Abstract - Engineering education has often been criticized for the inability to adequately meet or exceed the expectations of today's industry. One of the chief complaints is that most entry level engineering school graduates are ill prepared to apply the technical and interpersonal knowledge and skills in a real industry setting. The isolation between knowledge/skills taught in engineering classes and the real engineering world partially results from the theory-based unified curriculum and lecture-based traditional instructional methods in which knowledge and skills are not adequately situated in a real engineering world setting.

In an effort to cover the discrepancy between the needs of today's industry and engineering education in practice, the Engineering Leadership Development Minor (ELDM) in the College of Engineering at the Pennsylvania State University is innovating the curriculum and instructional methods of engineering education. Based upon a social cognition perspective of learning as a theoretical background on one hand, and upon the needs and expectations of industry on the other, the ELDM is attempting to integrate non-technical, professional skills; such as communication and interpersonal skills, teamwork, and creative and intuitive thinking skills, with non-traditional instructional methods designed to facilitate social interaction and cooperation among students via computer-mediated communication (CMC) technology.

This paper explores the potential of CMC as a facilitator of social interaction, engineering learning and instruction based upon social cognition perspective through the experience of implementing CMC in the ELDM. Why social interactions are so important in engineering education, how CMC facilitates engineering students’ social interaction, and how to maximize the potential of CMC in engineering education will be highlighted. It is intended that this paper will provide educators or instructional designers in the field of engineering with an opportunity to share the ideas and experience of innovating curriculum and instructional methods of engineering education through the application of CMC.

Introduction

Engineering, broadly speaking, means applying scientific knowledge and theory to solve real world problems. In this sense, engineering should not be isolated from the real world. However, many undergraduate engineering programs do not seem to accurately reflect real engineering world. Lecture-based mass classes are still a mainstay instructional method. In addition, often times the curriculum offered does not match either the demands or expectations of an engineering industry that expects newly hired engineering graduates to demonstrate higher-order thinking and leadership skills, as well as technical knowledge and proficiency.

Engineering curriculum and instruction that are isolated from real-world engineering are most often based upon the symbol-processing view of learning and cognition which has dominated educational theory and practice for a long time. The symbol-processing view treats human thinking and learning as mechanical operations upon information in a manner similar to the process of a computer [1]. The main epistemological assumption of this perspective is that knowledge exists independent of the situation in which it is acquired. Therefore, the primary concern of curriculum and instruction based upon the symbol-processing view is to analyze and extract abstract concepts from situational context and activity, and to then transmit these de-contextualized concepts in efficient ways so that learner can easily absorb and reproduce them later [2].

While it is true that the symbol-processing view has served as the basis for understanding human learning and cognition, it has severe limitations in the development of the higher-level learning and cognition demanded in today’s highly competitive, complex and global industrial environment. Anecdotal evidence of these limitations is easily found in the industry complaints concerning the inability of most newly hired engineering graduates to solve real world problems through the application of the knowledge and skills taught in classes. This inability is not attributable to the lack of conceptual engineering knowledge. Rather, it results from the inert nature of their knowledge and the inability to synthesize and apply this knowledge to real-world situations.

In an effort to address this discrepancy between the needs of today’s industry and an engineering education based upon the symbol-processing view in practice, the Engineering Leadership Development Minor (ELDM) was created in the Department of Electrical Engineering at The Pennsylvania State University.
University. The ELDM is an innovative curriculum based upon an alternative theoretical background, the social cognition view, on one hand, and upon the needs and expectations of industry on the other. The ELDM is attempting to integrate non-technical, professional skills; such as communication and interpersonal skills, teamwork, and creative and intuitive thinking skills, with non-traditional instructional methods designed to facilitate social interaction and cooperation among students via computer-mediated communication (CMC) technology.

Social Cognition View

The social cognition view on human learning developed in response to the limitations of the traditional symbol-processing view. The social cognition view asks questions such as whether knowledge can be separated from the social contexts in which the cognition takes place and whether learning can be fully understood as symbol process [3]. From the social cognition view, knowledge does not exist objectively and can not be transmitted from one person to another. Rather, knowledge is internally interpreted and constructed and it derives its meaning from the internal and external learning contexts. Abstracting knowledge from the context in which it is learned and applied results in inert knowledge that is memorized but cannot be used in or applied to real situations. Learning does not occur until a learner reflects and constructs the relationships between knowledge and its situation. This is accomplished through the active interaction between the individual’s cognitive structure and the learning environment. Resultantly, social context is regarded as an integral part of human learning.

