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The Development Process towards achieving a Framework for Incorporating Virtual Teams into Projects in Engineering Courses

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As the digital age advances, it is perhaps not surprising that the growth rate for students corresponding electronically is increasing greatly. This includes students who are working on projects in their classes. However, team dynamics is always a significant issue for students when working on teams and continues to be an even bigger source of concern for them once they graduate and go out into the work force.

In this paper, the authors talk about the process of initializing a study to study the functioning of partially distributed teams and developing a framework for incorporating projects into engineering courses where students are required to work on projects virtually (with student project members located at two or more universities) and hence be better prepared for 'real world work scenarios,' when they graduate and go into industry. This course curriculum design and research will include mapping engineering management courses between the Engineering Management Departments at Texas Tech University and California State University, Northridge and creating distributed project teams, by virtue of which the students would be compelled to work both traditionally (intra-university) and virtually (inter-university) and learn about managing partially distributed teams. Pedagogically, the researchers/professors will also be compiling information and lessons learned in coordination of this inter-university educational endeavor.

Keywords: Team Dynamics, Virtual Teams, Distributed Project Teams, Partially Distributed Teams

Introduction

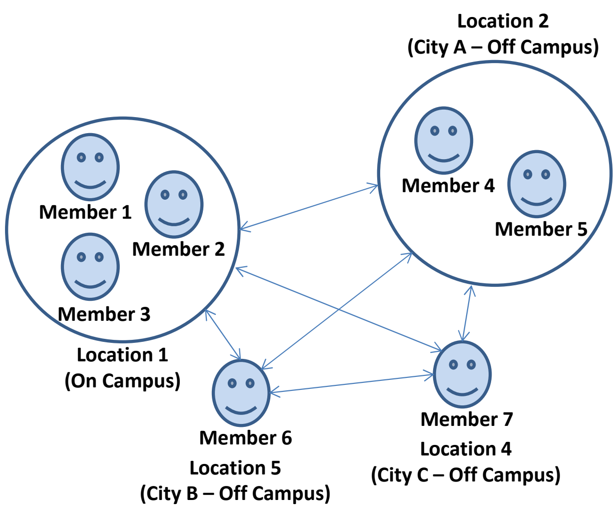
As the digital age advances, the growth rate for student enrollment in online courses has recently outpaced that of face-to-face courses[1]. Along with advances in technology, this trend is also being observed due to large universities embracing the model of online education to be able to serve larger student populations using the limited resources they have. Online classes include students who are distributed geographically in different parts of the country or world but also include partially distributed teams, which is when part of the team is in one location and the rest of the team is at another location. For example, if there was a team of six members, a partially distributed team would be when three of the team members were located in California and the other three were located in Texas. In this paper, the authors are going to be initializing a study on understanding the functioning of a partially distributed team.

Unlike traditional, correspondence-style programs, today's online courses often include settings where students must interact during the semester to complete the course requirements. Further, many online courses include both students who are located on campus and other students who are geographically-dispersed[14] . In a team project in such courses, this can lead to an unbalanced or hybrid situation in which a portion of the team is co-located, and thus can meet face-to-face, while other team members are geographically isolated and can interact only virtuality with the rest of the team; this is also referred to as a "partially-distributed team" configuration. Although a significant amount of work has focused on effective educational practices for online education and face-to-face education, respectively, fewer studies have specifically focused on the interactions between on campus and distance students, particularly in a partially-distributed team setting, and the impacts of these interactions on student learning outcomes. Thus, in this paper, the authors would like to talk about the initial efforts between two universities to set up courses by virtue of which students would be enabled to work on projects virtually; thus preparing them better to join the workforce.

Literature Review

A partially-distributed team is considered a team where at least two team members are co-located, while at least two team members are not co-located. That is, there is at least one subgroup consisting of co-located members, while other team members are geographically dispersed from this subgroup (although they may be co-located with each other). For members and subgroups that are geographically separated, there is a required reliance on electronic means for communication[15].

