
Abstract (Summary)

Social capital consists of resources embedded in social networks that are purposefully mobilized through personal interactions. This project examined the factors that affected the development of social capital in an electrical and computer engineering laboratory. Data were collected through participant observation over the course of a term, interviews with students, and a survey. Interview and observational data were analyzed to determine themes or patterns in behaviors and actions that indicated the presence of social capital and affected the development of social capital in this setting. The open-ended nature of the laboratory assignments and the complexity of a learning tool called TekBot(TM) required students to access information. The lack of relevant information from the teaching assistants, internet, and laboratory assignment handouts required students to mobilize information from each other to succeed. Multiple methods of data collection validate the result that specific factors encouraged the development of social capital in this laboratory.

I. INTRODUCTION

The importance of social interactions and the resources available through these interactions to individuals and groups has been researched extensively from settings ranging from the national to the classroom level. Stemming from the increasing interest and understanding of these interactions and related resources has been the application of social capital as a theoretical research framework. Social capital generally is considered to include resources available and mobilized through social interactions, social norms that support these interactions, and the value associated with these interactions and norms. Social capital has been shown to be positively correlated with economic productivity of nations (Fukuyama, 1995), health and well being of individuals (Putnam, 2000), innovative capabilities of businesses (Maskell, 2000; Saxenian, 1994), productivity in business (Greve and Benassi, 2004), and academic achievement in higher education (Etcheverry, Clifton, and Roberts, 2001).

Interest in social capital in the education setting was initiated by James Coleman (1988) and his research on parental support and networks and their relation to retention in high school. Since this seminal publication, extensive research has been done to investigate the relation between social capital and academic success in multiple academic settings and grade levels from K-16. Generally, these results indicate that social capital is important for achievement, students' attitudes and beliefs about their abilities, and retention. Each of these outcomes is important for engineering education, yet little research has been done on social capital in engineering education.

Social capital is of particular interest to engineering educators given the national interest in retaining more engineers and improving the abilities of engineering graduates (The National Academies, 2006), combined with the rigor and reported difficulty of succeeding alone in the engineering curriculum (Brown, 2005; Seymour and Hewitt, 1997). The goal of this study is to introduce the construct of social capital to the engineering education community and investigate social capital in an engineering laboratory setting. The concept of social capital is introduced, including a definition and a summary of existing research correlating social capital with positive group and individual outcomes. Based on this argument, research questions and a description of the research methodologies are presented, followed by the results. Concluding statements consider the applicability of these results to other settings and implications for further research.

II. WHAT IS SOCIAL CAPITAL?

Social capital has been researched in multiple fields, including economics, business, sociology,
and education. Because the concept is used in various fields, numerous definitions and applications of social capital have emerged, leaving the researcher with the task of choosing an appropriate definition. Like physical capital (investments that enhance productivity such as equipment, computers, software) and human capital (knowledge, skills, and training), social capital has associated value or resources. Social capital is unique in that it is embedded in the interactions that actors have with each other, actors being individuals, social groups, companies, or even countries.

The individuals most commonly credited with introducing and analyzing the concept of social capital are Bourdieu (1986), Coleman (1988), and Lin (2001). The definition of social capital proposed by each includes resources embedded in social networks. Pierre Bourdieu has been credited with having first introduced the concept of social capital, and suggested that the value of social interactions must be considered an asset in economic theory. Bourdieu (1986, p. 286) defines social capital as:

...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. . .

In this definition, social capital is viewed as resources, "collectively owned capital," that are substantiated by the presence of norms, "institutionalized relationships," and are available through social interactions. Coleman (1988) proposes that social capital contains two common elements; it consists of some aspect of social structures, and facilitates certain actions of actors. The value of social capital in Coleman's definition is summarized by Lin (2001, p. 23): "Whether any structural aspect is a capital depends on whether it serves a function for certain individuals engaged in certain activities. Social capital is the resources gained from relationships." Nan Lin (2001) has written extensively on social capital, and provided the most extensive and theoretical perspective. In his detailed analysis of existing research and proposal of a "theory of social structure and action," Lin analyzes in detail the works of Bourdieu and Coleman, and other social capital scholars, and proposes a definition of social capital. The definition of social capital in this research is based on that developed by Lin (2001, p. 12), "resources embedded in social structure which are accessed and/or mobilized in purposive actions."

