AC 2008-1896: MULTIDISCIPLINARY TEAM ASSESSMENT - A GENERALIZABLE INSTRUMENT

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Multidisciplinary Teamwork Assessment – A Generalizable Instrument

Abstract

During a semester long course entailing a multidisciplinary team project, students in computer engineering, electrical engineering, and mechanical engineering were required to work together to design, integrate, and test their project. Over the past four years, teamwork surveys for this project have been implemented and analyzed. Iterations of this survey have been revised to develop a shorter and non-project specific survey instrument that measures the effectiveness of teamwork. The purpose of a concise global teamwork survey is to allow assessment across projects in a consistent manner with established reliability and validity. Previous instruments with project specific items have been documented to have high reliability and strong predictive validity. During the fall, 2007 semester the revised brief teamwork survey was administered. The questions in this survey instrument contain wording such that the instrument could be applied to any project design experience and is not specific to what is being produced. This paper addresses the reliability and validity of the brief teamwork survey.

Introduction

Since the advent of the ABET's EC2000 requirements, engineering programs have increased their emphasis on multidisciplinary teamwork. Furthermore, ABET requires engineering programs to document that their graduates demonstrate "an ability to function on multi-disciplinary teams"[1]. Western New England College has a long history of incorporating engineering design into laboratory and course work. Additionally, interdisciplinary team efforts are initiated in the freshman year and continue for all four years.[2,3] This paper describes the assessment instrument used in a senior-level interdisciplinary course that students take during the fall semester. The design project brings together students from mechanical, electrical, and computer engineering in teams typically consisting of 4-5 members. During the most recent delivery of the course, due to a limited number of platforms and a larger senior class, the teams consisted of 7-8 students.

To achieve a good level of interdisciplinary teamwork, educators need to motivate students to truly engage in teamwork interaction as part of their multidisciplinary team. Previous researchers of the pedagogical aspects of teamwork have discussed the challenges engineering educators have in motivating students to interact effectively on team-based projects. They state that little in the professors' backgrounds or experiences provide a basis for knowing how students might show an ability to work effectively in multidisciplinary teams.[4] Many researchers have offered advice regarding this problem. It has been proposed that that team teaching one integrated course results in the best opportunity for interdisciplinary interactions[5]. In the course used to evaluate the assessment instrument described in this paper, the professors demonstrated cooperative multidisciplinary work by delivering an integrated course together.

Assessment of multidisciplinary teams is a related challenge facing engineering educators. Much of the early assessment efforts that occurred during the timeframe of the implementation of EC2000 "ranged from hastily constructed and poorly validated instruments to rigorously developed and empirically tested assessment processes."[6] These researchers also stated that the rigorously developed assessment processes were quite complex and impractical for most universities with limited resources. Their assessment work employed the simpler approach with a 20-item instrument using summative faculty instruments to assess team performance and to validate formative student assessment instrument. They also state that other researchers "within the engineering field have been working on defining outcomes in teaming and developing multi-source feedback systems. These researchers point out that many of the assessment instruments in use in engineering education have not been well validated."[6,7] In more recent research during the past three years, work has focused on validation of instruments.[8,9,10] Collaborating researchers from multiple universities have invested much time, effort, and expense to develop the Comprehensive Assessment of Team Member Effectiveness instrument using exploratory factor analysis and confirmatory factor analysis to help them select items for the final instrument.[11] This instrument ranges from 87 (full version) to 33 (short version) items. This instrument and others that have been validated are often fairly long instruments. In contrast, the instrument described in this paper is much shorter. Other researchers have suggested that using multiple measurements may help to validate the assessment process.[6,7] The authors of this paper employ these strategies using multiple measures to assess the reliability and validity of the instrument and provide an instrument that is much shorter than the aforementioned instrument.

The following sections provide a brief description of the project and a discussion of the instrument. Assessment of the reliability and validity of the instrument is also discussed as well as relationship of teamwork to project outcomes.

Project Description

In the fall of their senior year, students from the mechanical, electrical, and computer engineering disciplines are joined into teams typically with four to five members. This past year, due to limited resources, the teams were composed of seven to eight members. The team objective is to design, build, and test a solar powered vehicle that can carry two bottles of water and traverse a 300ft long parking lot in minimal time. Each vehicle weighs approximately 30 pounds including the solar panel and the two bottles of water. During the first or second week of November, the teams compete in a race in a sloped parking lot – traversing 300 feet with about 10 feet of elevation gain.