Figure 1, shown below, represents one of the types of partially distributed team configuration that could occur.



Distance education or extended learning programs may have students from all over the world. In order to be able to engage all the students and give them exposure to how projects work in the real world, once they graduate, many professors get the students involved on group projects and expect the workload to be distributed evenly (Ocker & Huang, 2011). Professors choose to do this because in most high tech/engineering jobs today, the teams are partially or completely virtual teams, so as to have an access to an expanded pool of workers at the best possible salaries[11] . However, in comparison to other disciplines in US higher education, engineering students are on the low end of the spectrum of having experience of interfacing with global counterparts, with only approximately 2% of engineering students having such experience[20] . Additionally, several universities are increasingly focusing on providing an international experience for their engineering students, in order to provide them with an informed awareness of the peoples, cultures, languages and nations of the world[7] . Also, working with global counterparts not only increases awareness among the students, but also leads to a sense of self-confidence due to being able to work with people from so many different backgrounds; thus becoming a more effective leader[6] . It was due to this realization as well as the fact that partially distributed teams are supposed to be at a disadvantage compared with face-to face teams, due to expected difficulties in team collaborations, that the authors of this paper decided to develop a framework to address this problem, so engineering students can be better prepared to work in partially distributed teams, many of which are distributed globally.

Collaboration between team members is regarded as a dominant determinant in virtual team's performance. Failure to effectively develop and manage collaboration is believed to preclude the team from achieving high quality results and otherwise diminish the team effectiveness. In fact, Holton[9] believes "the ability to work collaboratively is recognized as a core competency of a learning organization. By the same token, Anderson et al[2] stated that ensuring good communication between all members of the virtual team is one of the main challenges surrounding virtual team performance. Moreover, Jarvenpaa and Leidner[10] pointed out that regular and timely communication will establish a strong platform toward building trust and commitment between team members. However, it is truly a challenge to be able to communicate regularly and timely when working on virtual teams due to several factors such as cultural, social and time differences. Communication and collaboration are believed to positively impact the social aspect of the virtual teams by improving the team performance as well as satisfaction levels between the members[12]. Furthermore, collaboration in a virtual environment poses a number of unique difficulties, as Michael She[19] asserted, such as "feedback latency, reduced accuracy in comprehension, and technical challenges that impede effective communication." Despite the inherent difficulties involved in virtual team collaboration, there are several opportunities to improve the flow of communication, such as a predictable pattern of communication, e.g., daily conference calls, which generate a platform for exchange of ideas and brainstorming between the members and strengthen the element of trust among team members[19].

Additionally, collaboration on partially distributed virtual teams faces an additional challenge as it is likely to be divided into two separated forms: 1) collaboration between co-located team members within one sub-group and 2) communication between the dispersed sub-groups. Co-located team members build trust and cohesion amongst each other primarily through face-to-face interactions, which create an internal bond known as "in group dynamics," while subconsciously labelling the other members or subgroups as external components to the team[18]. Thus, in partially-distributed settings, team members are expected to favor the members who are closer in physical proximity to themselves[18]. This "Us vs. Them" dynamic could be particularly disastrous to team functioning in the event of a single, dominant (larger) co-located subgroup, with several smaller subgroups.

Studies suggest that the lack of trust formed with other subgroups in partially-distributed teams stems not only from communication, but also from the lack of perceived participation (collaboration) from other subgroups. It appears that co-located members believe that they carry most of the load because it is harder to physically see and assess the progress made from a distance by other members and subgroups[18]. Nonparticipation is easier to notice in smaller teams. Further, as the quantity of subgroups increases, this dynamic should further intensify as the largest subgroup increasingly gains a dominant position in the partially-distributed team. The co-located members' collaboration at this site should become stronger because they perceive themselves to be the primary link that holds all subgroups together[3].

