Social Capital in Engineering Education

Shane Brown¹, Larry Flick², Ken Williamson³

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 discussing social capital that is relevant to engineering education, from business and academic settings, and utilizing this literature base suggests that engineering education curriculum be designed in terms of developing both human capital and social capital. 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. Several educational methods are discussed that have been shown to increase student social capital, such as cooperative learning and service learning.

Index Terms – Social Capital, Workplace Readiness, Civic Responsibility, Engineering Education, Cooperative Learning, Service Learning

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. Both learning and social involvement can be achieved as complementary activities when viewed through the lens of social capital.

The audience of this paper includes individuals from a full spectrum of universities, including large research focused public universities, to small teaching focused private universities. Additionally, faculty members range from those experienced at progressive teaching techniques, including team oriented activities such as active and cooperative learning, to more traditional teachers that utilize a more didactic lecture style. One of the goals of this work is to introduce the engineering education audience to the concept of social capital, and it’s relevance and potential as a framework for understanding and improving undergraduate education. Another goal of this work is to provide some insight into methods and practices that can be implemented to develop social capital. Given the broad spectrum of audience members, this is a difficult task. With this in mind, several potential approaches are suggested, with an extensive list of references for the reader to access for further information on the discussed methods.

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 [1].

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 [2]. 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.” [2] 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.” [3]

The network aspect of social capital refers to “relationships among social entities, and the patterns and implications of these relationships.” [4] 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 [5]. 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.” [6] 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 [7, 8]. Additionally, based on personal observations in labs, 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>
<thead>
<tr>
<th>Trust, reciprocity, mutual respect</th>
<th>Individual associations</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Students work together with minimal barriers.</td>
<td>Students may want to work together but do not have a reason to, i.e. assignments are trivial.</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Students work together but are leery due to factors such as competition.</td>
<td>No trust or interaction.</td>
<td></td>
</tr>
</tbody>
</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 [5]. 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 [9]. 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.” [5]

The ability and the need for the university to prepare students for active citizenship is a well accepted proposition [10, 11]. John Dewey, a twentieth century philosopher of democratic education, states that, “Democracy has to be born anew every generation, and education is the midwife.” [12] 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 [13].

**Workplace Readiness**

There is increasing pressure on colleges and universities from companies 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 [14]. 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 [8]. Lecture settings provide little opportunity for student interaction and discussion [15]. 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 [16]. 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 [16]. 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 U.S. Department of Commerce estimates that 80% of organizational learning is informal [17]. Studies have shown that the primary source of information in technological workplaces is other employees [18]. 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

**TABLE 1 – THE NORMATIVE AND NETWORK ASPECTS OF SOCIAL CAPITAL**

<table>
<thead>
<tr>
<th>Trust, reciprocity, mutual respect</th>
<th>Individual associations</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Students work together with minimal barriers.</td>
<td>Students may want to work together but do not have a reason to, i.e. assignments are trivial.</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Students work together but are leery due to factors such as competition.</td>
<td>No trust or interaction.</td>
<td></td>
</tr>
</tbody>
</table>

**October 19-22, 2005, Indianapolis, IN**

**35th ASEE/IEEE Frontiers in Education Conference**

**S3D-11**
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 [19]. 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.” [19] 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.” [19]

**Teaching Standards and Educational Reform**

The need and benefits of involving students in the learning process is well documented and supported [20]. 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 response, is the dominant form of classroom discourse [15]. 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 [21]. From a Vygotskian perspective, all higher psychic functions are processes that are most commonly mediated through verbal interaction [22]. It is the socially mediating feature of language that guides the learner toward the solution of problems which 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 naive 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 [23]. 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 [24]. However the suggested new practices have run counter to the dominant, teacher-directed discourse of contemporary classrooms [15].