This definition captures the essence and spirit of definitions and measurements discussed previously, with one exception: social norms. Social norms are included in Bourdieu's definition, "institutionalized relationships." However, Lin (2001, p. 26) argues that social capital is a "relational asset, and must be distinguished from collective assets ... such as culture, norms, trust. . ." Further, Lin argues that these collective assets may be researched as precursors to or the result of social capital, but not as the definition of social capital. As an example, in an academic setting two students may have an established relationship based on trust and mutual respect that fosters sharing of information relevant to their courses between the students. Social capital, in this case, is the presence, availability, and sharing of resources. Trust and mutual respect may foster this sharing, but they are not social capital. A focus on social capital as embedded resources avoids the conflict between cause and effect, i.e., whether norms are a result of social capital or norms enhance social capital. In the work proposed herein, in alignment with Lin's definition, social capital includes resources in networks and accessibility to and mobilization of these resources.

III. WHY IS IT IMPORTANT TO RESEARCH SOCIAL CAPITAL IN EDUCATION?

A significant body of research has investigated correlations between social capital and both retention and academic achievement. Carbonaro (1998) found that social capital was positively related to student retention and mathematics achievement test scores. Morgan and Sorensen (1999) similarly found that mathematics achievement for eighth graders was positively correlated with density of friendship and parental networks. In a study of university undergraduate students, Etcheverry, Clifton, and Roberts (2001) found that perceptions of support from other students related positively to student self confidence and grade point average. Social support - an easily observable manifestation of social capital - has been shown to be a key factor in
Given the inherent difficulty of the engineering curriculum, it is likely that social capital is
important for academic achievement and retention in engineering. The construct of social capital
in the studies summarized was mainly sense of support from faculty, students, and parents and
density of networks of these individuals. This focus is somewhat divergent from the definition of
social capital utilized in this study focusing on resources embedded in social networks that are
mobilized by individuals. Sense of support, as utilized in previous research, may indicate the
availability of resources, but not on the mobilization or type of resources. Work from this study
will focus on the resources available and mobilized in an engineering laboratory setting.
Resources available to engineering students through social networks can include multiple items,
such as personal support, but social capital has been shown to play a vital role in people’s access
to information and is most relevant to students working in an engineering laboratory.
IV. SOCIAL CAPITAL AND ACCESS TO INFORMATION
Engineering laboratories are generally characterized by students as including significant social
interactions related to the laboratory assignment. Students can access information utilizing both
human and non-human resources, including the teaching assistant, other students, laboratory
instructions, and internet resources.
Although research on information acquisition in engineering education is sparse, similar work in
the business setting provides substantial evidence that in business people use other people more
than non-human sources to acquire information. An ethnographic report conducted by the U.S.
Department of Commerce estimates that 80 percent of organizational learning is informal (Center
for Workforce Development, 1998). Studies have shown that the primary source of information in
technological workplaces is other employees (Allen, 1977). 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 percent of managers who were
studied at a consulting firm were found to receive knowledge critical to the successful completion
of an important project from other people (Allen, 1977). 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
(Saxenian, 1994). Similarly, social capital has been shown to contribute to productivity because
individuals use their personal contacts for getting advice and solving problems (Greve and
Benassi, 2004; Saxenian, 1994).
While there are clear differences between businesses and engineering education and employees
and engineering education students, social capital is relevant and valuable to both. In both
settings individuals are charged with completing tasks that can be open-ended, challenging, and
require multiple individuals to achieve in an effective and efficient manner. Individuals who have
taught engineering laboratories will generally agree that students rely heavily on other students
and teaching assistants in the laboratory setting for information, yet little is known about factors
that may encourage this information sharing.
Evidence suggests that a strong link between social capital and both retention and academic
achievement exists, and that social capital is linked to access to information in the business
setting. However, no research was found that investigates the presence of and factors that
influence the development of social capital in engineering education using the in-depth and
exploratory methods of qualitative research. Also, little is known about factors that may result in
students using each other for access to information in engineering education. The current study
built on this work by examining how social capital works at a more detailed level in an electrical
engineering laboratory.
V. PROPOSED RESEARCH AND METHODOLOGY
The intent of this research is to investigate social capital in an undergraduate engineering
laboratory. The definition of social capital utilized for this research is reiterated as follows: Social
capital consists of "resources embedded in social structure which are accessed and/or mobilized
in purposive actions" (Lin, 2001, p. 12). The specific research questions are:
* Is social capital present in this research setting, as indicated by the presence of students
accessing information (resources) through social interactions?
* What factors encourage or discourage the formation of social capital in the laboratory setting?

