Incorporation of Distance Engineering into an Introductory Freshman Undergraduate Course in Civil Engineering

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Abstract

This paper presents the results of a pilot study conducted by the Civil and Environmental Engineering (CEE) Department at Worcester Polytechnic Institute (WPI) to investigate the impact of distance communication on student project work. An introductory freshman civil engineering course with a project-based collaborative format was modified to incorporate a distance engineering component based on a hypothesized highway design project. Student groups were separated into home and field teams, with home teams playing the role of design engineers located in the office, and the field teams playing the role of field engineers completing required field measurements and calculations. Both home and field teams were located in the civil engineering building, but were physically separated by two floors. The test group only used remote technologies (e.g. telephone, fax, email, file transfer, shared folder, chat, and video-conferencing) for all communication between home and field teams. A control group was allowed unrestricted face-to-face communication between home and field teams. Student performance was assessed by evaluating quizzes, group presentations, and project reports. Interpretations of student performance in terms of personality and cognitive style indicators for both the control and test groups indicated that effective group interactions are a key to the successful completion of integrated projects in a distance engineering environment. Student journals and survey responses indicated that students found the introduction to remote communication technologies to be valuable. The results demonstrate the importance of integrating distance engineering applications and information technology into the undergraduate curriculum.

1. Introduction

An increasing number of projects require the integration of services from people at remote locations. These remote interactions are also promoted by rapid advances in communication technologies. For example, many engineering offices are in the process of implementing new means for real-time discussion using written communication, shared drawing space, and simultaneous audio and visual contact. Any engineer interested in advancing his or her career must be able to adapt and flourish in this new “distance engineering environment" (DEE). However, while the arrival of this distance engineering environment is imminent, there are still many unanswered questions about the effectiveness of engineering projects completed with these constraints. In addition, only limited information is available on how these topics should be incorporated into the undergraduate curriculum. An overview of some literature related to distance engineering education can be found at http://cee.wpi.edu/ceedee/. For the purposes of this paper, we only note one comprehensive investigation which revolved around a collaborative course by the British Open University that involved student groups from three countries.[9] This investigation showed that the collaborative approach enhanced motivation, enjoyment, and camaraderie. However, the authors noted the importance of promoting effective student interactions. More investigation is necessary to understand the nature of these student interactions and performance under distance engineering constraints.

Objectives and overview This paper presents the results of a pilot study conducted at Worcester Polytechnic Institute (WPI) to investigate the potential impact of distance communication on student project work. The specific objectives of the pilot study were:

(1) to assess the effects of distance engineering on the technical analyses, oral presentations, written reports, and student interactions in student projects,
(2) to assess the potential for the use of distance communication technologies in courses and student projects, and
(3) to establish a foundation upon which distance engineering concepts can be further integrated into the curriculum.

These objectives are intended to provide a framework for expanding the use of distance engineering techniques in student projects completed at the regional scale, the national scale, and even the global scale through WPI's Global Studies Program. The role of distance engineering is investigated by integrating remote communication technologies into CE 1030, an introductory freshman-level civil and environmental engineering (CEE) course at WPI. After a brief description of this course, this paper presents the technology and instructional model used in modifying CE 1030 to achieve these objectives. The role of distance engineering in student project work is assessed by evaluating student performance and by characterizing this performance in terms of group dynamics. These assessments are presented with a description of student perceptions in Section 4, followed by conclusions in Section 5.

2. Background - CE 1030

The pilot study consists of the integration of distance communication technologies into and evaluation of student perceptions and performance in CE 1030, an introductory civil engineering course in the Civil and Environmental Engineering (CEE) Department at WPI. WPI's CEE Department has developed a number of initiatives to refine its curriculum to better satisfy the needs of the professional community. Computer skills and written and oral communication skills are key attributes for engineers entering the workforce. Therefore, to introduce students in civil and environmental engineering to these components as early as possible in the program, the CEE Department developed a freshman level introductory civil engineering class entitled "Introduction to Civil Engineering and Computer Fundamentals". [2 3] The primary objectives of this course are (1) to provide students with a technical background in computer use, (2) to introduce students to the technical fundamentals of the various disciplines in civil and environmental engineering, and (3) to provide students with written and oral communication skills that will better prepare them for giving presentations and writing professional reports. A number of studies have shown that collaborative learning approaches enhance the learning process by encouraging active learning.[6 7 8] The approach promotes critical thinking and team decision-making - all of which are critical attributes essential for success in the professional workplace. Since collaborative learning approaches are considered effective in providing problem solving skills and social skills required to work in a team environment, these approaches have been integrated into the course curriculum. The course typically consists of an integrated project consisting of a sequence of one-week mini-projects in which students work in teams addressing related design problems in the various sub-disciplines of civil engineering. Instruction is aided by a teaching assistant (TA) and a number of peer learning assistants (PLA's). The TA helps students by answering questions and assisting with technical problems, and the PLA's work with teams to assist them with their communications and problem solving approach. A more complete description of CE 1030 can be found at the course website at http://cee.wpi.edu/CE1030/.