The idea that general and scientific knowledge is socially constructed has gathered more and more support during the last 30 years [25]. 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 [26]. 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 [27-31]. Carbonaro tested Coleman’s hypothesis in a new setting and found that social capital was positively related to dropout status and math achievement test scores [28]. Morgan and Sorensen similarly found that math achievement for 8th graders was positively correlated with density of friendship and parental networks [29]. In a study of university undergraduate students, Etcheverry found that student perceptions of support from other students related positively to student self-confidence and grade point average [32].

The number of retention studies in college math, 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, math, and engineering majors [8]. One of the most striking differences between students leaving engineering and students leaving math 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 that 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 [23]. 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 [7]. Astin proposes that students who have contrasting values and beliefs than peers in their major are likely to leave that peer group in favor of one that has similar values and beliefs [33]. 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 math 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.” [33]

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 [8]. Tobias reports that teachers discouraged classroom interaction and students found it difficult to interact with their classmates in this didactic environment [7]. 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.” [34] 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 affect on retention of minority students.

**Educational Practices that Encourage the Development of Social Capital**

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. Encouraging the development of social capital can be achieved in several different ways.

Many engineering educators are involved in teaching practices that encourage the development of social capital. A detailed survey of a variety of teaching practices aimed as active student engagement is found in the January 2005 issue of the Journal of Engineering Education [35]. Print and Coleman recommend designing curriculum based on engaging students in active participation to build trust, cooperation, and networking skills [36]. 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, service learning, teaching assistant behaviors, and difficult open ended lab activities.
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 professional 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 [37]. 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 [38,39]. Jones suggested that higher order questioning was essential to encourage discourse [37], while van Zee utilized questions that developed conceptual student understanding [39].

Students should be required to present new ideas to foster discourse [37], and students were found to engage in discourse when they were able to propose and discuss issues that are relevant to them [37], and they are familiar with [39]. Each of these behaviors must be conducted in an environment that is both supportive [37] and comfortable [39], in which students can negotiate and compare their understanding with accepted knowledge [37].

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 [21,40,41]. In scientific communities of practice, learning occurs through verbal and written interaction, and knowledge is shared and advanced through language, diagrams and images. However, in the classroom, learning is almost never accomplished using these instruments. Roth [42] 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 suggests 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 proposes 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 [43] investigated student views of concept mapping to understand student perceptions of their learning and their 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.

Structure of Lab Activities

In a recent qualitative research project, factors that affected the development of social capital in an electrical engineering lab setting were investigated [44]. In this particular setting the students utilize a TekBot™, a small robot that students build, modify, program, and troubleshoot throughout the entire four year electrical engineering curriculum. The open ended nature of the lab assignments, extensive need for troubleshooting, and teaching assistant behaviors encouraging students to work on their own were found to be instrumental in developing social capital.

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 [45]. 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.” [45] 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." [46] Additionally, students involved in service learning have increased comprehension of course material and develop an awareness of their local community [47]. 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 [48]. 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 [2, 5].

**IS SOCIAL CAPITAL PRESENT?**

The ability to assess the presence of social capital is valuable when implementing efforts to encourage development of social capital. Normally observational methods are too time consuming and costly to implement on a continuing basis. However, surveys can be used to measure the presence of social capital. Very few surveys have been implemented for this purpose and the surveys that have been developed must be used with care as each survey was based on a specific conceptualization of social capital. Etcheverry developed a social capital survey, assessing the presence of faculty and peer support [32]. Recently a survey was designed to assess the presence of social capital in the lab setting [44]. Social capital was assessed as teaching assistant and peer support. Either all or part of these survey instruments could be used to assess the presence of social capital. Additionally, surveys could be used to gather information on student achievement and statistical analyses performed to assess the correlation between social capital and achievement.

**MAKING SENSE OF IT ALL**

The introduction to this paper suggested that the goal of universities to graduate students that 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 students 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.

Each of the suggested educational 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. Social capital surveys are available to assess the presence of social capital.

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.

**ACKNOWLEDGMENT**

The financial support of the National Science Foundation under grants EEC-0230679 and EEC-0342055 and the William and Flora Hewlett Foundation Engineering Schools of the West Grant Initiative are gratefully acknowledged.

**REFERENCES**