A. 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(TM) platform, a small robot that students utilize as a platform for learning in multiple courses throughout the curriculum (Thompson et al., 2004; Traylor, Heer, and Fiez, 2003). The TekBots(TM) program is continuously evaluated and improved through a design research approach (Thompson et al., 2004). As part of this approach, auricular improvements are continuously designed, evaluated, and modified. The overarching goals guiding the effort reported here are to understand the factors that affect the development of student social capital and to utilize this information to make auricular changes.

Participants in this research were students in "Introduction to Electrical and Computer Engineering Concepts" (Concepts) and "Digital Logic Design Laboratory" (Design), lower division undergraduate courses required of all ECE students. Concepts focuses on fundamentals of electrical engineering, including current and voltage, and students construct their TekBot(TM) during laboratory assignments. Design is a more advanced course and students modify their TekBot(TM) and are required to program the TekBot(TM) to perform physical tasks.

B. Data Collection
Data collected includes:
* Student survey administered in Concepts, winter term 2004
* Student laboratory handouts and assignments from Concepts and Design
* Observations in one 3-hour laboratory period in 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

A survey was administered to the entire student population (116 students) enrolled in Concepts Winter Term 2004. The survey contained 44 questions and the intent was to pilot a survey measuring social capital and sense of community. Complete results of this survey research are available elsewhere (Brown, 2005). Only three questions directly related to factors influencing the development of social capital were utilized in the research presented here: student responses to the statements "I have asked for help from other students and been turned down," "I am willing to help other students in this laboratory even if they don't help me," and "I spend time helping others in lab."

Observations were made in the Concepts and Design laboratory setting. The Concepts course was observed prior to observing the Design course. Since these courses are almost always taken in sequence by students, the student population was generally the same in both courses. A total of seven laboratory sections were offered for both Concepts and Design. One 3-hour Concepts laboratory section was observed over the course of the winter term and 24 students were present in this laboratory section. Data were collected for students in two 3-hour Design laboratory sections over the course of spring term; 22 students were present in the first section and eight in the second. The second section was held in the evening, when laboratories traditionally have fewer students. The Concepts laboratory section and the two Design laboratory sections were representative of other laboratory sections for these courses in terms of academic ability of students, 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 were no obvious unique attributes of the students or the laboratory sections offered during the winter or spring term, it is reasonable that the results can be generalized to future laboratory sections of these courses.

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. The most appropriate way to collect data on interactions is through firsthand participant observation. To capture the most relevant information it is necessary for the researcher to observe interactions firsthand, and use his or her own knowledge and experience in interpreting observations (Merriam, 1998). Observations conducted in Concepts and in weekly teaching assistants meetings were not guided by specific protocol. The intent of the Concepts observations was exploratory, to begin to understand how and why students work together. However, an observation protocol was developed for observations conducted in Design to capture who students interacted with, the nature of their interactions, and the time they spent interacting. The observation protocol increased 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 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. Specifically, student responses at the last interview were consistent with those of previous interviews. 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 a full range of attributes of the laboratory sections. 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. The interview protocol was developed based on initial findings from observations in the laboratory. These interviews were audio taped and transcribed.

C. Data Analysis

Both research questions (Is social capital present? and What affects its development?) were addressed utilizing an interpretive perspective (Patton, 2002). This perspective is appropriate when analyzing observational and interview data, and is based on the premise that the individuals being observed view the same social setting in very different ways. These views are created by the individuals through ideosyncratic interactions with their surroundings. In other words, people create individual realities by interpreting events, as opposed to observing an objective reality. An interpretive analysis allows the researcher to understand an individual's views of his or her experience and interpretation of that experience. An interpretive research perspective is readily understood by considering the work of a historian who interprets people's recollections and explanations of historical events. In an attempt to explain a historical event, the historian gathers information on the event through available written accounts, historical artifacts, and interviews. The historian's account of the event is based on his or her interpretation of the data collected. Kratwohl (2004) states, "the historian interprets not only in selecting what is important but also in determining how important facts are juxtaposed and organized; the latter implicitly creates relations and imports ideas" (p. 575). The same is true for the researcher wishing to describe and analyze events and causes in a social setting. The researcher gathers information through observations, interviews, surveys, and archived documents, and analyzes the data to describe and explain this setting and reasons for action in the setting.