3. Course format

The overall approach Since CE 1030 has included collaborative learning and project-work for the last five years, the course provides an excellent forum for investigating the significance of distance constraints on student project-work. WPI's schedule includes 4 seven-week terms (Terms A through D) during the nine-month academic year. CE 1030, as all other undergraduate courses at WPI, is taught at a fairly intensive pace over the seven-week duration. The course format typically includes one-hour lectures on Monday, Tuesday and Friday, a three-hour laboratory on Wednesday and a one-hour laboratory on Thursday. The students learn the background material for the week's topic on Monday and Tuesday, work on the project in the laboratories on Wednesday and Thursday, and present their results on Friday, and submit their final report on the following Monday. The course content was easily adjusted to satisfy the objectives of this investigation by incorporating technology to accommodate distance communication and developing an appropriate integrated project and associated mini-projects that serve as an instructional model to assess the role of distance communication in the project. The CE 1030 class used for this investigation was offered to 17 students in D Term (a seven-week period during March and April) of 1997. Professors El-Korchi and Hart developed the project, and also served as instructors. One teaching assistant (TA) provided assistance with technical aspects and grading, while two peer-learning assistants (PLA's) worked with students to assist with group dynamics.

The technology Components for distance communication include asynchronous techniques, which impose some delay between the receipt of a message after it is sent, and synchronous techniques which accommodate real-time communication. Relevant asynchronous techniques used in this project include fax, email, file transfer protocol (ftp), and the World Wide Web (WWW). Synchronous technologies of interest include telephone, chat, whiteboard, shared folder, and audio/visual communication techniques. Because of the growth in capabilities and applications using the World Wide Web (WWW), WWW-based technologies were emphasized in this project. Since no integrated products that incorporated a full range of remote WWW-based communication technologies could be identified at the time of this investigation, separate hardware and software components were selected to provide the capabilities noted above. For asynchronous communication, students were able to send messages primarily through email and fax, and they could also transfer data and files using email and file transfer protocol (FTP). For synchronous communication, students could use telephone, chat, whiteboard, and shared folders.

They could also use Connectix VideoPhone for combined audio/visual (A/V) communication via the WWW. While students were allowed to use the package for any communication, this package was primarily used to accommodate integrated presentations in which field teams were included through the A/V link. Due to network speed constraints, only the visual component of the Connectix package was used in these presentations, with the Audio component was provided through speaker telephones.

The instructional approach The instructional approach is formulated using an integrated project consisting of a series of six one-week individual laboratories that serve to introduce various sub-disciplines in civil and environmental engineering, and introduce the software and hardware tools necessary to perform appropriate calculations, complete reports and present results. For each laboratory, each student group solves an engineering problem, completes a report summarizing the group's results, and gives a group presentation to communicate their results. In addition to the group report and presentation grades, an individual student's grade for a particular laboratory is based on a quiz grade, and a peer evaluation grade, which serves to maintain individual accountability. The first two laboratories of the course were intended to introduce students to the computer and did not include any distance engineering components. For these two laboratories, the seventeen students enrolled in the course were separated into three groups. For the remaining laboratories of the course, the student groups were adjusted to accommodate experiments with distance engineering. For their integrated project, each student group played the role of an engineering company employed to complete specific tasks associated with the layout, design, and construction of a highway proposed for a fictitious location in South America. The project involved both office and field tasks in the framework of an idealized distance engineering environment. The "office" was defined to be located in a computer laboratory on the second floor of Kaven Hall, the building that houses the CEE Department. The "field" was represented by a physical scale model located in another laboratory in the basement of the same building. The physical model, which is shown in Figure 1, consisted of a 5-foot square sandbox with a topographical features sculpted using sand, rocks, papier-mâché and paint. Laboratory topics were chosen to introduce students to a variety of civil and environmental engineering areas that would pertain to the proposed highway. For the distance engineering laboratories, students used the AutoCAD package to prepare a scale map of the field site for Laboratory 3, investigated the impacts of a waste discharge on the river adjacent to the project area for Laboratory 4, determined the optimal layout for a highway for Laboratory 5, and constructed and tested a model bridge for Laboratory 6. A picture showing students working on the final model bridge is included as Figure 2. The entire course schedule for this particular experimental period may be found at http://cee.wpi.edu/CE1030/D97.