As early as 1978, Vygotsky suggested that social interaction between individuals provides inputs to most epistemological processes [4]. Social interaction with others and participation in the life of one’s cultural community are fundamental underpinnings of human learning and cognition. Knowledge and its social or cultural environment cannot be separated from, but rather are integral to human learning and cognition. Additionally, the relationship between the individual and his or her social or cultural environment are parts of a mutually constructed whole [1].

From the prescriptive point of view, the social cognition view would appear to have three important implications upon undergraduate engineering education. First, the curriculum needs to actively reflect the social contexts of knowledge by integrating the environment, needs and expectations of real-world engineering. In the norm, the curriculum of undergraduate engineering education has most often focused upon the transfer of technical skills and abstract concepts which are not reflective of real-world engineering. It is often the case that students simply memorize the engineering concepts and acquire computational and analysis skills without developing understanding or reflecting upon the importance, application or relevance of the knowledge. Furthermore, most do not deem the non-technical, professional skills such as leadership, teamwork, effective communication, or creative thinking skills to be as important as technical skills.

Second, the instructional method employed in most engineering education has been highly dependent upon lectures where the instructor is the primary resource of both instruction and knowledge. The role of the learner is to individually assimilate the knowledge the instructor deems important and to reproduce that knowledge upon demand usually in the form of an examination. As indicated by the social cognition view, knowledge separated from activity is no more than rote memory and cannot be used in new problem situations. The instructor’s knowledge which is transmitted and assimilated is not the learner’s knowledge until the learner becomes actively involved in the learning process to construct their own meanings in context.

Third, the social cognition view suggests a socially collaborative learning environment in which several group members perform together in the context of a shared task as an effective instructional method which increases the learners’ active involvement in real situations. Implicitly or explicitly, in most undergraduate engineering education today, learners are expected to learn and to perform individually. However, this is not the case in real-world engineering. Most engineering tasks in industry are successfully accomplished by sharing ideas and expertise of several individuals. Paris & Winograd indicate three benefits of collaborative learning for increasing shared cognition and knowledge. First, a collaborative learning environment has the potential to provide help to those who need it. This mutual peer helping most often results in higher achievement. Second, the discussion among group members has the potential to help each group members reflect upon and restructure their ideas. Lastly, a collaborative learning environment can improve learners’ motivation while lessening anxiety compared to an individual or competitive learning environment [5].

In a socially-mediated intellectual community, it is inevitable to use some tools to build a bridge between individual and others. Vygotsky proposed language as the most important tool for mediating individuals of intellectual community [4]. However, as technology has developed, more and more attention is focused upon its educational potential as a tool to facilitate social interactions among individuals within the intellectual community. Computer-mediated communication (CMC) represents one such technology.

Computer - Mediated Communication

Computer-mediated communication in an educational setting refers to networked computers with an aim to facilitate
communication among geographically distant learners. Information exchange through electronic mail (Email), on-line discussion for distance learning, and group problem solving through Group Decision Support Systems (GDSS) are examples of educational CMC. Some theorists regard computer-mediated communication as a form of computer-aided instruction. However, CMC differs from computer-aided instruction for three primary reasons. First, CMC focuses upon the interaction between individuals rather than upon the interaction between an individual user and a computer. Second, and directly related to the first, computer-mediated communication relies upon a group rather than individual. Lastly, CMC focuses upon communication rather than upon guided tutoring.

Despite the attention being paid to the educational potential of a marriage between computer and communication technology, there has been little documented thought concerning educational CMC based upon the social cognition perspective. Rather, reflective of the information processing theory of learning, the tendency has been to regard CMC as a form of media to facilitate symbol processing. For example, according to the information processing model of learning, a typical example of symbol-processing view, all humans are in alike in that they are information processing systems. This approach has serious limitations because of the serial nature of information processing and the limited capacity of short-term memory [6]. The general perspective of the information processing model is then extended to group activity through the assumption that group activity is also an information processing system in which information is mutually transmitted to group members. However, as is the case for the individual, the productivity of face-to-face group activity is limited by the serial nature of the information processing systems and limited size of the short-term memory of individuals. CMC can provide practical tools to overcome this type of limitation by allowing group members to be freed from the need to pay attention to external inputs because ideas from others are recorded electronically and are thus available at any time. This availability, in turn, releases the group members’ short-term memories for processing additional ideas. Additionally, CMC can switch parallel ideas from others to serial information by allowing them to be stored and retrieved later [7].