It is important to consider two items relating to the interpretive perspective. First, this perspective allows for a detailed examination of complex social settings, which results in an in-depth understanding of these settings and what factors impact how they function, in this case, how students solicit, receive, and use information in an engineering laboratory. Second, it is the job of the researcher to bring good judgment and training to the analysis of data. As stated by Michael Patton (2002), researchers "are meant to think and to choose and they are judged by the intelligence and honesty with which they do both." The validity of these studies is enhanced by triangulation of data, "gathering data from multiple sources and through the investigation of rival explanations," (Kratwohl, 2004, p. 275) and by member checking. Member checking involves validating proposed results with members of the research project. In this case, students from the observed laboratory sections were interviewed over the course and at the conclusion of the term. In these interviews students were asked if the hypothesized reasons for their actions were
accurate.

Data analysis was performed using the constant comparative method. This method of analysis involves comparing new pieces of data with all existing data trends (Maykut and Morehouse, 1994). If the new data do not fit into existing trends, a new trend is hypothesized and all existing data are reanalyzed to look for occurrences of the new trend.

VI. RESULTS

The presence of social capital is confirmed and a model describing factors affecting the development of social capital is presented and discussed.

A. Presence of Social Capital

Prior to determining factors that influence the development of social capital, it was important to determine if, in fact, social capital was present in the electrical engineering laboratory. The presence of social capital was indicated by evidence of social interactions and resources available and mobilized through these interactions. It is possible that in any situation where individuals worked in close proximity to each other social interactions would occur and resources would be available and mobilized through these interactions. However, the intent of this section is only to show that interactions in this setting were focused on the requirements of the course. The presence of such interactions validates the research interest in what factors affect the development of social capital.

A total of 692 minutes of student interactions, and the focus of each interaction were observed and annotated in two different Design lab sections. The portion of the total interactions focused on particular categories of interaction is summarized in Table 1. Students spent 96 percent of interaction time discussing aspects of the lab and 4 percent on personal conversations. Of the 96 percent, a majority of the time was spent on completion of assignments, and troubleshooting mechanical issues. Although the percentage of time that students spent in discussion in proportion to the total time in lab was not recorded, observations indicated that students were continuously engaged in verbal interaction throughout the lab. It was very rare for a student to spend more than five minutes working without engaging in a verbal interaction. The combination of a substantial amount of time spent interacting, and almost all of this time being spent on laboratory related issues indicates that student interactions were present and information relative to the laboratory was being shared: in other words social capital was present.

Students confirmed the sharing of information in the student interviews. In the discussion of factors influencing the development of social capital below, more evidence reveals the presence of social capital. To avoid duplication of presentation of results, this evidence is not presented in this section. Extensive evidence of students' perceived value of working with other students to be successful in the lab was noted in interviews. For example, the following exchange was recorded in an interview with students from the Design lab:

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(TM) stuff. A lot of problems might come in like for trouble shooting. They say three hints are better than one. It helps to be a team.

The presence of social capital was confirmed by the presence of social interactions and information sharing during these interactions.

B. Factors Affecting the Development of Social Capital

A comparison between Concepts and Design reveals differences in the need for students to access information from one another to be successful. A survey was conducted in Concepts to assess students' willingness to help other students and their perceptions of how much time they spend helping other students. Students appeared to perceive a supportive environment in the Concepts class. Responses to the three questions regarding social capital are provided in Figure 1. Eighty-six percent of students responded either "strongly disagree" or "moderately disagree" to the question, "I have asked for help from other students and been turned down." Similarly, 84 percent of students responded 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. Fifty-four percent 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 Concepts class are willing to help each other, but do not spend much time engaged in this activity.

