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# Facilitating Team Processes in Virtual Team Projects Through a Web-Based Collaboration Tool and Instructional Scaffolds

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## Abstract

Because of the global nature of the workforce, teams are becoming increasingly distributed and virtual. These teams typically use a variety of web-based information and communication technologies (ICT) to collaborate from remote locations. Although there has been increased emphasis on developing teamwork skills and abilities in engineering students through the use of collaborative projects, our understanding of successful strategies to enhance learning outcomes in these distributed settings is lacking. There has also been little emphasis on key processes for virtual collaboration such as development of shared team cognition, clarifying goals and expectations, using communication and collaboration technologies and communicating with diverse project stakeholders (internal and external customers). Instructional and procedural scaffolds embedded with information and communication technologies have great potential as suitable mediums for enhancing these processes. They can also support the development of critical teamwork skills. This paper describes and evaluates an evidence-based intervention aimed at supporting team processes in distributed student teams. The platform and associated activities and tools were focused on developing key team processes identified in the team effectiveness literature from industrial and organizational psychology.



**Keywords**
Virtual teams, team effectiveness, information and communication technologies, engineering education, collaborative learning


## Introduction

Current and future trends are forcing engineering schools to reconsider the role of their future graduates in the workforce along with the education needed for graduates to fit in that role. Most companies in this new global work environment use distributed teams as an integral part of their business processes and activities. These teams often rely on information and communication technologies (ICT) to collaborate from remote locations.

Realizing these needs, leading engineering scholars and educators increasingly recognize teamwork and communication skills as critical competencies required for successful professional practice[1,2]. In response to these trends, many engineering courses have being designed to incorporate a team element. Examples include Columbia University's Gateway design course[3], Massachusetts Institute of Technology's undergraduate design course and its "New Products Program"[4] and Rowan University's Engineering Clinics Program[5].

Team projects in current work environments are largely supported with ICT with often minimal direct personal contact among team members. However, most existing engineering programs don't fully incorporate the opportunity for students to master technology-supported teamwork as a core element of the curriculum[6,7]. Team projects are often incorporated into courses with little consideration of cognitive and behavioral processes such as team building, clarifying goals and expectations, using communication and collaboration technologies, consensus building and conflict resolution[7,8]. A recent review of research on engineering student teams suggests that our understanding of how best to cultivate and assess collaborative learning outcomes in engineering students is largely underdeveloped[9]. Others have noted an opportunity to capitalize on much of the life-long learning that can occur through team dynamics and interaction[5]. This paper explores the use of web-based collaborative platform with embedded instructional scaffolds aimed at supporting team processes. The platform is informed by foundational knowledge on team effectiveness from the industrial and organization psychology field and by social-constructivist learning theory.

## Theoretical Foundation

Working in teams requires that students learn how to interact with each other, share and process information in a collaborative learning environment. There is vast evidence indicating the benefits of collaborative learning grounded in social-constructivist learning theory[10]. Social constructivist learning theory suggests that learning is largely a social process and that deep understanding develops through collaboration and engagement with others[11,12]. Collaborative work largely reflects the actual environment in engineering-intensive organizations creating team-based communities of practice to solve engineering problems. By carefully constructing guidance to learners, instructional designers can create and validate how interactions should be structured to ensure that the degree of challenge to groups and individuals is at the appropriate level.

The theoretical foundation for this study also emerges from theories outlining the importance of scaffolds suggesting that learning can be best facilitated by scaffolded instruction that allows for collaboration and interaction in authentic environments using state of the art tools and processes[8]. Scaffolds are defined as instructional supports in the guise of feedback, directions or guided instructional materials and tools embedded in instructional activities. Scaffolding has been identified as a powerful approach to support learning in complex collaborative environments[8,13]. Through scaffolding, learners can accomplish complex tasks that otherwise they could not successfully complete on their own[10]. Providing this expert support for learners is much more effective for transferring knowledge than unsupported instruction[8].

The scaffolding activities for the proposed project described will follow the Quintana et al.[14] model by focusing primarily on the following two aspects:

- Investigating and characterizing the cognitive tasks, social interactions, tools and artifacts that constitute the scientific practices in the discipline of teams, in particular, engineering teams. Practice in these disciplines will involve construction of knowledge through participation in team-related activities within the context of a project using ICT.
- Identifying the aspects of the team and project-based activities that are more likely to negatively affect learning and performance, and providing support to overcome those obstacles (building commitment without direct face-to-face contact, clarifying goals, supporting coordination, solving conflict, etc.).