Earlier studies that have focused on degree of virtuality described the condition of virtuality as "discontinuities" that differentiate the real-time actions of teams by the following: "temporal, spatial, work group, organizational, relationship and cultural" [21]. Meanwhile, Cohen & Gibson[5] , defined virtuality as a reliance on technology to communicate, rather than defining it as virtual teams' use of technology to accomplish project related tasks. George[8] further defined virtuality as a measure of degree instead of a condition. That is, rather than measuring each "discontinuity" as a dichotomy and stating that the virtuality exists or it does not, George[8] suggested that each "discontinuity" (dimension of virtuality) can be measured on a continuous scale.

Therefore, degree of virtuality can be measured as a continuum ranging from 0%, for completely face-to-face teams, to 100%, for a completely virtual team with no co-located members[21].. Schweitzer & Duxbury[21] proposed that degree of virtuality should be measured based on three dimensions: "proportion of team work time that the team members spend working apart [work virtuality], the proportion of team members who work virtually [member virtuality], and the degree of separation [distance virtuality]." In analytical terms, degree of virtuality can be measured by calculating the work virtuality, member virtuality, and distance virtuality. Work virtuality is calculated by the total hours members spent working apart divided by the total number of working hours, multiplied by 100. Member virtuality is calculated by the total number of subgroups divided by the total number of members, multiplied by 100. Distance virtuality is dependent on what the team considers as the main site for the partially-distributed team. Schweitzer & Duxbury[21] state that a predetermined, set quantity must first be assigned on a scale and the members who must travel the farthest to get to the main site would receive the highest measure on the scale[21]. Measuring degree of virtuality as a measure of work, member, and distance virtuality will assist in understanding the true effects of factors that influence partially-distributed teams. While numerous studies have identified contributors to the outcomes of virtual teams in general, the impact of the degree of virtuality specifically remains an open area with little previous research which is what the authors are going to focus on building a framework to address.

Research Objectives

The primary goal of this research study is to form a framework which will enable the incorporation of experiencing working on virtual teams in engineering. In order to do this the authors have to understand the impact of changes in degree of virtuality on student engineering team learning outcomes. For this purpose, there will be five basic hypotheses to be tested as part of the research plan. In Hypothesis 1, the authors have referred to the U-shaped relationship, which is when the relationship initially starts out well and then hits a low, after which over a period of time, it bounces back. They hypothesis are as listed below:

H1: Degree of virtuality (partial distribution) has a U-shaped relationship with collaboration

H2: Collaboration in partially-distributed teams is positively related to team productivity

H3: Collaboration in partially-distributed teams is positively related to team satisfaction

H4: Leadership moderates the relationship between degree of virtuality and collaboration in partially-distributed teams

H5: Co-located team members in partially-distributed teams assign higher collaboration ratings to one another than they do to geographically-dispersed members

Although the authors will start this research program in an engineering educational setting, as partially-distributed teams are common in work settings, it is expected that project findings can also be applied to enhance the effectiveness of partially-distributed teams in other fields and work settings as well. Furthermore, as recommendations and guidelines are developed for educational settings as a result of this study, their use will enhance engineering faculty's ability to prepare students to function on partially-distributed teams when the students graduate and go out into the work force.

Research Approach

To achieve the project objectives, the authors will focus on partially-distributed teams composed of students at Texas Tech University (TTU) and at California State University, Northridge (CSUN) who are enrolled in undergraduate and graduate engineering courses which have team projects.

In particular, this research study will be carried out using a quasi-experimental design, in which the team distribution will be varied systematically across participating courses during the three-year project, starting in Fall 2015 and the corresponding effects on degree of virtuality and team learning outcomes will be studied. In many of the configurations, on and off campus students at TTU will be working in collaboration with on and off campus students at CSUN. The major tasks required to reach the research objectives of this project are depicted in Figure 2 and Table 1 and then described in the text below.