Contrary to the information processing model which stresses the role of CMC as a media for efficient information exchange among group members, the use of CMC technology is regarded as a tool to facilitate the creation of an intellectual learning community in which group members construct and exchange knowledge. In such an intellectual community, CMC plays the role of a bridge between individuals. Thus, the intellectual community is not limited to collect and share multiple ideas to solve ad hoc problems. It’s main function is to create the social context in which individuals exchange their own knowledge and reconstruct it through reflective thinking processes in a fashion similar to a community of scientists in which each continuously exchanges their own scientific knowledge, which is, as the result, refined and constructed through the social interaction.

Mason proposed a role of CMC as a facilitator of self-directed learning by emphasizing four elements which distinguish CMC from lecture-based instruction: the active role of the learners; the facilitation of discussion; the development of knowledge through the formulation of ideas; and the fostering of cooperation rather than of competition [8].

In a CMC learning environment, the subject of learning is the learners. Learners create their own learning community in which they discuss, collaborate and construct their own knowledge. Further, Davie and Wells identified the self-directed feature of a CMC learning environment to have a positive impact upon learner empowerment. In the traditional lecture-based approach, learners develop an over-dependence upon the instructor and usually lack contact among themselves. These two factors represent severe limitations to empowering learners. In contrast, they contend that CMC has the potential for empowering learners by providing learners with opportunities of unlimited contact with other learners and while changing the role of the instructor from a knowledge transmitter to a learning facilitator [9].

CMC has potential as a tool for improving learners’ higher-order thinking skills which, in the social cognition view, are regarded to be more important than knowledge itself. Knowledge needs to be seen as on-going process regulated by an individual’s thinking skills. CMC is an excellent candidate for improving higher-order thinking skills because it provides learners with opportunities to reflect their own thinking skills while comparing them with the multiple alternatives provided by others.

**CMC in Practice - Initial Results of the Integration of CMC into the Engineering Leadership Development Minor Core Courses**

The goal of the ELDM is to prepare engineering students for the demands of a complex global society by creating an engineering community in which learners expect to experience real engineering world. Based upon the social cognition perspective, the ELDM has established three instructional features which distinguish it from traditional lecture-based engineering programs: a multidisciplinary curriculum, portfolio assessment and evaluation, and collaborative problem solving. To achieve a multidisciplinary curriculum, the ELDM integrates non-technical, professional skills, such as communication and interpersonal skills, teamwork, creative and intuitive thinking with both technical skills and the basic business and
organizational concepts essential for success in industry after graduation. Portfolio assessment and evaluation are totally different from traditional testing in that students are required to construct, assess and evaluate their own portfolio in terms of the quality of the process, as well as specific outcomes based upon criteria provided. As a result, student achievement is evaluated by means of self-reflection of progress rather than by comparison to others. Lastly, the core courses of ELDM highly emphasize group-based collaborative problem solving. Learners are required to conduct group problem solving activities or case study analysis numerous times in each course. Each of the cases or problems are sufficiently complex to accurately reflect the complexity of the real world context.

In the Spring, 1997, semester, we are trying to integrate the educational potential of CMC into the ELDM core course work. To accomplish this, a CMC system was developed and integrated into the web site used for the ELDM core courses. This CMC system was created through the use of Allaire Forums; a personal computer-based communications program. In this CMC system, every student enrolled in either the ELDM or in ELDM courses has the ability to send and receive messages, both synchronously or asynchronously, at any time from any location with any or all of the other students or student teams in the ELDM or ELDM courses.

As a first step in the ongoing evaluation process of the effectiveness of CMC for facilitating group problem solving activity, student perceptions as to the effectiveness of CMC for group activity, in terms of quality and satisfaction of group outcomes and process, were compared to the more traditional face-to-face form of communication. For the purpose of comparison, a class of eighteen students was divided into six groups of three members each. Three groups were required to conduct group case study activity using CMC exclusively, while the other three groups were required to do their group case study in face-to-face. Each group was given the same case, each was required to submit a final written analysis of the case for evaluation, and each member of a group received the same grade as the other members.