The structure and goals of the instructional scaffolds were evidence-based and built upon our foundational knowledge of team processes and team effectiveness[15-17]. The specific learning goals for the scaffolds can be mapped to a team process framework proposed by Marks et al. [15] that has been accepted in subsequent literature as one of the most solid model for understanding and studying the processes of work teams[16,17]. Through this framework, team activities are studied as a series of related Input-Process-Outcome cycles or "episodes" composed of action and transition processes that accrue performance while receiving feedback and managing interpersonal relationships[15]. Transition processes relate to preparation for work accomplishment whereas action process involves the actual execution of the task. Definitions of the types of action and transition processes from the team literature and the associated scaffolds used as part of the intervention evaluated in this study are presented in table 1.

Table 1
Instructional Scaffolds and Associated Teamwork Processes (adapted from Marks et al.[15])

| | **Process Dimensions** | **Process Definition** | **Process Scaffolds (cognitive tasks, social interactions, tools and artifacts)** |
|---|---|---|---|
| TRANSITION PROCESSES | Mission analysis, formulation and planning | Interpretation and evaluation of the team's mission, including identification of its main tasks, the operative environmental conditions and resources available | Team Charter (artifact)<br>Project plan (artifact)<br>Shared mental model and team identity building (cognitive task) |
| | Goal specification | Identification and prioritization of goals and sub goals for mission accomplishment | Definition of team Roles and Responsibilities under project plan (artifact) |
| | Strategy formulation | Development of alternative courses of action for mission accomplishment | Communication strategy (artifact)<br>Project plan (artifact) |
| ACTION PROCESSES | Monitoring progress toward goals | Tracking task and progress toward mission accomplishment, interpreting system information in terms of what needs to be accomplished for goal attainment, and transmitting progress to team members | Task tracking (tool)<br>Feedback through discussion boards (tool)<br>Task status updates (tool)<br>Team mid-project evaluation (artifact) |
| | Systems monitoring | (1) internal systems monitoring (tracking personnel, equipment, and information), and (2) environmental monitoring (tracking the team's environmental conditions) | Document repository (tool)<br>Team activity tracking (tool)<br>Information exchange indicator (tool)<br>Stakeholder/customer feedback (tool)<br>Project plan (artifact) |
| | Team monitoring and backup behavior | Assisting team members to perform their tasks. Assistance may occur by (1) providing a teammate feedback/coaching, (2) helping a teammate in carrying out actions, or (3) assuming and completing a task for a teammate | Discussion boards (tool)<br>Mid project peer evaluation (artifact)<br>Project plan (artifact) |
| | Coordination | Executing and orchestrating the sequence and timing of interdependent actions | Project plan evaluation and adjustment (artifact and cognitive task) |

## Preliminary data

The research team collected some initial data that provides preliminary evidence of success for the proposed intervention. The first set of data provides information on student experience using some elements of the proposed scaffold to complete a team project in an existing course. These data include students' self-reports regarding their team experience; comparing it to that of the best team experience they had in the past. Students assessed their teams in terms of efficiency, quality and work excellence. Data was obtained from more than 100 students on their perception of the team project experience and over 65% of students rated their team as being superior or very superior in terms of the qualities indicated above.

The second set of data is mostly qualitative and largely anecdotal, including comments from students regarding the overall experience in the team project collected through anonymous feedback. The vast majority of the comments received by the PI in the past have highlighted the team project as an authentic learning experience in teams. The comments supported the project and its benefits and also provided suggestions for improvement, some of which will be incorporated to build the scaffolded modules for the proposed project. One student now working in industry noted:

> *"I learned a lot about teams, and realized that my team in my current company has many issues we could improve upon. I have mentioned the project to my team lead and we will work on implementing some of the things I learned in your class."* (*Student, Spring 2000)*

Additional comments collected from students over the past semesters:

> *"I felt that the final project was a great learning tool. I would allow a longer team building duration and provide guided team building activities. I feel that the final project was the more useful experience I had lately." (Student, Spring 2009).*

> *"I want to thank you for what I have learned from the group project. It was a pleasure to work with all my team members. The main challenge was how to work in newly formed team, especially in our case where many of us are from different countries. But we did a good job. It was really good learning experience for me. One more good thing is that my confidence about writing a technical report is increased now." (Student, Fall 2008)*

Based on this preliminary evidence, we designed an empirical study to formally evaluate the impact of the proposed intervention at the undergraduate and graduate level in two engineering courses. Next, we describe the research study and the results obtained during the first round of data collection.

