized as including challenge and support, and is measured using a survey. Although the authors provide ample evidence that the challenge a student receives has been shown to be correlated with achievement, there is no evidence from other literature on social capital that challenge is a key component of the social capital construct. Support includes faculty and peer support and positive affect. Positive affect refers to the student’s general feelings about the university setting. Faculty and peer support are clearly appropriate measures of social capital in that they address the network component of the definition. However, no explicit measures of the normative aspect of social capital were included in their survey instrument. In a paper designed to provide guidance in measuring social capital, Grootaert and Bastelaer [29] suggested that it is essential to measure both the network and normative aspects of social capital.

According to the working definition, in order for social capital to be present, networks and norms must promote outcomes that would not be possible in their absence. The above mentioned studies conducted in the K-12 setting utilized subject specific achievement as outcomes, while Etcheverry et al. utilized both college GPA and self concept of ability as outcomes. Following the argument presented by Etcheverry et al. suggesting that both GPA and self concept of ability are important outcomes of higher education, this study utilizes laboratory grade and self-concept of ability as the capital component of social capital. As suggested by Etcheverry et al., self concept of ability represents students attitudes about their abilities, and the importance of developing these concepts has been established [17, 68].

This study builds on and extends existing work in that it examines social capital theory in higher education, in an electrical engineering lab, and through measures of both the normative and network aspects of social capital. The specific research goal addressed is to investigate correlations between network and normative aspects of student social capital and laboratory grade and self-concept of ability.

Research Setting

This research is situated within a larger programmatic effort designed to understand and improve undergraduate education in the School of Electrical Engineering
and Computer Science (EECS) at Oregon State University (OSU). The core of this effort lies in the introduction of the TekBot™, a small robot that students utilize as a platform for learning™ in multiple courses throughout the curriculum [19, 20]. Curricular improvements are continuously designed, evaluated, and modified through a design research perspective of educational reform [21]. The overarching goals of this specific effort are to develop an understanding of relationships between student social capital and academic achievement, and to utilize this information to make curricular changes. Participants in this research were students in a second term freshman engineering course, Introduction to Electrical and Computer Engineering Concepts (EECS Concepts). This course consists of two one-hour lectures per week and six laboratory sections. Laboratory assignments are designed for students to assemble, test, and program their TekBot™. Each laboratory assignment contains an extra credit challenge portion, in which students perform an exceptionally difficult task utilizing their TekBot™.

**Operationalizing Social Capital**

Based on an abundance of agreement from noted scholars and published literature, social capital consists of networks, norms, and the value of these networks and norms. The definition of social capital utilized for this research is the set of social resources relevant to academic performance that are available to students in the engineering laboratory as a result of interactions with other individuals and norms that promote these interactions. This study used a researcher-designed instrument to measure the amount of student financial capital, human capital, and perceived social capital.

The conceptual model is displayed in Figure 2 below, and proposes that financial, human, and social capital, as well as gender and age are related to student academic achievement. Social capital lies at the intersection of academic achievement and networks and norms, which is appropriate as it entails both networks and norms, and the value of these networks and norms. Social capital would not be present in the absence of any of these three constructs.

Academic achievement was measured as self concept of ability and two measures of laboratory achievement, laboratory grade and the number of extra credit exercises the student was able to complete (extra credit exercises). Although laboratory grade and
extra credit exercises will be highly correlated, as extra credit exercises will certainly increase students’ grades, extra credit exercises are a unique aspect of the laboratory. Based on previous observations of the laboratory setting, the extra credit exercises required extensive interactions with both other students and TA’s. Self concept of ability was measured using a 3-item scale modified from Brookover, Patterson, and Thomas [77].

**Figure 2 - Operationalizing Social Capital**

Previous research has shown that both human capital and financial capital [17, 68] are positively correlated with academic achievement. Financial capital refers to monetary resources available to pay for college-related expenses such as books, tuition, and rent. Human capital is the knowledge, skills, and training that students bring with them to college. Human capital was measured as the student’s cumulative college GPA [78]. Financial capital was measured as the educational level of the student’s parents [79].
Data for the highest level of education obtained for both parents were added to obtain a combined value for parents’ educational achievement. This measure is obviously only appropriate for students who are being supported by their parents, and for the purposes of this study, as most of these students are college freshman, this is a reasonable assumption. Gender and age have both been shown to affect academic achievement, and are included in the model [12, 17, 68, 80].

Operationalizing the network and normative aspect of social capital is based on student perceptions of interactions in the laboratory setting. Interactions can occur either with other students or TA’s. According to the proposed definition, social capital consists of the relevant social resources. In other words, interactions among individuals do not constitute social capital in and of themselves. In this light, three aspects of interactions are measured for both student-student and student-TA interactions: quantity of interactions, quality of interactions, and relevance of interactions to academic success in laboratory. Social capital would not be present if a large number of interactions occurred, but these interactions were not about the laboratory material. Similarly, interactions would not be valuable if not characterized by social norms, such as a sense of support, trust, and reciprocity [1, 5, 6, 72, 81].

The survey development process included: developing initial items based on the construct of social capital and existing social capital surveys, conducting a focus group with college students to pilot the survey and evaluate individual survey items, implementing the survey to the target population, and finally, utilizing survey results to evaluate individual items and reliability of individual construct scales. The original survey contained 40 items. Survey scales were developed for quantity, quality, and relevance of both student and TA interactions, as discussed previously and presented in Figure 2. Survey items were developed using existing items from other surveys, and in some cases original items.