A comparison of the course handouts, observations from each laboratory, and student comments from interviews indicates that differences in the content and implementation of these laboratories led to substantial differences in the need to work together and access information from one another. Students are introduced to the TekBot(TM) in Concepts and are required to completely assemble a kit, while performing numerous laboratory experiments. The focus of the course related to the TekBot(TM) is on construction and not on programming. For example, students are provided a detailed handout on soldering as part of the class materials. Observations of the Concepts lab indicate that students spent a majority of their time in lab following straight-forward directions on how to construct their Tekbot(TM). Students rarely sought help from one another in this lab. Results of student interviews provide further evidence that differences exist in the complexity of these courses, and the resulting need for information. For example, one student commented on the difficulty of the labs being related to the need to work together:

Interviewer - If your labs were easier do you think that you would work together with people as much?
Student 5 - No, like in 112 I would do everything on my own.
Interviewer - Because there was no need to work with other people?
Student 5 - Yeah.

In contrast, the focus of Design was on advanced programming of the Tekbot(TM). In Design, students utilize multiple programmable circuits to program the TekBot(TM) to perform advanced functions such as sense objects and perform specific actions when sensing objects. Also, as will be discussed later, the student constructed Tekbots(TM) were replete with issues that resulted in students having great difficulty in programming.

The contrast between Concepts and Design, in terms of general level of difficulty and need for programming and troubleshooting, indicates that these factors may be influential in terms of developing social capital.

Observations and interviews conducted in Design suggest that two primary factors necessitated that students access information in order to succeed academically. Substantial evidence indicates that necessary information was only available from other students, as displayed in Figure 2. Taken together, these data show that students require access to resources (information) embedded in social networks.

In order to make the argument that students must access information from one another to be successful in this setting, it must be shown that the research setting was a closed environment. For the purposes of this research, a closed environment is one in which students do not have access to relevant outside information that is useful in completing the laboratory assignments, specifically internet or outside personal resources. Observations of students indicate that although they did utilize the internet for information relevant to the labs, the information from the internet in itself was not sufficient for students to complete their assignments. Additionally, students did not utilize any personal contacts outside of this setting to acquire information to complete their lab assignments.

The inherent complexity of the TekBot(TM) and the open-ended nature of the lab assignments appeared to require students to access information to be successful. Information was necessary both to troubleshoot the TekBot(TM) and to complete the lab assignments. Students spent approximately 30 hours assembling their TekBot(TM) in the Concepts course, which included hundreds of connections. Although the physical components and functionality of the TekBot(TM) 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(TM) to perform given tasks. As noted in Table 1, 38 percent of students' interactions were spent on troubleshooting and mechanical issues. Students commented on how much time they spent troubleshooting in interviews, "The whole class spent a lot of time troubleshooting, every class, probably two out of three hours." This level of complexity of the TekBot(TM) and associated need for troubleshooting 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 spent several hours troubleshooting a problem that was the result of a loose connection or a poor quality solder joint. Student 5 reported that, "The whole thing went to crap ... so I had to look over everything, over and over, and figure out that one wire was plugged in the wrong spot." 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. Students were observed saying, "I am frustrated that stuff doesn't work," and "I had the same issue. Here is how to solve it." The students who worked in isolation 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:

Interviewer - Is there value in working with other people when you are troubleshooting?
Student 2 - Yes . . . you are coming from different viewpoints so it's 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. It's 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 by the students during both observations and interviews 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. For example, students were required in a lab to program their robot to sense a collision with another object and to turn around to avoid additional collisions with the object. Although this aspect of the laboratory reportedly was a source of frustration for many, it resulted in students not only recognizing the need to work together, but also seeking out help from one another. 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.

The need for extensive troubleshooting and the open-ended and vague nature of the laboratory assignments required that students have access to information to be successful in completing the assignments. This information could potentially be available from the teaching assistants, in the lab handouts, or from internet resources. However, none of these potential information sources were used for differing reasons.

Teaching assistant behaviors in the laboratory appeared to have an impact on students interacting with each other to accomplish the laboratory task. In weekly teaching assistant meetings, teaching assistants discussed the laboratory assignment and shared techniques utilized in the laboratory that appeared to promote student success. The researcher was present during these meetings, and the teaching assistants were aware of this research project. Teaching assistants were asked 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 to guide the students in finding answers to their questions, rather than to provide direct and specific answers. Throughout the term, not a single incident was observed in which a teaching assistant provided a direct answer to a student or performed a laboratory task for a student. During informal interviews, the laboratory students were asked why they didn't ask the TA how to do something. Students would respond, "He never gives us a direct
answer." 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 teaching assistants 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 [the TAs] 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.