**Research Methodology**

A quasi-experimental research study was conducted to address the following research question: *What is the impact of the proposed collaborative tool and the associated instructional scaffolding on teamwork competencies?*

An intervention was designed consisting of web-based information and communication technology (ICT) tool to support virtual collaboration with embedded instructional scaffolds designed to support team processes in the context of a group project in two engineering courses. The web-based tool includes elements such as team profile, team charter, Gantt chart, message board, automatic reminders, project repository, task progress tracking, etc. The scaffolds were developed during Spring 2014 and baseline data was collected during that same period from 2 courses in the Department of Engineering Management at Old Dominion University. Both courses are offered through hybrid delivery with some students present on campus and others attending live via web-based technology.

The intervention consisted of a web-based collaboration tool and instructional scaffolds embedded into existing courses. The implementation of the web-based tool and associated scaffolds required some course-specific customization because the nature of the class project, its context and complexity varied between the two courses. The first course is required for all undergraduate engineering students and the team project was completed within a 6-week period. It accounted for 45% of the grade. In the graduate level course, the project was completed in 9 weeks and it accounted for 55% of the grade.

The analysis was aimed at evaluating whether the intervention had a significant impact on teamwork skills. For that purpose we compared teamwork skills of the treatment group (team project using the collaboration tool and scaffolds) and control groups (team project with no intervention). We used prior teamwork experience in student teams and work teams as a control variable to account for possible pre-existing differences on teamwork skills.

The Teamwork KSAs[18,19] instrument was used to measure teamwork competencies. This instrument is a widely accepted quantitative assessment of team competencies[20]. The specific competencies that will be evaluated in this paper are self-management skills and interpersonal skills.

**Variables**
***Dependent variables***
The response variables measured in this study were teamwork knowledge, skills and abilities (KSAs). This variable was further broken down into two subscales, self-management KSAs and interpersonal KSAs.
*Self-management KSA* measures the ability to set goals, manage their performance and plan and coordinate their work.
*Interpersonal KSAs* measures the ability to set collaborative problem solving, communication and conflict resolution.

McClough and Rogelberg[20] found that the teamwork-KSA test successfully predicted individual team member behavior such that higher scores on the teamwork-KSA test were associated to greater individual effectiveness within teams. Their research provided evidence of the validity of the teamwork KSA measurement to assess teamwork competencies.

Table 1 further describes the elements included under the two categories of self-management and interpersonal skills.

Table 1. Description of Teamwork KSAs (Adapted from Stevens and Campion[18,19])

| **Self-management KSAs** |
|---|
| 1. Goal Setting and Performance Management KSAs. Assessment of competencies related to establishing specific, challenging, and accepted team goals; and monitoring, evaluating, and providing feedback on both overall team performance and individual team member performance. |
| 2. Planning and Task Coordination KSAs. Assessment of competencies related to coordinating and synchronizing activities, information, and tasks between team members, as well as aiding the team in establishing individual task and role assignments that ensure the proper balance of work- load between team members. |
| **Interpersonal KSAs** |
| 3. Conflict Resolution KSAs. Assessment of competencies related to recognizing types and sources of conflict; encouraging desirable conflict but discouraging undesirable conflict; and employing integrative (win-win) negotiation strategies rather than distributive (win-lose) strategies. |
| 4. Collaborative Problem Solving KSAs. Assessment of competencies related to identifying situations requiring participative group problem solving and using the proper degree of participation; and recognizing obstacles to collaborative group problem solving and implementing appropriate corrective actions. |
| 5. Communication KSAs. Assessment of competencies related to understanding effective communication networks and using decentralized networks where possible; recognizing open and supportive communi-cation methods; maximizing the consistency between nonverbal and verbal messages; recognizing and interpreting the nonverbal messages of others; and engaging in and understanding the importance of small talk and ritual greetings. |

***Covariates***

The analysis included two control variables to account for *prior student team experience* and *prior work team experience in industry*. Prior experience working in student teams was assessed using a 2-item scale including the following items: "I have prior experience working on team projects for classes" and "I have prior experience working on virtual team projects for classes". Prior team experience outside the classroom was assessed using a 3-item measure including : "I possess prior experience managing a project team in industry", "I have prior experience managing others" and "I have prior experience in work teams".