Survey Validity

Internal and external validity are considered in the design of this survey. External validity refers to the ability to generalize the results to other populations. This research was conducted on the entire population of freshman electrical and computer engineering
students at a research extensive university. Utilizing the entire population enables the results to be applied in a range of settings. The obvious choices are freshman electrical and computer engineering cohorts at other research extensive universities, while results may be applied to cohorts from other disciplines and at other universities. Internal validity refers to the extent that the survey measured the construct in question. Oftentimes, the term construct validity is used in this context. Construct validity was addressed through a thorough investigation of the existing literature on social capital and survey instruments utilized to measure social capital in various settings. The ability of this instrument to measure the construct of social capital was addressed by conducting a focus group evaluation of the survey, as discussed below.

**Focus Group**

A focus group was held with 10 college science students to evaluate the survey items. The goal of this focus group was to obtain student feedback on the wording and their perceived understanding of survey items, and the response scales. At the start of the focus group, the survey was conducted with all students. Students were asked to record their thoughts and impression of survey items as they took the survey. After all students had completed the survey, an extensive discussion of the survey items was conducted. The researcher took notes on this discussion, and changes were made to several survey items as a result of this focus group. The final survey contains 36 items.

**Statistics**

The statistical analyses utilized in this research include primarily two main tools, correlations and multiple linear regression. Multiple linear regression statistics are discussed below in the regression results section. Correlations are used to evaluate relations between variables and to evaluate the reliability of groups of questions utilized to measure a specific construct, otherwise known as a scale [82]. The Pearson product moment correlation is used in all cases [83]. Results of the correlation include the r-value, or correlation coefficient, and the p-value, or significance [83]. The reliability of scales is evaluated using the Cronbach-Alpha reliability coefficient (reliability
(coefficient) [84], which is a measure of the overall correlation of all items in the scale. Inter-item correlation is a measure of the correlations between the items in a scale.

Survey Reliability

Both temporal and internal consistency reliability were addressed. Temporal reliability refers to the measurement consistency of the instrument over time [82]. The survey was implemented during week 9 of a 10 week term to the entire population of students in laboratory. During week 10, the survey was administered to a selection of 25 students in the same population. The correlation coefficient calculated comparing the two samples is 0.712.

Survey Implementation

The survey was administered in the laboratory sections of EECS Concepts during week 9 of a 10 week quarter, winter term 2005. The total enrollment in the course at the time of the survey was 127 students. Laboratory sections contained between 21 and 24 students. Based on a discussion with the instructor immediately after the survey was administered, the number of students who were still active in the course was 111. A total of 97 usable surveys were returned (87% response). Of the 97 respondents, 86 were male and 11 were female. Two surveys were not utilized because students had not responded to items on the second page of the survey. Students were asked to allow the researcher to access their laboratory grade and cumulative GPA on the survey. Seven students denied access to the laboratory grade and 17 students denied access to their grade point average. The TA’s compared the laboratory grades of the students allowing access to those who denied access and found that no significant difference exists between these two groups (mean difference of 0.10% of grade, p = 0.283). The correlation between OSU GPA and laboratory grade was found to be 0.374, p = 0.000. It is reasonable to consider the students who did allow access to their laboratory grade and/or their OSU GPA to be similar to those who did not. Response rates for all survey items other than OSU GPA and laboratory grade ranged from 95-97 out of 97 usable surveys.
Data Analysis

Data analysis procedures include analysis of social capital survey items, establishing reliability of the survey scales, investigating correlations between variables, and developing linear regression models to test the relations between social capital and academic achievement.

Analysis of Social Capital Survey Items

Following is a discussion of the specific survey items as they were after the focus group, and the deletion and inclusion of specific survey items based on analysis of survey data. As a reminder, social capital is operationalized as including interactions with both students and TA's. In both cases, the quantity, quality, and relevance of interactions are considered critical aspects of social capital, as displayed in Figure 2. Survey items that were not utilized in the analysis of social capital and academic achievement are shown in italics.

Quantity of Interactions

The quantity of interactions with both students and TA's is a critical aspect of the social capital construct in this setting, as discussed previously. Items addressing the construct of student and TA quantity of interactions are presented below. Possible responses for items 1-3, and 5 and 6 were Likert scale, ranging from strongly agree to strongly disagree, and responses for the items 4 and 7 included percentages ranging from 10% to 100%.

Student Quantity

The reliability coefficient for student quantity (items 1-4) is 0.764. However, the last item is weakly correlated to items 2 (r = 0.280) and 3 (r = 0.363), and strongly correlated to item 1 (r = 0.644). Based on this fairly strong correlation, and on similarity of both items addressing the quantity of time, item 4 was removed. The reliability coefficient for items 1-3 is 0.725 with inter-item correlation coefficients ranging from 0.340 to 0.599. The relatively low correlation coefficient of 0.340 between items 2 and 3 is expected, as these items address how much time is spent helping others and how much time other students spent helping this student. The goal of this construct is to address the
total amount of time interacting, and it is appropriate to include items on bi-directional interactions.

1. I spend a significant amount of time working with other students in this lab.
2. I spend a significant amount of time helping other students in this lab.
3. Other students spend a significant amount of time helping me in this lab.
4. On average, what % of time do you spend working with other students in this lab?

**TA Quantity**

The reliability coefficient for TA quantity, including items 5-7 is 0.799. Item 7 displays a relatively weak correlation with items 5 ($r = 0.497$) and 6 ($r = 0.540$), compared to the correlation between items 5 and 6 ($r = 0.703$). This is somewhat surprising, as items 5, 6, and 7 refer to the quantity of time spent interacting with TA's. It is possible that differences in response scales (Likert vs. percentage) resulted in these differences. Item 7 was removed based on this concern. The reliability coefficient for items 5 and 6 is 0.825, with an inter-item correlation of 0.703.

5. I spend a significant amount of time asking the teaching assistants questions in this lab.
6. The teaching assistants have spent a significant amount of time helping me in this lab.
7. On average, what % of time do you spend interacting with teaching assistants in this lab?