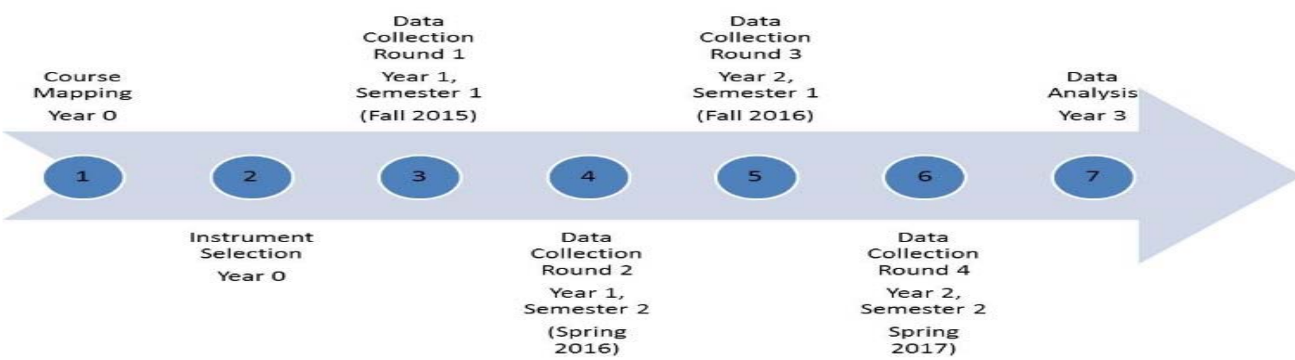


Figure 2. Time sequence of research tasks

Table 1. Descriptions of Research Tasks

Task	Timing	Name	Description

1	Year 0	Course Mapping	Determine which courses to pair for the quasi-experimental design from the undergraduate and graduate courses at the two universities involved in this study, at which the authors are faculty members
2	Year 0	Instrument Selection	Select the data collection instruments for the study.
3	Year 1, Semester 1	Data Collection Round 1	This round will use 100% face-to-face teams for on campus students and 100% virtual teams for off campus students at both campuses.
4	Year 1, Semester 2	Data Collection Round 2	This round will use 50%/50% composition of students from each campus. In a team of 6, 3 students will be from TTU and 3 students will be from CSUN
5	Year 2, Semester 1	Data Collection Round 3	This round will use a 33.3% composition from TTU (2 students in a team of 6) and 66.7% from CSUN (4 students in a team of 6), or vice-versa.
6	Year 2, Semester 2	Data Collection Round 4	This round will use a 16.7% composition from TTU (1 student in a team of 6) and 83.3% degree from CSUN, (5 students in a team of 6), or vice-versa.
7	Year 3	Data Analysis	Data analysis, conclusions and recommendations.

For the course mapping task, the authors of this paper, who are faculty members at the two universities involved, have carefully studied the undergraduate and graduate courses that they teach to determine which courses are most compatible for the purposes of a shared course project. It is from these mapped (paired) classes, shown in Table 2, that the student teams will be formed for this research project.

Due to constraints in the course timing imposed by graduation requirements, i.e., each school must offer courses at a certain frequency in order for students to graduate on time, it was not generally possible to match up the two courses with the closest catalog equivalence. Instead, complementary courses were selected that offer a unique cross-disciplinary learning experience for the students.

Table 2. Courses Pairing for Texas Tech University and California State University, Northridge

Semester	**California State University, Northridge**	**Texas Tech University**
Fall 2015	MSE 602 Engineering Innovation Management	IE 5321 Decision Theory
Fall 2015	MSE 607B Systems Engineering	IE 5346 Total Quality Systems

Spring 2016	MSE 304 Engineering Economy	IE 2311 Engineering Economic Analysis
Spring 2016	MSE 617 Seminar in Quality Management	IE 5323 The Engineering Management Environment
Fall 2016	MSE 602 Engineering Innovation Management	IE 5325 Productivity and Performance Improvement in Organizations
Fall 2016	MSE 607B Systems Engineering	IE 5324 Advanced Economics of Systems
Spring 2017	MSE 402 Project Management	IE 5320 Systems Theory
Spring 2017	MSE 507 Lean Manufacturing	IE 5346 Total Quality Systems