## Research hypotheses

H1: Students using he collaboration platform has a significant positive impact on student self-management skills
H2: The collaboration platform has a significant positive impact on student interpersonal skills

## Sample and Method

A quasi-experimental design was conducted to evaluate the impact of the collaboration platform (web-based technology and associated instructional scaffolds) on self-management and interpersonal skills. Participants were selected from two engineering writing-intensive courses, one undergraduate and one graduate level, over two consecutive semesters. The undergraduate course is Ethics in Engineering and the graduate course is a systems analysis class at the graduate

level. Both courses have a team project that accounts to approximately 50% of the total course grade.
Next, we describe the samples used to test the hypotheses.
Control group: baseline data collection using the same courses and projects as the treatment without using the collaboration platform
Undergraduate n=40, Graduate n=24
Treatment group: students enrolled in the same selected courses participating in the same type of projects without using the collaboration platform
Undergraduate n=33, Graduate n=40

We analyzed the impact of the intervention on teamwork KSA and the two subscales (self-managing skills and interpersonal skills). Prior psychometric studies of the teamwork KSA test suggest analyzing the overall and also the two subscales[20].

Analysis of Covariance (ANCOVA) was conducted to determine whether the intervention had an impact on teamwork skills. The undergraduate and graduate sample was analyzed separately. We conducted a t-test to determine whether there were any pre-existing differences in prior teamwork experience between treatment and control groups. Results from the test suggest that there are no significant differences between both groups as can bee seen in Table 2.

Table 2. Mean and Standard Deviation for the Covariates in the Control and Treatment Groups

| | **Control** | | **Treatment** | | |
|---|---|---|---|---|---|
| | **Mean** | **Std. Dev.** | **Mean** | **Std. Dev.** | **p-value** |
| **Team management experience** | 5.8623 | 1.08315 | 5.6346 | 1.2889 | 0.350 |
| **Student team experience** | 4.8587 | 1.51167 | 4.4623 | 1.3511 | 0.171 |

The ANCOVA analysis was aimed at evaluating the impact of the intervention on teamwork skills controlling for prior team experience. We found evidence of a significant impact of the intervention on self-managing skills for the graduate student sample ($F=4.651$, $p=0.036$, $R^2=0.284$), that is students in the treatment group did significantly better than those in the control group. Table 2 displays the estimated mean and standard deviation of self-managing skills for treatment and control groups.

Table 3. Estimated Mean and Standard Deviation for Self-Managing Skills

| | **Control** | **Treatment** |
|---|---|---|
| Mean | 6.65 | 7.58 |
| Std. Dev. | 0.337 | 0.261 |

The analysis of the graduate student sample displayed above indicates a mean difference of 0.93 in favor of the students that used the collaboration platform and scaffolds in their projects, representing a 9.3% difference in self-managing skills (mean difference= 0.93 in a scale of 0-10). One could argue that this is a sizable difference considering that the intervention only took place over one semester. The observed power of the analysis for the graduate sample was 0.6.

The intervention did not have a significant impact on student's self-management skills (p=.840) for the undergraduate student sample, but the power of the test was below 0.4 and the sample was smaller than for the graduate course. We are collecting additional data to conduct a more robust test of the hypotheses.

The last analysis in this section looked into the impact of the intervention on interpersonal skills. For the undergraduate student sample we did not find a significant impact of the intervention (F=3.228, p=0.082, power=0.415, $R^2$=.297). For the graduate student sample we did not detect a significant impact of the intervention (F=1.152, p=.228, power=.183, $R^2$=.068). We are in the process of collecting additional data so that we can re-evaluate the hypotheses with a larger sample size.

## Conclusions and Implications

Teamwork skills have been identified as critical competencies for engineering students [1,2] and numerous efforts have been ongoing over the years to develop these skills as part of the engineering curriculum. This study builds on these efforts by evaluating an intervention aimed at improving these skills in distributed student teams without face-to-face interaction. Teamwork skills are measured using a validated instrument that has been widely used for competency assessment. We provide a detailed description of an intervention that achieved a significant improvement of these critical abilities[19] in a selected sample of graduate students. Although no significant impact was not found in the undergraduate student sample, some potential explanations are the small sample size, missing data and the nature of the assignment in the undergraduate course. Additional data is being collected at the graduate and undergraduate level. The research team is currently analyzing interview data from participants to establish which specific elements of the collaboration tool and instructional scaffolds were more conducive to improving teamwork skills and team project management.

We found that ICT combined with the use of instructional scaffolds can be a suitable approach to support teamwork skill development. Scaffolds were purposely designed and implemented to support critical teamwork processes. The intervention targeted typical obstacles faced by virtual teams. Our preliminary results from a graduate student sample suggest that teamwork skills can be developed using instructional scaffolds embedded in existing courses. The proposed intervention is potentially scalable into any project-based course with a large team component. Future research could evaluate the impact of similar intervention in a larger sample of courses and disciplines. The proposed intervention could also be used as a key element in distance learning courses to support collaborative work while developing teamwork skills.

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