**Quality of Interactions**

In order to constitute social capital in this setting, interactions must not only occur, but must be characterized by a sense of support. A 10-item scale was developed to evaluate student quality of interactions, and a 5-item scale was developed to evaluate TA quality of interactions. Items assessing the presence of a supportive environment are partially based on items from the Classroom Life Survey developed by Johnson and Johnson [85].

**Student Quality**

Student quality consists of three factors: the presence of a supportive (quality) environment, trust, and reciprocity. The set of items on trust and reciprocity evaluates social norms relevant to social capital [5, 72]. Survey items on reciprocity were developed to assess whether or not students had a sense that they should help other
students in need and whether or not they expected other students to help them. All items in the quality and relevance construct require Likert scale responses, ranging from strongly agree to strongly disagree.

The reliability coefficient for the original supportive environment scale is 0.766, with inter-item correlation coefficients ranging from 0.198 to 0.753. Correlation coefficients between items 11 and 12 and items 8-10 are all low, ranging from 0.272 to 0.371. Additionally, the correlation coefficient between item 11 and 12 is 0.198. However, the reliability coefficient for items 8-10 is 0.859 with inter-item correlations ranging from 0.632 to 0.753. Considering these factors, the final student quality scale consists of items 8-10.

Supportive environment

8. I enjoy working with other students in this lab.
9. I get along well with other students in this lab.
10. Other students want me to do well in this lab.
11. I have asked for help from other students and been turned down.
12. I don't like asking other students for help.

Trust

13. When other students help me, I trust their advice.
14. Students in this lab have given me bad advice.

Reciprocity

15. I will help other students if they ask for it.
16. I feel like I should help other students in this lab.
17. Other students have gone out of their way to help me.

The original intent was to include a scale to evaluate students’ sense of trust with other students. Trust is a notoriously difficult concept to define and operationalize. Items 13 and 14 are weakly correlated (r = 0.169). Additionally, based on student comments during the survey focus group, it was unclear exactly what items 13 and 14 were addressing. Students made comments like, “what do you mean by trust, do I trust them not to lie to me, or do I trust that they know what they are doing?” Similarly, students in the focus group provided mixed responses to item 14. Although the original
wording was modified based on focus group comments, it appears that items 13 and 14 do not measure the same thing. Additionally, insufficient evidence exists to know what exactly these two items are measuring. As a result, they were not utilized in the analysis of social capital and achievement.

Similar issues arose for the reciprocity scale. Student involved in the focus group were unclear what was meant by “gone out of their way” and “I feel like I should help.” The reliability coefficient for items 15-17 is 0.472, with inter-item correlations of 0.173, 0.280, and 0.312. The lack of consistency may be a result of the bi-directional nature of the items, and the inclusion of hypothetical and action based items. For example, item 16 is about a student’s sense that they should help, while item 17 indicates actions taken. Future attempts at trust and reciprocity scales may include separate scales for sense and action on these two constructs. Due to the low reliability of these scales and the concerns addressed above, these items were not included for further analysis. It is important to note that a student’s sense of a supportive environment can be considered a social norm, and is a reasonable indication of the quality of student interactions.

**TA Quality**

The quality of time spent with TA’s was assessed with a four item scale. Trust was not included in this scale as no evidence exists that students do not trust the TA’s or that TA’s have given bad advice. Similarly, reciprocity was not included as TA’s willingness to help is not based on a sense of reciprocity with the students. The reliability coefficient for this scale is 0.898, with inter-item correlation coefficients ranging from 0.599 to 0.760. All items in this construct were used for further analysis.

18. I enjoy working with teaching assistants in this lab.
19. The teaching assistants want me to do well in this lab.
20. Teaching assistants help me to do my best in this lab.
21. I get along with the teaching assistants in this lab.

**Relevance of Interactions**

The third component that is necessary for the presence of social capital is the relevance of interactions. Students may have a significant number of quality interactions with other students and TA’s, but if students do not perceive these interactions to be
valuable to their achievement in laboratory, then they would not constitute social capital, as defined. The relevance of interactions with students and TA’s was assessed with three and two item scales, respectively. The reliability coefficient of the student relevance scale is 0.880, with inter-item correlation coefficients from 0.697 to 0.730. The reliability of the TA relevance scale is 0.676 with an inter-item correlation of 0.515. All items in this scale were included in the final analysis.

**Student Relevance**

22. Working with other students has helped me understand the concepts in this lab.
23. I have learned a lot from other students in this lab.
24. It is important to work with other students in this lab to be successful.

**TA Relevance**

25. The teaching assistants have been valuable to my learning.
26. It is important to interact with teaching assistants to be successful in this laboratory.

A total of 9 items were removed from the survey prior to the analysis of relationships between student social capital and academic achievement. Following is a description of steps taken in the analysis of data from the remaining survey items.

**Reliability of Survey Scales**

The networks and norms aspect of social capital is operationalized as consisting of student interactions with TA’s and students. The reliability measure and the minimum and maximum inter-item correlation for these scales is summarized in Self concept of ability was evaluated using a 3-item scale. The reliability coefficient for this scale is 0.772, with a minimum and maximum inter-item correlation of 0.507 and 0.548, respectively.

**Correlation Among Variables**

Correlation coefficients were calculated for all variables, including both degree of correlation and significance.
Table 4. Reliability coefficients ranging from 0.676 to 0.898 indicate that the scales are reliable.

Self concept of ability was evaluated using a 3-item scale. The reliability coefficient for this scale is 0.772, with a minimum and maximum inter-item correlation of 0.507 and 0.548, respectively.

Correlation Among Variables
Correlation coefficients were calculated for all variables, including both degree of correlation and significance.