The experimental approach The approach for investigating the role of distance engineering in student projects is to assess student performance and perceptions when they work on projects that require the interaction of students working at remote locations. The role of distance engineering is assessed by comparing group performance for two cases: one in which student group members working at remote locations can only use electronic means for communication, and another in which no constraints on communication are imposed. To provide this control, the seventeen students enrolled in CE 1030 were randomly separated into Teams A and B. Students in both of these teams were then randomly subdivided into sub-groups 1 and 2. Students in each sub-group

Figure 1 - Picture of sandbox used to represent field conditions

Figure 2 - Picture of students working on model bridge

were instructed to organize themselves into typical engineering team roles of project manager, chief engineer, engineer, and client representative. For laboratories incorporating a distance component, one subgroup was designated as the "home" subgroup and the other designated as the "field" subgroup. While an ideal approach would be to maintain a large separation to prevent the possibility of communication between home and field teams, this approach would be difficult to coordinate and was not deemed necessary for the purposes of this pilot investigation. Rather, home subgroups were situated in the AutoCAD Laboratory on the second floor of the CEE Department in Kaven Hall at WPI, and field subgroups were situated in the Materials Laboratory in the basement of Kaven Hall. All students pledged that, when asked to serve in a distance engineering capacity, they would only communicate with each other via electronic means, which included fax, email, telephone, computer audio/video, shared white folder, and shared folders.

Table 1 shows the group assignments for each of the final four laboratories of the course (Labs 3 through 6) and also lists the location (i.e. home or field) for each subgroup. Groups that are highlighted in gray shading completed the projects under distance engineering constraints. Groups that are not highlighted in gray had no distance constraints, and were free to communicate face-to-face. Laboratory 4 served as a control since no distance engineering requirements were included was involved and all subgroups completed their projects independently. For Laboratory 3, Team B used only electronic means for communication between Subgroups B1 and B2, while Team A served as a control since they had no such constraints and could communicate freely. For Laboratory 5, Team A became the subject of the distance experiment while Team B served as the control. Finally, for Laboratory 6, Subgroups A1 and B1 jointly served as the home team, while Subgroups A2 and B2 jointly served as the field team. The group assignments assured that each student in the course experienced a distance engineering environment from both the home and field perspectives.

Table 1 - Group assignments

	Team A		Team B	
	A1	A2	B1	B2
Lab 3 – Distance Lab	Home	field	field	home
Lab 4 – Control Lab	Home	home	home	home
Lab 5 – Distance Lab	Field	home	home	field
Lab 6 – Distance Lab	Home	field	home	field

(shaded) = Communication restricted to electronic means only
(unshaded) = No restrictions on communication

4. Assessments

Assessments of the role of distance engineering in student project work in CE1030 include assessments of group and student performance, consideration of the role of group dynamics, and also assessments of the perceptions of the students, teaching assistants, and peer learning assistants. Due to the nature of the experimental model and the limited number of students enrolled in the course, formal statistical analyses are not completed and this assessment is limited to a qualitative review for the purposes of this paper.

Group and student performance The primary information used for analysis of performance included group deliverables, presentations, and individual student quizzes, and indicated by the grades received. Surprisingly, for the two laboratories in which one of the two teams was working in a distance environment (Labs 3 and 5), the team with distance constraints received higher grades than the team that was allowed face-to-face communication. For example, in Laboratory 3, Team B received higher grades than Team A, even though Team B had to overcome the distance constraints while Team A could communicate face-to-face. Subsequent trends for Labs 4 and 5 reveal that Team B's grades decrease, while Team A's grades increase. For Laboratory 5, the distance lab in which Team A had to overcome distance constraints, Team A's grades were higher than Team B's grades.

Role of group dynamics To better understand these trends, the implications of individual learning styles and group dynamics were considered. Many investigators have found that students have unique personalities and learning styles that influence their learning in particular situations. [5 10] Type indicators provide a methodical approach for assessing the role of these personality and learning styles in student project work. For this investigation, the Gordon's Cognitive Style Typology (initially developed by Gordon and Morse in 1969[1]), and the Myers-Briggs Type Indicator [4] were applied. Both of these indicators are standardized surveys that allow inferences to be made about personality type and learning style. For the purposes of this paper, some interpretations developed from analysis of the Myers-Briggs Type Indicator® (MBTI) results are included. Additional information regarding the MBTI can be found at can be found at http://www.cpp-db.com (the website of Consulting Psychologists Press, Inc.) and also in a host of references. In this paper, some observations are summarized which present one interpretation of MBTI results as related to the groups listed in Table 1, and a more detailed description of the results from the MBTI analysis is available at http://cee.wpi.edu/CE1030. It is noted that the interpretations presented in this paper are considered to be preliminary since a full analysis of MBTI results would require extensive analyses. However, some observations of the characteristics of the groups may provide insight into the performance results described above.