Each team is required to analyze and predict their vehicle's velocity profile. The prediction must be compared to the data collected by the vehicle's microprocessor and sensor/signal conditioning subsystems. Several constraints are specified for the design effort. The vehicle has to be a) untethered; b) powered by a specified solar panel; c) fabricated in the engineering facilities with the assistance of the school's machinist; and d) must to cost less than $300 (not including the power source). The effort must result in a working prototype, a performance prediction, and a system to collect vehicle performance data. Each team is required to do the following: conduct a product design feasibility study, conduct design brainstorming sessions, review a 20 page lessons learned document that is compiled from previous student project reports, conduct conceptual design studies, conduct component optimization tests, design and fabricate a prototype vehicle, analyze and predict vehicle performance, design and fabricate on-board procedures to collect and store data, analyze performance data, and use the collected data to verify the performance prediction from the analytical analysis. As far as teamwork goes, one of the most important steps in the process, that is also used to promote continuous improvement, is the requirement for teams to review a "lessons learned" document compiled from the project reports of previous years' teams. The purpose of the multi-year feedback is to allow students to learn from the mistakes of their predecessors. During the second week of the course, the teams give their first power-point progress report. Within this report, the teams detailed their initial concepts, project schedules, and reviews of the "lessons learned" document as well as strategies to avoid some of the historical challenges and pitfalls detailed in the document.

Documentation of the designs is kept in a team logbook that was graded each week by three faculty members. As with typical engineering logbooks, the students documented their designs and revisions to the designs. The teams in this project were also required to document their meetings (attendance and minutes), and all component and vehicle integration testing. Students were instructed to record the date and time of testing and the team members present during the testing. These aspects of the logbooks along with race time, and race data were used by faculty in conjunction with survey instrument questions to ensure the integrity of the student responses. Some of the questions in the survey were designed to allow the faculty to identify surveys that were filled out indiscriminately.

Assessment and Evaluation

At the conclusion of the course, multidisciplinary groups put together formal presentations and papers to be presented to the class and faculty sponsors. Following these presentations, the Interdisciplinary Teamwork Evaluations were administered. This assessment survey was filled out by all participants in the course with regard to their group's teamwork. The assessment survey included 16 item teamwork questionnaire about how successful the team was in the accomplishment of specific project milestones as well as project management milestones. All statements were rated on a 4 point Likert scale from Strongly Agree to Strongly Disagree. Neutral options were not available as raters have a tendency to gravitate toward neutral categories which compresses the variability. In addition, conceptually we thought students should be able to commit to whether they agreed or disagreed with a statement. An examples of project specific teamwork item was *Team members (across disciplines) worked together to calibrate the wind speed sensor with the anemometer*. An example of a conceptual project management teamwork item was *Team members (across disciplines) discussed design tradeoffs during the project*. The complete survey items are included in Table 1 along with the means and standard deviations across all responses. The review of the means and standard deviations is encouraging; there is reasonable variability across most of the items and there is not evidence of ceiling effects which can be challenging when students rate their peers.

Table 1 – Survey Questions with mean and standard deviation reported.

Question	Mean	Std Dev
Team members (across disciplines) worked together in initial brainstorming meetings	3.1	0.61
Team members (across disciplines) reviewed and summarized the "lessons learned" from previous solar car teams	2.9	0.75
Most of the frame of the vehicle was assembled at the time of the mid-semester review	3.4	0.84
Most weeks the logbook was updated just before the weekly progress report	1.8	0.65
Team members (across disciplines) worked to calibrate the wind speed sensor with the anemometer	2.3	0.86
Our team tested the vehicle on the pavement enough before the race day find and correct problems	3.0	0.87
We were able to gather good data on race day	2.5	0.94
Our team had a member or members who did not participate/contribute very much	2.2	0.98
I wish my group would have worked better as a team	2.3	0.87
The vehicle would have performed better if we had better teamwork	2.5	0.87
There was a high level of interdisciplinary interaction between most team members	2.6	0.71
Team members (across disciplines) discussed design tradeoffs during the project	2.7	0.73
Our team made necessary adjustments to avoid the pitfalls from previous teams	2.9	0.71
Team members (across disciplines) worked together to integrate and test the project	3.0	0.72
Our team tested the project with sufficient time to find and correct problems.	2.9	0.78
Our group worked well as a team.	2.9	0.81

The purpose of conducting this survey was to determine if a more succinct, reliable teamwork scale could be developed that would apply to multiple projects and would be feasible to apply in many teamwork projects. In this mission, we wrote the last five items in the scale in a more global manner so they may apply to many different types of design projects. While these items still reference the project at hand, they tap into different types of teamwork throughout the course of a project including design tradeoffs, learning from previous teams' experiences, integration and testing. Thus, this measure could be adapted to pertain to many multidisciplinary projects. We embedded this scale in the larger questionnaire so we could use some of the other items to assess validity. Thus, the brief teamwork scale included the following questions.