Table 4 - Reliability Evaluation of Social Capital and Self-Concept of Ability Scales

<table>
<thead>
<tr>
<th>Construct</th>
<th># of Items</th>
<th>Reliability</th>
<th>Inter-Item Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Coefficient</td>
<td>Min</td>
</tr>
<tr>
<td>Networks and Norms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TA Quantity</td>
<td>2</td>
<td>0.825</td>
<td>0.703(1)</td>
</tr>
<tr>
<td>TA Quality</td>
<td>4</td>
<td>0.898</td>
<td>0.599</td>
</tr>
<tr>
<td>TA Relevance</td>
<td>2</td>
<td>0.676</td>
<td>0.515(1)</td>
</tr>
<tr>
<td>Student Quantity</td>
<td>3</td>
<td>0.725</td>
<td>0.340</td>
</tr>
<tr>
<td>Student Quality</td>
<td>3</td>
<td>0.859</td>
<td>0.632</td>
</tr>
<tr>
<td>Student Relevance</td>
<td>3</td>
<td>0.880</td>
<td>0.697</td>
</tr>
<tr>
<td>Self-Concept of Ability</td>
<td>3</td>
<td>0.772</td>
<td>0.507</td>
</tr>
</tbody>
</table>

(1) 2 item scales only have one possible inter-item correlation.

Linear Regression Analysis
The results of multiple linear regression analyses normally include the regression coefficients from the regression equation and r-squared values [83]. The regression coefficients are essentially correlation coefficients in that they indicate the strength of the relation among the dependent and independent variables. However, regression coefficients are not Pearson product moment correlations. The r-squared value is an indication of the percentage of variation in the dependent variable that is explained by the independent variables.

Linear regression models were developed to examine the proposed theory relating social capital and achievement in the laboratory setting. Models consisted of five groups of independent variables and one group of dependent variables, as displayed in Figure 2. The groups of independent variables are social capital, financial capital, human capital, age, and gender. Dependent variables are measures of academic achievement. Models
utilizing these three dependent variables (self concept of ability, laboratory grade, and extra credit exercises) were examined independently. For each dependent variable, two models were tested to determine if the addition of the social capital variables to the model increased the percentage of the dependent variables explained by the independent variables, and the relative effects of all variables. The first model included only background factors, financial capital, human capital, age, and gender, and the second model included these variables and social capital variables.

Assumptions of linearity, normality, and constant variance were verified. Linearity was confirmed by an investigation of bivariate scatterplots of each dependent variable as a function of all independent variables. Assumptions of normality were confirmed by examining the conditional distribution of the dependent variables. Reasonably constant variance of the dependent variables at different levels of the independent variables was found. It is possible that variation in each of the dependent variables may be attributed to factors associated with the laboratory section, such as the student’s and/or TA’s present in a particular section. This possibility was explored by creating indicator variables for laboratory section and interaction variables for laboratory section and each of the six student and TA social capital variables, resulting in 42 variables (six for laboratory section and 36 for each of the six laboratory sections interacting with each of the six social capital variables). The significance was examined by including all of these variables in models for each of the dependent variables. None of the possible effects was found to be significant (p<0.10) in predicting number of extra credit exercises. In terms of predicting laboratory grade, only one of the 42 variables (Quantity of TA time-Section 18) was found to be significant. Two of the 42 variables were found to be significant (Relevance of TA-Section 12, Relevance of TA-Section 10) in predicting self concept of ability. As a result of the minimal presence of potential significant effects, these laboratory section-specific variables were discarded from all subsequent models.

Results

Correlations, means, and standard deviations were calculated for all dependent and independent variables and are presented in Table 5. Correlations discussed in this
paragraph are all significant at the 0.10 level. A positive correlation exists between laboratory grade and extra credit exercises. This is expected, as the number of extra credit exercises that a student is able to complete will certainly increase their grade. Self-concept of ability is positively correlated to laboratory grade and extra credit exercises, and student quality and TA quality. Neither age nor gender are significantly correlated with any other variables. Parent’s education level is positively correlated with student quantity, quality, and relevance of interactions. OSU GPA is positively correlated with both laboratory grade, extra credit exercises, self-concept of ability, and parent’s education level. Quantity of student interactions is positively correlated with both student quality and student relevance, and TA quality and TA relevance. A significant correlation does not exist, however, between student quantity and TA quantity. Student quality is positively correlated with student relevance, TA quality, and TA relevance. TA quantity, quality, and relevance are positively correlated with each other.

In Table 6 below, the results of the regression models are presented, including unstandardized regression coefficients first, standardized regression coefficients second, and significance values third. It is important to note that the term “effect” is used in the following discussions. This term does not imply cause and effect, rather is used to imply a model effect. In other words, an increase in human capital has a positive effect on laboratory grade. This does not mean that the higher laboratory grade is a result of an increase in human capital, but that an increase in laboratory grade is associated with human capital.

In all models the addition of social capital variables increased the percentage of variation in the dependent variable explained by the independent variables (r-squared), by 0.095, 0.186, and 0.214, for laboratory grade, number of extra credit exercises, and self-concept of ability, respectively. This increase is the difference in the r-squared model between the first and second model. The results indicate that age, gender, and financial capital do not have significant effects in any of the models. Human capital has a significant positive effect on laboratory grade and extra credit exercises, parameter values ranging from 0.304 to 0.377, but not on self-concept of ability.
<table>
<thead>
<tr>
<th>1 - Laboratory Grade</th>
<th>2 - Extra Credit Exercises</th>
<th>3 - Self Concept of Ability</th>
<th>4 - Age</th>
<th>5 - Gender</th>
<th>6 - Parent's Ed Level</th>
<th>7 - OSU GPA</th>
<th>8 - Student Quantity</th>
<th>9 - Student Quality</th>
<th>10 - Student Relevance</th>
<th>11 - TA Quantity</th>
<th>12 - TA Quality</th>
<th>13 - TA Relevance</th>
<th>Mean</th>
<th>Std Dev</th>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>.550</td>
<td>.266</td>
<td>.046</td>
<td>-.061</td>
<td>.069</td>
<td>.374</td>
<td>.009</td>
<td>.072</td>
<td>-.123</td>
<td>.026</td>
<td>.134</td>
<td>.027</td>
<td>1.04</td>
<td>0.145</td>
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<tr>
<td></td>
<td>.000</td>
<td>.009</td>
<td>.658</td>
<td>.556</td>
<td>.194</td>
<td>.000</td>
<td>.928</td>
<td>.486</td>
<td>.242</td>
<td>.801</td>
<td>.916</td>
<td>.797</td>
<td>1.65</td>
<td>1.116</td>
</tr>
<tr>
<td>Top value</td>
<td>Correlation Coefficient</td>
<td>Bottom value</td>
<td>Significance</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r = 0.550</td>
<td>p = 0.000</td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
Table 6 - Parameters for Linear Regression Models Investigating the Relationship Between Achievement and Student Social Capital