First, the MBTI analyses revealed that the characteristics of the members of Team A were quite heterogeneous, even when Groups A1 and A2 were each considered separately. However, the MBTI surveys for Group A1 did indicate that this group's members all had a uniform tendency towards a logical objective approach for decision making. While this group's heterogeneous nature could lead to problems in group interactions and decision-making, it could also prove to be an asset in developing a complete solution if any such problems can be overcome. Thus, the poorer performance of Team A (the control team) in Laboratory 3 may have resulted from communication problems and a lack of leadership due to this heterogeneity. However, a concerted effort to work through these problems (combined with stronger leadership provided by Group A1) could explain this team's subsequent improvements and strong performance in Laboratory 5, when electronic communications were used for communication between Team A2 (the home team) and Team A1 (the field team).

Second, while MBTI results indicated that Groups A1 and A2 were heterogeneous, the MBTI results indicated that Groups B1 and B2 were more uniform in nature. For example, for Group B1, MBTI surveys indicated that the majority of the members tend to "draw their energy from within" or act individually, and also tended to be rather spontaneous and flexible. These traits may indicate a group that could have trouble interacting and working in an organized fashion towards a solution. For Group B2, MBTI results indicated that members tend to "look toward the possibilities" or think creatively when approaching problems, and most members emphasized thinking (logic) in their decision making. As a result, this group may be expected to perform quite well with the class's innovative use of technology. The strong performance of Team B in Laboratory 3 may be a result of a motivated group (Group B2) that provided strong leadership and flourished in the DEE environment. The spontaneous and independent characteristics of Group B1 may have been inconsequential when Group B1 served as the field team in Laboratory 3. However, the same characteristics may have led to a lack of leadership when they served as the home team in Laboratory 5. This lack of leadership, combined with a possible lack of motivation of Group B2, may explain Team B's reduced grade in this laboratory. In all cases, the motivation and leadership success in a distance engineering environment were essential ingredients for project success.

Specific perceptions - student journals - Student journals were used to gain more insight into the individual perceptions of the students. The journal entries further substantiate the assessments interpreted from student group performance and MBTI surveys, and also show that group dynamics has an important effect on student performance on projects with a distance engineering component. Specific examples may be found in the previously cited website.

General perceptions - To obtain an objective characterization of the students' general perceptions, interviews were conducted at the end of the course, and surveys were administered at the beginning and completion of the course. Students were asked a variety of questions pertaining to their background and perceptions regarding computers, collaborative learning and group work, and distance communications. The surveys indicated that the students gained an appreciation for the importance of working effectively in teams and they indicated that they prefer the cooperative learning approach to the traditional lecture approach. Many noted that working with the communication tools under stringent time constraints was difficult and frustrating at times and many even developed an increased apprehension of their abilities for effectively using the computer. Students did seem to prefer not to use remote communication technologies, and responses were mixed regarding the present capabilities of these technologies. However, they still felt that the technologies were valuable for data exchange and they expect these technologies are become extremely important to master in engineering projects. In general, students indicated that they found the course to be a positive experience that increased their enthusiasm for civil and environmental engineering.

5. Conclusion

The use of distance engineering in CE 1030 provides a foundation for future developments in this area, and also demonstrates some important points to consider when incorporating distance engineering into undergraduate courses. First, extensive preparation is necessary to ensure that the software and hardware is operable such that it can be utilized effectively by the students. In addition, the course content must be carefully planned to ensure that students can learn the use of the technologies in a short-time frame. Second, the assessments described above demonstrate the importance of student interactions and group dynamics in student project work. Due to some of the features of distance engineering projects, the results suggest that group dynamics can be especially important to consider for these projects. Learning styles and personality type indicators provide insight into these dynamics and associated group performance. It is recommended that the potential implications of these interactions be considered when developing a course with distance engineering components. For example, for a project that involves remote communication, a successful project clearly depends on effective communication between the home and field teams. Effective communication requires some level of expertise in the use of the communication tools and software. If no members of a team have this expertise, and no members have the motivation to gain this expertise, communication will likely become a significant barrier - especially when the team is faced with stringent time constraints. We believe that careful consideration of these issues can help when introducing technology into undergraduate projects.

In summary, since an increasing number of projects require the integration of engineering services from remote locations, it is extremely important for undergraduates to be introduced to these technologies in their undergraduate program. The technologies can also provide opportunities to develop projects that integrate academia with the professional community, integrate field experiences into the educational process, and expand the student's range of experience beyond the boundaries of the university. Since this investigation involved only four groups participating in a single course, additional research is recommended to fully understand the relationships between remote communications and student performance in group projects.

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