As part of the instrument selection process, five primary measures will be used as summarized in Table 3, shown below

Table 3. Summary of Instrument Selection Process

Name	**Type**	**Instrument**
Degree of Virtuality (Partial-Distribution)	Independent Variable	Degree of Virtuality Dimensions
Collaboration	Mediator Variable	CATME
Productivity	Dependent Variable	Instructor Rubric
Satisfaction	Dependent Variable	General Satisfaction scale from the Team Diagnostic Survey
Leadership	Moderator Variable	Extent and Focus of Team Leader Coaching scale from the Team Diagnostic Survey

First, degree of virtuality will be measured as a formative index, using the three dimensions proposed by Schweitzer & Duxbury (2010): "proportion of team work time that the team members spend working apart [work virtuality], the proportion of team members who work virtually [member virtuality], and the degree of separation [distance virtuality]." The degree of virtuality resulting from the different partially-distributed team configurations will be the primary independent variable for the study. However, as Schweitzer & Duxbury's (2010) research also showed only small correlations between the three dimensions, it is reasonable to assume that the dimensions may have differential effects, i.e., some dimensions may have stronger effects than others. Thus, in secondary analyses, each dimension of degree of virtuality will be analyzed as an independent variable against each of the three dependent variables. The distance virtuality and member virtuality can be calculated by the instructors, as these dimensions are based on team member location, which will be known. Work virtuality must be determined through surveys of team members as only the team members will know the full amount of time they spent working, both online and offline, on the project. However, as a supplement to this measure, the instructors will also review online team work records captured through Blackboard or other online collaboration software used by the students. The overall degree of virtuality measure (formative index), as well as the distance virtuality and member virtuality will exist at the team-level only. The work virtuality will exist both at the individual-level (raw data) and team-level (aggregate data).

Collaboration will be measured using the Comprehensive Assessment of Team Member Effectiveness (CATME) Tool[13,16] , which captures a team member's ratings of each of his or her other members on the collaboration dimensions of contributing to the team's work, interacting with teammates, keeping the team on track, expecting quality and having relevant knowledge, skills, and abilities (KSAs). The CATME is freely available online (https://engineering.purdue.edu/CATME). A team member's average rating of his or her other team members will be used to represent his or her perception of team collaboration (individual-level data). The average collaboration rating for a given team will be used to represent that team's collaboration level (team-level data)

The learning outcomes of the student teams will be assessed using two team outcome measures which were proposed by Campion, Medsker and Higgs[4] : productivity and satisfaction. Satisfaction is entirely perception-based, while productivity has tangible factors that can be used for its measure, although perception-based aspects can be incorporated as well. In an educational setting, both measures are types of learning outcomes as they represent standards tied to course learning objectives, against which student performance can be assessed, and for which the instructor has pre-defined expectations as to minimal acceptable student performance.

The measure of productivity will assess the extent to which each of the project requirements have been met by the team. For this purpose, the PIs and co-PIs will design a standard rubric that the course instructor will use to measure productivity when evaluating the team final report and presentation. It should also be noted that both instructors will be completing the rubric for each of the paired course projects. Thus, the interrater reliability of each instructor pair can also be measured and adjustments made, if needed, to the initial rubric to ensure measure consistency. The productivity rating will be at the team-level only.

Satisfaction will be measured using the General Satisfaction scale from the Team Diagnostic Survey[22]. Meanwhile, leadership will be measured through the Extent and Focus of Team Leader Coaching scale from the Team Diagnostic Survey. To ensure that all team members have a leader to rate, teams will be required to select a leader as part of their team projects.