<table>
<thead>
<tr>
<th></th>
<th>Laboratory Grade</th>
<th>Extra Credit Exercises</th>
<th>Self-Concept of Ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back ground Factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.080 (0.007)</td>
<td>0.096 (0.064)</td>
<td>0.032 (0.031)</td>
</tr>
<tr>
<td></td>
<td>0.444 (0.008)</td>
<td>0.370 (0.017)</td>
<td>0.777 (0.024)</td>
</tr>
<tr>
<td>Gender</td>
<td>0.007 (-0.016)</td>
<td>-0.008 (-0.032)</td>
<td>0.114 (0.676)</td>
</tr>
<tr>
<td></td>
<td>0.943 (0.780)</td>
<td>0.940 (0.787)</td>
<td>0.302 (0.293)</td>
</tr>
<tr>
<td>Financial Capital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parent's Education Level</td>
<td>-0.027 (-0.002)</td>
<td>0.066 (0.039)</td>
<td>0.007 (0.006)</td>
</tr>
<tr>
<td></td>
<td>0.796 (0.002)</td>
<td>0.538 (0.009)</td>
<td>0.951 (0.018)</td>
</tr>
<tr>
<td>Human Capital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSU GPA</td>
<td>0.377 (0.017)</td>
<td>0.304 (0.481)</td>
<td>0.177 (0.410)</td>
</tr>
<tr>
<td></td>
<td>0.001 (0.074)</td>
<td>0.005 (0.560)</td>
<td>0.114 (0.289)</td>
</tr>
<tr>
<td>Student Social Capital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity of Interaction</td>
<td>0.245 (0.014)</td>
<td>0.192 (0.089)</td>
<td>0.163 (0.114)</td>
</tr>
<tr>
<td></td>
<td>0.178 (0.014)</td>
<td>0.273 (0.114)</td>
<td>0.352 (0.114)</td>
</tr>
<tr>
<td>Quality of Interaction</td>
<td>0.017 (0.001)</td>
<td>-0.007 (-0.005)</td>
<td>0.348 (0.317)</td>
</tr>
<tr>
<td></td>
<td>0.907 (0.001)</td>
<td>0.958 (0.005)</td>
<td>0.023 (0.005)</td>
</tr>
<tr>
<td>Relevance of Interaction</td>
<td>-0.327 (-0.019)</td>
<td>-0.409 (-0.193)</td>
<td>-0.442 (-0.321)</td>
</tr>
<tr>
<td></td>
<td>0.058 (-0.019)</td>
<td>0.014 (-0.019)</td>
<td>0.007 (-0.019)</td>
</tr>
<tr>
<td>TA Social Capital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity of Interaction</td>
<td>0.072 (0.007)</td>
<td>-0.079 (-0.063)</td>
<td>-0.172 (-0.200)</td>
</tr>
<tr>
<td></td>
<td>0.552 (0.007)</td>
<td>0.493 (-0.063)</td>
<td>0.148 (-0.200)</td>
</tr>
<tr>
<td>Quality of Interaction</td>
<td>0.331 (0.024)</td>
<td>0.384 (0.229)</td>
<td>0.293 (0.262)</td>
</tr>
<tr>
<td></td>
<td>0.052 (0.024)</td>
<td>0.019 (0.229)</td>
<td>0.074 (0.262)</td>
</tr>
<tr>
<td>Relevance of Interaction</td>
<td>-0.201 (-0.027)</td>
<td>-0.350 (-0.378)</td>
<td>-0.220 (-0.354)</td>
</tr>
<tr>
<td></td>
<td>0.269 (-0.027)</td>
<td>0.047 (-0.378)</td>
<td>0.207 (-0.354)</td>
</tr>
<tr>
<td>R²</td>
<td>0.144 0.239</td>
<td>0.112 0.298</td>
<td>0.043 0.257</td>
</tr>
</tbody>
</table>

1st Row - Unstandardized regression coefficient, 2nd Row - Standardized regression coefficient, 3rd Row - p-value

The effects of social capital on laboratory grade vary from strongly negative to strongly positive. Student and TA quantity of interactions appear to have no significant effect on any measures of achievement in this laboratory. Only student relevance of
interactions and TA quality of interactions are significant in terms of predicting laboratory grade. The relevance of student interactions has a negative effect on laboratory grade (-0.327), and TA quality of interactions has a positive effect (0.331). Student relevance of interaction, and TA quality and relevance of interactions are the only significant social capital variables in predicting the number of extra credit exercises completed. Student relevance of interactions has a negative effect (-0.709), TA quality of interactions has a positive effect (0.384), and TA relevance of interactions has a negative effect (-0.350). Three social capital variables are significant with both positive and negative effects on self-concept of ability, student quality of interactions (0.348), student relevance of interactions (-0.442), and TA quality of interactions (0.293).