During observations, students did utilize the internet to access information. However, information accessed was a result of links associated with the course homepage being provided in the laboratory handouts. Since the TekBot(TM) and the associated assignments were unique to this curriculum and this university, information resources that were useful to students in completing the laboratory assignments were not available online. There is no record of students being observed using internet resources to complete their assignments, other than those specified in the laboratory assignment.

The laboratory handouts only provided information on lab requirements and general information on how to complete the lab. Again, observational data reveals that students did not utilize information from laboratory assignment handouts to complete the lab, only to determine what was required. Student interview responses confirm the lack of information in the handouts:

Interviewer - What things in this lab encourage you to work with other people?

Student 3 - The difficulty, and especially in this lab, it is so vague we really have no idea what we have to do.

Both observational data and interview responses indicate that due to the open-ended nature of the assignments and the need to troubleshoot, students required access to information to successfully complete the laboratory assignments. This information was not available from teaching assistants, internet resources, or in the lab assignments. Students were purposeful in mobilizing information (resources) in their social interactions with other students to be successful in the laboratory.

VII. CONCLUSIONS

This research setting was very unique in that it was in electrical engineering, at the sophomore level, in the laboratory setting, and at a single university. Generalizing to other populations is challenging because of the uniqueness of the setting and should be done with caution with qualitative research results. When considering the application of these results to another setting, one must consider if that setting is comparable in terms of the description given in this research (Patton, 2002) (open-ended, limited access to information outside of other students, etc. . .), more importantly than if the setting is the same as this research setting (electrical engineering laboratory).

The ability to generalize will be increased given future research in settings that vary in factors shown to be relative in this research and in ways not present in this research setting. In this research the need for information and the lack of such information from sources outside of other students required students to purposefully mobilize information from one another. It is this unique combination of need and lack of resources that fosters the development of social capital. However, this combination is not unique to this setting. Many engineering laboratories are open-ended and characterized by a high level of difficulty with limited access to resources necessary to complete assignments, except for teaching assistants and other students. It would be expected that student collaboration is valuable in such academic settings. Future research could investigate laboratory settings in which students do have access to non-human information sources and identify factors that encourage students to preferentially select information sources and the extent to which social capital is developed. This would allow for comparison of results from business settings that employees preferentially utilize human sources for information over non-human sources (Center for Workforce Development, 1998).

Other factors may also be important to information sharing and social capital development, such as personal characteristics of the participants, institutional factors, and relative difficulty of the assignment. Important personal characteristics impacting the development of social capital may
include tendency to collaborate, age, gender, and the extent of previous interaction of the participants. While the unit of analysis in this study was all students in the course, future studies with the individual as the unit of analysis would highlight individual differences that may be influential in the development of social capital.

If more was known about laboratory and personal characteristics that encourage the development of social capital in the engineering laboratory setting, should engineering curriculum and laboratories be designed to encourage the development of social capital? While there is obvious value in requiring information sharing, there are inherent dangers in designing laboratories in this way. Confirmed by this research is the proposition that students who do not engage with their teaching assistants and peers in this type of setting do not have access to information necessary to complete the required assignments and may have difficulty succeeding academically. Students who do not engage may do so not by choice, but as a result of being excluded by the group; a negative consequence of social capital that has been investigated and confirmed elsewhere (Portes, 1998). If a learning atmosphere is designed to necessitate interaction for academic success, the responsibility to encourage interaction among students who are isolated falls in the hands of the course designers and instructors.

The higher education setting is a social enterprise in which students rely heavily on one another, teaching assistants, and faculty to be successful. In business, research and practical experience has confirmed the value of personal interactions on employee satisfaction, productivity, and innovation, resulting in substantial investment to foster the development of social capital. Although engineering educators have paid closer attention to practices such as cooperative learning and living learning communities that foster productive interactions, less attention has been committed to understanding the value of encouraging productive interactions on a more holistic basis. The construct of social capital provides a research framework and cultural description to further investigate these interactions.

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