Brief Teamwork Assessment

Team members (across disciplines) discussed design tradeoffs during the project
Our team made necessary adjustments to avoid the pitfalls from previous teams
Team members (across disciplines) worked together to integrate and test the project
Our team tested the project with sufficient time to find and correct problems.
Our group worked well as a team.

A first step in examining the validity of the ratings involved comparing the ratings for project specific teamwork items with objective measures from the semester. In this regard, the authors compared the ratings with the faculty notes, logbook entries and ratings from weekly meetings to validate responses. For example, logbooks were checked and documented weekly, faculty documented whether vehicles effectively gathered data, and race times were documented by faculty race judges. Comparison of these objective measures with students' ratings about these issues yielded overwhelming correspondence. While this step was not quantitative, it did enhance the confidence that students filled out the surveys with sufficient attention and honesty to provide "good" data to test our hypotheses.

While individual item level analyses can be informative, often summary measures have more utility. Quite often a single item is not as multifaceted nor does it contain as much variability as a summary measure from a scale based on multiple indicators of teamwork. The teamwork scale score was the sum of the ratings for the 5 items. Thus, the possible range of scores was from 5 to 20. Across our 56 respondents, the range for our students ratings on the teamwork scale was from 7 to 18 with a mean = 14.49 and standard deviation = 2.67. While the score variability was sufficient, the next aspect to examine was internal consistency. The alpha = 0.78 which is a respectable level of internal consistency (reliability) particularly for such a brief scale.

With face validity and confidence that surveys were completed with integrity in addition to reliability, the authors hypothesized that if the survey was really measuring teamwork then we would expect that team members within a group would have reasonably consistent ratings. We also expected significant between group differences in how the different groups rated their own teamwork performance. This was the only factor we expected to differentiate teamwork ratings. While we had other measures such as grade point average or discipline we did not anticipate that they would differentiate teamwork performance assessments as these were meant to focus on the group's performance. In a preliminary analysis to examine the effect of group on the teamwork scale score, an ANOVA was conducted to determine whether the teamwork scale score differentiated between teamwork rated by each team. The ANOVA indicated there were significant differences between the groups with regard to teamwork; $F(7, 48)=3.73$, $p<0.01$.

In addition, we compared the teamwork scale with other related teamwork questions. Table 2 displays the positive correlations that are further indications of the validity of the brief teamwork scale.

Table 2. Correlations between the Brief Teamwork Scale and other teamwork items.

Other Teamwork Items	Correlation with Brief Teamwork Scale
High level of interaction between most team members	0.61**
Worked together in initial brainstorming meetings	0.71**
I wish my group worked better as a team	0.59**

** correlation is significant at the 0.01 level

Finally, as another step toward validation the authors examined the predictive validity of the Brief Teamwork Scale in predicting the performance of students on their team-based project. Thus a linear regression model was tested that assessed the extent to which teamwork predicted performance in the course. The dependent measure used was the students' final project averages. In addition, we controlled for the group to which each student belonged. In this model, the brief teamwork scale and group accounted for 22% of the variance in the students' final project average. These results clearly demonstrate that while teamwork is not the only factor influencing the success of a project, it does play a significant role.

Discussion

These results are initial steps in examining the reliability and validity of a brief multidisciplinary teamwork measure that the authors piloted. The Brief Teamwork Measure yielded high reliability and decent predictive validity. This brief measure can be applied to other multidisciplinary team-based projects. The results documented the relationship between teamwork and the success of project outcomes.

The results also hold promise for the critical role that effective interdisciplinary teamwork plays in design and production environments. Next steps will continue validation studies with additional measures that were administered during the same project. Another source of data that was collected included assessments of team cohesion based on dyadic ratings of individual team members' contributions. Additionally, students responded to multiple open-ended questions about the project and teamwork required to succeed. Examination of this information will guide our work in the future.

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