Discussion

The proposed model suggests that social capital consists of networks and norms, both operationalized as student and TA interactions, and value, operationalized as laboratory grades, extra credit exercises, and self-concept of ability. Additionally, it was suggested that financial and human capital, and age and gender may be related to the measures of academic achievement. Results from this research both confirm and disagree with previous research in this area.

The lack of significance of age, gender, and financial capital on any of the measures of achievement does not agree with previous research [12, 80]. This may be the result of a relatively homogeneous sample of students with respect to age (mean = 19.1, standard deviation = 2.08), and the small number of female students in the sample (n = 11). Being that these students are college freshman with a relatively young average age, it is not unreasonable to assume that most are dependent on their parents. Also, parent’s education level has been used as a reliable indicator of financial capital [79]. This result may also be a consequence of the overall high level of achievement in the laboratory, and corresponding lack of differentiation of high and low achieving students.

Human capital was found to be positively correlated with laboratory grade and extra credit exercises, but not significant in predicting self-concept of ability. The positive relation between human capital and laboratory grades and extra credit exercises is not surprising. However, the lack of correlation between human capital and self-
concept of ability does not correspond with other research [12]. Although Etcheverry et al. did not conceptualize human capital as GPA, they did find a significant positive correlation between GPA and self-concept of ability.

Surprisingly, sub-constructs of social capital are both positively and negatively related to the three measures of academic achievement. The finding that the quantity of TA and student interaction is not significant in predicting any measures of achievement does not infer that interaction is or is not important, just that no statistically significant relationship exists. It seems that quantity of interaction may or may not be important in terms of achievement.

Relevance of student of interactions has a negative effect on laboratory grade, extra credit exercises, and self-concept of ability, and relevance of TA of interactions has a negative effect on extra credit exercises. It is important to note that this does not mean that the perception that student and TA interactions are relevant to success will cause a student to be successful, only that students who have these perceptions are less likely to achieve at a higher level in this setting. One possible explanation is that students who are not high achievers and do not have a high self-concept of ability rely on interactions with other students and TA’s to be successful. Additionally, this suggests that high achievers in this setting do not consider student or TA interactions to be valuable in terms of their success. Quality of TA of interactions is a measure of students perceptions of positive interactions and support from TA’s. Considering that quality of TA of interactions has a positive effect on all three measures of academic achievement, it appears that students who achieve at a higher level perceive positive interactions with TA’s, while the opposite is true for students who are relatively low achievers. TA’s may exhibit preferential treatment of high achievers in this setting, resulting in low achievers lack of a sense of support. It is possible that an interaction exists between relevance of student interactions and quality of TA interactions. For example, low achieving students may perceive a lack of support from TA’s, and as a result, turn to students for assistance in completing the laboratory.

Relevance of TA interactions was not found to have a significant effect on laboratory grade, but was found to have a negative effect on extra credit exercises.
Additionally, quality of TA interactions was found to have a positive effect on both laboratory grade and extra credit exercises. In other words, students’ perceptions of the importance of TA interactions on success in laboratory were not related to laboratory grade, but to a positive effect on extra credit exercises. This result is difficult to unravel due to the highly related nature of laboratory grade and extra credit exercises, especially since the extra credit exercises are notoriously difficult to achieve without assistance from TA’s. A possible explanation is that quality of TA interactions is an indication of students comfort level interacting with TA’s. This perception led to these students being able to acquire the help of the TA’s in completing the extra credit exercises.

Both student and TA quality of interactions have a positive effect on self-concept of ability, indicating that students who perceive supportive interactions with TA’s or other students rank their own quality of work higher than those that do not. Students who rank themselves higher in quality of work may have more positive perceptions of their interactions, or the positive perceptions of interactions may result in a higher self-concept of ability.

Another discernable pattern is that student and TA quality were found to have an overall positive effect on achievement, while student and TA relevance were found to have an overall negative effect on achievement. This supports the previous propositions that high achievers may receive preferential treatment from both students and TA’s, and that low achieving students rely on TA and student interaction for success more than their high achieving counterparts.

It is worthy of noting that no evidence exists to suggest that student’s sense of TA or student social capital has a differential effect on achievement. In other words, it does not appear that student perceptions of interactions with TA’s or students are more important in terms of achievement.

**Conclusions**

The mixed results on the relations between student social capital and achievement allude to the complex nature of the social capital construct. Perhaps the most interesting possibility is preferential treatment of high achieving students by both students and TA’s in concert with the possibility that low achieving students have a stronger sense of the
need for interactions with students and TA's to be successful. Previous research has suggested that TA behaviors can influence student interactions with other students [86]. This leads to several possibilities for future research on questions such as: Do TA’s exhibit preferential treatment to students based on abilities and how does this relate to achievement? As TA’s are unlikely to accurately respond to questions of this nature on a survey, a qualitative investigation utilizing extensive observations would be appropriate.

In this research social capital was considered to be greater if student perceptions of the relevance of TA interactions were high. However, TA relevance was found to be negatively correlated with student laboratory grade. This is not evidence that social capital does not consist of TA relevance. It may suggest, however, that some students are more reliant on social capital than others. In other words, student and TA interactions may be more important to some students than others. In order to utilize results from future research on social capital to implement curricular changes, it is important to determine TA and student behaviors that influence the development of social capital, if some students have a greater need for student and TA interactions to be successful, and what characteristics are unique to this group of students.
Chapter 6 - Conclusions

The goal of this research was to investigate social capital in engineering education. In Chapter 2, evidence was provided to suggest that engineering departments should design curriculum to encourage the development of social capital. Social capital has been found to be related to multiple positive outcomes in educational settings, including retention [1, 14, 17, 58] and academic achievement [9, 10, 12]. Additionally, in the business setting, social capital has been associated with productivity and innovation [40, 66]. Respected learning theories suggest that learning is a social enterprise in which students learn through interaction with more knowledgeable members of a community [42, 50, 51]. Teaching standards recommend that science education consists of student-generated scientific discourse [41, 75]. In light of these findings as a whole, it is recommended that efforts be made to develop student social capital in engineering education. Existing practices such as active, cooperative, and service learning; collaborative concept mapping; and student focused discourse are promising in terms of developing specific student skills and student social capital.