To facilitate data collection, work virtuality, team satisfaction, and leadership will be measured using a single team survey. The instructor rubric and team survey will be configured to include open ended questions asking the respondent to describe the strengths and opportunities for improvement for the team as well any other comments the respondent has about the team. This will allow the collection of additional, qualitative data for tertiary analyses.

The survey development process will be iterative and will be sent out to peers for feedback which will be incorporated into subsequent versions before being used to collect the data.

As part of the data analysis, the authors will continuously screen the collected data for errors and conduct preliminary data analyses. However, the bulk of the analyses will occur at the end of the study, once all study data has been collected. Table 4 summarizes the analyses to test the study hypotheses. Regression will be the primary method used to analyze the data and the type of regression will be selected based on the nature of the hypothesis (i.e., whether the relationship between the independent variable and dependent variable is hypothesized to be linear or non-linear). Remedial measures such as variable transformations to address non-normal data or missing data replacement methods will be employed as needed based on the characteristics of the data set. A significant regression relationship with a well-fitting model will indicate support for the given research hypothesis. A model that does not fit well will indicate a lack of support for the hypothesis and posthoc analyses will be employed to developed hypotheses for future research.

Following the quantitative analysis, the research team will also code the qualitative data on team strengths and opportunities for improvement, as well other comments about the teams, collected through the open ended questions in the instructor rubric and work virtuality survey (tertiary data analyses). The themes identified through this analysis will be used to further interpret the quantitative analysis results. The research team will use the findings of both the quantitative and qualitative analyses to develop recommendations, guidelines and support material for undergraduate and graduate engineering courses including partially-distributed teams.

This part of the research project will also include making recommendations for future studies that can be done based on the findings of this research in order to broaden the impact of this study. While the majority of these recommendations will depend on the actual findings of the research, two areas for future research that have already been identified are getting additional schools with industrial engineering or engineering management programs involved in future studies, as well as ultimately expanding the research to include other disciplines of engineering.

Table 4. Tests of Study Hypotheses

Hypothesis	**Primary Analysis**	**Secondary Analysis**
H1: Degree of virtuality (partial distribution) has a U-shaped relationship with collaboration	Collaboration regressed on degree of virtuality (composite measure as a formative index) using a non-linear regression Team-level data	Collaboration regressed on the three dimensions of degree of virtuality using a non-linear regression Team-level data
H2: Collaboration in partially-distributed teams is positively related to team productivity	Productivity regressed on collaboration using a linear regression Team-level data	None

H3: Collaboration in partially-distributed teams is positively related to team satisfaction	Satisfaction regressed on collaboration using a linear regression Team-level data	None
H4: Leadership moderates the relationship between degree of virtuality and collaboration in partially-distributed teams	Collaboration regressed on degree of virtuality (composite measure as a formative index) using a non-linear regression, with leadership included as a moderator variable Team-level data	Collaboration regressed on the three dimensions of degree of virtuality using a non-linear regression, with leadership included as a moderator variable Team-level data
H5: Co-located team members in partially-distributed teams assign higher collaboration ratings to one another than they do to geographically-dispersed members	Paired t-test of team member ratings of co-located vs. non-co-located members Individual-level data for co-located team members only	None

Summary and Expected Findings

The authors expect that the findings of this study will advance the state of knowledge by studying how changes in partially-distributed team configuration, as measured through the degree of virtuality, impact student engineering team collaboration processes and learning outcomes. A quasi-experimental field study of partially-distributed teams composed of undergraduate and graduate engineering students at Texas Tech University and California State University, Northridge.

The authors expect the distance and the frequency of communication to be major factors that could impact student learning outcomes when the students are working on projects which involve virtual teams.

Although this research is focused on engineering students, it is expected to have broad industry impacts as well, as industry projects also often use partially-distributed or even fully-distributed teams. Thus the research project will provide better "real world" training for both students who participate in the paired course projects and future students who use the curricular materials developed.

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