To assess the perceived effectiveness of CMC in comparison to face-to-face communication, an eighteen item, five point, Likert-type scale questionnaire was administered to the course participants. Of the eighteen items, five addressed the quality of outcome, five addressed the quality of process, four addressed satisfaction with the outcome, and four addressed satisfaction with the process associated with the group process in completing the case analysis.

The results of the data analysis for this study show that the response mean scores of the groups employing CMC were higher in all four categories investigated than those of the groups employing face-to-face communication. To determine reliability, reliability coefficients (Alpha) of each category of the questionnaire were conducted. Table 1.1 presents a summary of the response mean scores and reliability coefficients for each category.

Table 1.1 Summary of the Comparison of Response Means Between Student Perceptions of CMC and Face-to-face Group Communication Media

<table>
<thead>
<tr>
<th>Category of Items</th>
<th>Mean (CMC/FtoF)</th>
<th>Std Dev (CMC/FtoF)</th>
<th>Reliability Coefficient (Alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of Outcome</td>
<td>3.84/3.24</td>
<td>.31/.56</td>
<td>.7559</td>
</tr>
<tr>
<td>Quality of Process</td>
<td>4.09/3.13</td>
<td>.39/.71</td>
<td>.8353</td>
</tr>
<tr>
<td>Satisfaction with Outcome</td>
<td>3.89/3.53</td>
<td>.49/.89</td>
<td>.7824</td>
</tr>
<tr>
<td>Satisfaction with Process</td>
<td>3.61/3.53</td>
<td>.53/.78</td>
<td>.7831</td>
</tr>
</tbody>
</table>

One-way ANOVA analyses were conducted in order to determine the statistical significance, if any, between the response mean scores. The mean response score for Quality of Outcome for the groups employing CMC was significantly higher than that of the groups employing face-to-face communication (F(1,16) =8.1910, p <.001). Similarly, the mean response score on the Quality of Group Process for the groups employing CMC was significantly higher than that of the groups employing face-to-face communication (F(1,16) = 12.4301, p <.003). A summary of the ANOVA analysis is provided in Table 2.1.

Table 2.1 Summary of Significant Differences Between Student Perceptions of CMC and Face-to-face Group Communication Media Response Means

<table>
<thead>
<tr>
<th>Category of Items</th>
<th>Mean (CMC/FtoF)</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of Outcome</td>
<td>3.84/3.24</td>
<td>8.1910</td>
<td>.001</td>
</tr>
<tr>
<td>Quality of Process</td>
<td>4.09/3.13</td>
<td>12.4302</td>
<td>.003</td>
</tr>
<tr>
<td>Satisfaction with Outcome</td>
<td>3.89/3.53</td>
<td>1.1458</td>
<td>.300</td>
</tr>
<tr>
<td>Satisfaction with Process</td>
<td>3.61/3.53</td>
<td>.0478</td>
<td>.830</td>
</tr>
</tbody>
</table>

In the final analysis, there were no significant differences in learner satisfaction between the groups based upon the communication media. It is interesting to note that the mean scores for both quality and satisfaction was higher for the groups that used CMC than for those using face-to-face communication. Resultantly, the effectiveness of CMC to facilitate group interaction in the ELDM courses was positively perceived by the students participating in the course.
Conclusion

Today’s engineer is inundated by the flood of information on changes in the profession and emerging technologies that occur at an ever-increasing rate. As a result, few individuals are able to remain state-of-the-art in terms of knowledge. The accumulation of massive technical skills and an encyclopedic knowledge of engineering is no longer a practical or primary objective of today’s practicing engineer. Rather, higher-order thinking skills and an emphasis in non-technical, professional skills such as creativity, problem solving, and leadership skills are in great demand. If it is the goal of undergraduate engineering education to prepare students to become productive and successful in the engineering field, educational institutions must develop and offer a curriculum that reflects today’s needs and expectations.

Through the presentation of the findings associated with techniques tested in the ELDM core courses at Penn State, we have tried to suggest and share a practical and theoretical framework which may provide for the innovation of engineering education. The social cognition view, the theoretical framework suggested in this writing, implies that efforts should be made to “shorten the distance” between the real engineering world and undergraduate engineering classes. Students must be challenged to learn how to think deeply and creatively. CMC, a recently devised technology, potentially represents an ideal tool to help foster the innovative atmosphere and attitude needed to recreate the engineering learning environment.

References