In Chapter 3, the role of social capital in the retention of engineering students was discussed. Student responses indicate that social capital does play a role in the retention of engineering students. Both students who remain in engineering and those that have left reported that positive interactions with peers, faculty, and advisors were important to retention. Both groups indicated that few opportunities exist in the lecture setting to interact with other students, but the dormitories provide opportunities to develop relationships with other students. Both groups voiced frustration with mostly poor interactions with faculty and advisors. Similarly, both groups indicated that their sense of community in freshman engineering courses is low, and they are frustrated with the competitive norms in engineering. Only those students who left engineering voiced dissatisfaction with teaching methods that encourage plug and chug problem solving, characterized by little discussion or opportunities to ask questions about assumptions or approaches. Utilizing evidence from the previous chapter, it is recommended that efforts be made to develop student social capital to improve retention in the College of Engineering.
In Chapter 4, factors that affect the development and the value of social capital were presented. The open endedness of the laboratory assignments, requirement for extensive troubleshooting, and TA behaviors encouraging students to work on their own appear to encourage the development of social capital. Social network analysis was used to investigate correlations between social capital, measured as the student’s location and number of connections within a social network, and academic achievement. Degree centrality was found to be positively and significantly correlated with laboratory grade, while there was no significant correlation between closeness centrality and laboratory grade. The multiple methods of data collection and analysis appear to validate the result that social capital is developed in this laboratory and that social capital is positively correlated with academic achievement.

In Chapter 5, correlations between student social capital and academic achievement were presented. A researcher-designed survey instrument was used to evaluate student social capital and academic achievement in the laboratory setting. Student social capital consists of interactions with students and TA’s. Interactions are considered to have three components relevant to social capital: quantity, quality, and relevance. For this study, academic achievement is measured as laboratory grade, the number of extra credit assignments the student was able to complete, and self-concept of ability. Survey results indicate that the effects of social capital on academic achievement vary from strongly negative to strongly positive. Student and TA quantity of interactions appear to have no significant effect on any measures of achievement in this laboratory. Student relevance of interactions has a negative effect on laboratory grade, and TA quality of interactions has a positive effect. Student relevance of interactions, and TA quality and relevance of interactions are the only significant social capital variables in predicting the number of extra credit exercises completed. Student relevance of interactions has a negative effect, TA quality of interactions has a positive effect, and TA relevance of interactions has a negative effect. Three social capital variables are significant with both positive and negative effects on self-concept of ability: student quality of interactions, student relevance of interactions, and TA quality of interactions.
These results may indicate that relatively low achieving students in this setting rely more on student and TA interaction than high achieving students.

The theoretical argument presented in Chapter 2 is based on research from several different settings. Future research could investigate some of these theoretical propositions. For example, it was argued that in the business setting social capital is important in terms of access to information, productivity, and innovation. Although results presented in Chapter 4 confirm the importance of social capital to student access to information and success in the laboratory, the results do not investigate any relations between social capital and innovation. The importance of innovation to engineers has been universally accepted. In this light, research investigating the relation between student social capital and innovation in higher education would have significant benefits in terms of both theoretical understanding and programmatic changes.

Results from Chapter 3 indicate that both students that have left engineering and those that remain perceive social capital to be important in terms of retention in the college of engineering. However, few differences were found between these groups. In Chapter 5, it was found that aspects of social capital were negatively related to achievement. Based on this finding, it was hypothesized that high achieving students may not rely on interactions with students and TA's to be successful in laboratory. The results from both of these studies indicate that social capital may be important to some students in terms of retention and achievement and not for others. As mentioned in Chapter 5, future research could focus on differences between these groups of students. Specifically, how do students that rely on social capital to be successful differ from those that do not. Results from an investigation of this nature could lead to programmatic changes leading to retention of these high achieving students that leave engineering and curricular changes to encourage the development of student social capital for those students that require these interactions to be academically successful.

The intent of this research was to develop a theoretical framework and serve as a foundation for future research on social capital in engineering education. The wealth of research suggesting multiple benefits of social capital in a variety of settings is an
indication of the research and pragmatic potential of social capital in the higher education setting.
Chapter 7 - Significance

The practical implications discussed below are focused primarily on the finding that some students may rely on social capital for retention and achievement more than others. Although this research does not provide insight into differences between these two groups, evidence exists to suggest that differences may exist. In the following discussion four main issues are discussed: fungibility of social capital, male privilege, and minority students. Recommendations are made for implementations to address these differences and for future research.

Fungibility generally refers to the degree to which instances of a commodity are interchangeable. In other words, a gram of gold essentially has the same value in multiple settings, or is fungible. An additional useful example of fungibility is the transfer of power in nations. For example, if economic power could be translated into military power, then power would be considered to be fungible. Relating to social capital in engineering education, the question arises, is student social capital fungible? More specifically, does social capital translate from one context to another? This is of interest, because some students may bring social capital with them to engineering education and, as a result, have an immediate social network. For example, in the Design laboratories discussed previously, students' source of information was shown to be primarily from other students. In some cases, students had previous long-term relationships with other students in the laboratory. One pair of students had been friends since grade school, and were observed working together extensively over the course of the term. Similarly, students were observed working with other students that they had develop friendships with in the dormitories, or in the military. In contrast, multiple students that had transferred from local community colleges did not have any social connection, or social capital, at the beginning of the class. Practically speaking, it would be useful to identify the level of social capital that students bring with them to engineering education, recognizing the importance of social capital to achievement and retention. This information could be used to identify students that may need more social support to be successful. Significant research potential exists, as it would be very fruitful to investigate
the fungibility of social capital in different contexts, and the level of success of students who bring social capital to engineering education.

Male privilege is a social concept that suggests that males have certain advantages and/or rights that are not granted to women. A similar concept exists for white privilege and the same argument could be made for white students. Male privilege is of concern, because this privilege may allow for white males to more easily develop social capital within engineering education. For example, it is possible that a male student would find it easier to acquire help from other students. Similarly, male students may be sought out for help, allowing more learning and social networking opportunities. The observations conducted in the Design laboratory indicated that some students were sought after much more than others for help in the laboratory. Although extensive data was not collected to determine quantitative measures of which students were more sought after than others, it was clear from observations that differences existed among students. From a practical standpoint it would be useful to be knowledgeable of the nature and extent of white privilege in engineering education. Potential research could investigate the white male privilege phenomena and its relation to the development of social capital in engineering education.

Minority students likely face unique issues in the development of social capital. As discussed in Chapter 3, minority students face cultural values of group membership that are in conflict with the individualistic and competitive culture of engineering. The result of this research that some students rely more on social capital than others for retention and achievement coupled with the unique cultural values of minority students indicates that these students may not only have increased difficulty developing social capital, but may have an increased need for social capital to prosper in this environment. This is obviously a dangerous combination for the success of minority students. Practically speaking, it is important to identify and evaluate the social capital needs of minority students and to provide opportunities for developing social capital.

The issues of fungibility, male privilege, and minority status are related in considering the student need for social capital for academic success, the social capital that students bring to engineering education, and the corresponding difficulty of students
developing social capital in engineering education. As stated above, minority students face significant challenges in all three areas, they have cultural values of community, it is unlikely that they bring social capital with them to the extent that other groups do, and they potentially face increased difficulty in developing social capital once they arrive. In contrast, a white male is likely the opposite in all three arenas: fungible social capital, need for social capital, and ease of development of social capital.

Two main streams of thought follow these concerns. What future research is appropriate and useful? In addition, what programs could be implemented to address these issues? Concerning future research, it would be valuable to more specifically determine the differences between students that require social capital to be academically successful and those that do not. It appears that this need may be primarily based on students' personal values, including need for community and family. Additionally, it would be useful to determine how much social capital students bring with them to engineering education, and factors that may influence their ability to develop social capital. The research would lead to a survey to assess student risk for leaving engineering.

Even in the absence of future research, existing retention programs provide some insight into addressing the issues of social capital. Active, cooperative, and service learning opportunities have significant potential, but have been discussed previously. As such, they will not be discussed further here. However, recognizing the differential need for social capital, and the potential for differential treatment of students, teaching assistant training programs would have some value. Through these training programs teaching assistants could be made aware of some students need for interaction to be successful, and the possibility that preferential treatment of students may be occurring.

The most beneficial pragmatic approach to developing additional understanding of social capital in engineering education would be to develop a design research program for this subject. Design research is a process that combines research with curricular implementation and testing. It is a circular process in which curricular changes are based on research, and research is based on the assessment of curricular changes. This type of
approach would allow for real time implementation and assessment of social capital understanding and building efforts.
Bibliography


Appendices

Appendix 1 - Interview Protocol for Retention Study

Please state name and how far you went in the engineering program and your current major?

Can I contact you in the future?

1. Background/Intro
   a. Why were you originally interested in engineering?
   b. Why did you leave engineering?

2. Social Capital
   a. Engineering
      i. How much interaction with engineering faculty did you have?
      ii. How helpful were engineering faculty?
      iii. How helpful were engineering TA's?
      iv. Describe your experience in engineering courses?
      v. As an engineering student did you study alone or in groups? Why?
      vi. What did you have in common with your study partners in engineering?
      vii. Do you have the same values as your study partners?
      viii. Do classes engage you in activities that help you meet people?
   b. Same question for non-engineering.

3. Personal/Demographics
   a. Family/Friends
      i. How many siblings do you have?
      ii. Are you the youngest or oldest sibling?
      iii. How close are you to your siblings?
      iv. Do your parents live in state?
      v. How often do you visit home?
      vi. How often do you call home?
   b. Outside Involvement
      i. What social activities do you participate in?
      ii. What types of extracurricular activities are you involved in?

4. Conclusion
   a. What recommendations do you have to improve retention in the college of engineering?
Appendix 2 - Interview Protocol for Role and Development of Social Capital

General Questions
1. What did you like the most about this lab?
2. What did you like least about this lab?
3. How could this lab be improved?
4. What do you think the goals of this lab are?
5. What did you learn in this lab?
6. How was this lab effective in teaching you about digital logic design?
7. Are the lab assignments clear?
8. What would you do to improve the lab assignments?

Social Capital Questions

Networking
Teaching Assistants
1. How helpful were the TA’s in this lab?
2. Which TA was most helpful and why?
3. Why were they helpful or not helpful?
4. What feedback do you have for the TA’s for them to be better?

Students
5. How helpful were other students in this lab?
6. Why were they helpful or not helpful?

Most helpful for success
7. Who is(are) the individual(s) that has(have) been most important in your success in this lab?

Development of Norms
1. When students give you advice or help you on the lab do you believe them? Why or why not?
2. Do you need to work together to be successful in this lab?
3. What factors encourage you to work with others?
4. What factors discourage you from working with others?
5. Are you willing to help other students in lab? Why or why not?
6. If you finish your lab ahead of time do you help other students? Why or why not?
## Appendix 3 - Observation Protocol for Design Class

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