

## **AC 2007-1508: MULTIDISCIPLINARY TEAM ASSESSMENT**

### **Denine Northrup, Western New England College**

Denine A. Northrup is an Associate Professor of Psychology at Western New England College. Prior to joining Western New England College, she was the Director of Quality Improvement for the Connecticut Department of Mental Health and Addiction Services, Assistant Professor of Psychiatry in the Yale University Medical School, and a Research Associate in the Vanderbilt University Institute for Public Policy Study. She earned a Ph.D. in Applied Social Psychology from Vanderbilt University, a Masters of Science in Clinical Psychology from Eastern Michigan University, and a Bachelors of Arts in Psychology from the University of Michigan.

### **Steven Northrup, Western New England College**

Steven G. Northrup is an Assistant Professor of Electrical Engineering at Western New England College. Prior to joining Western New England College, he was an electronics design engineer for the Ford Motor Company Electronics Division and a software engineer for Nichols Research Corporation. He earned an M.S. and a Ph.D. in Electrical Engineering from Vanderbilt University and a B.S. in Electrical Engineering from the University of Michigan.

# Multidisciplinary Team Assessment

## 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, build, and test a solar car. It is the hypothesis of the faculty that students who have more multidisciplinary interaction in the design and implementation of the project will produce a better project. To evaluate this hypothesis, the authors have designed a new assessment instrument to effectively assess the level of multidisciplinary teamwork and the students' ability to function on a multidisciplinary team. While there are some existing instruments available, few have documented reliability and validity<sup>1</sup>. For this reason, a new multidisciplinary team assessment instrument was piloted during the Fall, 2006 semester with additional measures. This approach allowed for a thorough assessment of the reliability and validity of the new instrument. The multidisciplinary assessment instrument data was also compared with independent measures of the outcomes of the project to determine the effect of multidisciplinary team work.

## Introduction

It is well known that multidisciplinary teamwork is a valuable part of engineering education and that ABET requires engineering programs to document that their graduates demonstrate "an ability to function on multi-disciplinary teams"<sup>2</sup>. Western New England College has a long history of incorporating engineering design into its laboratories and courses. In addition, interdisciplinary team efforts are initiated in the freshman year and continue for all four years<sup>3,4</sup>. This paper describes assessment of one such interdisciplinary lab exercise, performed in the fall of the students' senior year. The design project brings together students from mechanical, electrical, and computer engineering in a 4-5 member team.

One of the challenges facing engineering educators is how to get students to truly engage in teamwork interaction as part of a multidisciplinary team. Felder and Brent state that "Little in their (faculty's) background or experience provides a basis for knowing how students might show an ability to work effectively in multidisciplinary teams"<sup>5</sup>. Many researchers have offered advice regarding this problem. Davis, for example, proposes that team teaching one integrated course results in the best opportunity for interdisciplinary interactions<sup>6</sup>. The project being discussed in this paper is team taught by professors from three separate disciplines - electrical, computer, and mechanical engineering.

Assessment of multidisciplinary teams is a related challenge facing engineering educators. Powers et. al. state that "previous assessment efforts have ranged from hastily constructed and poorly validated instruments to rigorously developed and empirically tested assessment processes."<sup>7</sup> They also stated that the rigorously developed assessment processes were quite complex and impractical for most universities whose resources are limited. Their work employed the simpler approach with a 20-item instrument. They used summative faculty instruments to assess team performance and to validate formative student assessment instrument. Powers et. al. 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.”<sup>7,8</sup> They suggest using multiple measurements to validate the assessment process. The authors of this paper employ similar strategies using multiple measures to assess the reliability and validity of the new 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 new instrument is also discussed as well as relationship of teamwork to project outcomes.

## Project Description

In the fall of the senior year, students from the mechanical, electrical, and computer engineering disciplines are joined into teams of four to five 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 lbs. 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 the parking lot adjacent to the engineering building. The parking lot is about 300 feet long and has an elevation gain of about 10 feet.

Each team is required to analyze and predict the vehicle’s velocity profile. The prediction must be compared to the data collected by the vehicle’s microprocessor and electrical 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 at the College with the help of the College machinist; and d) must to cost less than \$300. The effort has to 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, 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 prototype data to verify the performance prediction from the analytical analysis. Additionally, to promote continuous improvement, teams were required to review a “lessons-learned” document compiled from the project reports from previous years’ teams. The purpose of the multi-year feedback was to allow students to learn from the mistakes of their predecessors. During the second week of the course, the teams gave 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 detailed.

Documentation of the designs was 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 20 teamwork questions about how successful the team was in the accomplishment of specific project milestones as well as project management milestones. All twenty statements were rated on a 4 point Likert scale from Strongly Agree to Strongly Disagree. A neutral response category was omitted to eliminate the tendency of students to avoid committing in one direction or another. Additionally, opportunity was available to indicate if there was insufficient information or experience to respond. Examples of project specific teamwork items included *Team members (across disciplines) worked together to calibrate the wind speed sensor with the anemometer*. Conceptual project management teamwork items included *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.

Table 1 – Survey Questions with mean and standard deviation reported

Question	Mean	Std Dev
Team members (across disciplines) worked together in initial brainstorming meetings	3.32	0.66
Team members (across disciplines) discussed design tradeoffs during the project	3.00	0.57
Team members (across disciplines) reviewed and summarized the “lessons learned” from previous solar car teams	3.32	0.62
Our team made necessary adjustments to avoid the pitfalls stated in the “lessons learned” from previous solar car teams	3.24	0.59
Most of the frame of the vehicle was assembled at the time of the mid-semester review	3.57	0.69
The team logbook was updated each week	2.97	0.75
Most weeks the logbook was updated just before the weekly progress report	2.84	0.92
During the first 6 weeks, the team met more than once each week (on average)	2.97	0.89
After the first 6 weeks, the team met more than once each week (on average)	2.74	0.86
Team members (across disciplines) worked to calibrate the wind speed sensor with the anemometer	2.34	0.75
Team members (across disciplines) worked together to integrate and test the vehicle	3.42	0.55
Our team tested the vehicle on the pavement enough before the race day find and correct problems	3.32	0.75
We were able to gather good data on race day	2.97	1.05
On race day our lowest time from heats 1 and 2 was below 40 seconds	2.95	1.22
On race day our highest time from heats 1 and 2 was over 40 seconds	3.08	1.09
Our team had a member or members who did not participate/contribute very much	2.26	0.92
I wish my group would have worked better as a team	2.34	0.63
The vehicle would have performed better if we had better teamwork	2.08	1.22
Our group worked well as a team.	3.03	0.59
There was a high level of interdisciplinary interaction between most team members	2.95	0.77

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.

With face validity and confidence that surveys were completed with integrity, 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 performance 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 assessment, ANOVAs were conducted across the 20 items. For 12 of the 20 items there were significant differences in how teamwork was assessed between the 8 different groups. The results of the ANOVA are included in Table 2. These results also support the increased consistency of ratings within groups. As expected there were no significant differences in group teamwork based on discipline.

Table 2 – ANOVA results.

Question	F	Df	$p < .05$
Team members (across disciplines) worked together in initial brainstorming meetings	1.08	7, 30	
Team members (across disciplines) discussed design tradeoffs during the project	3.33	7, 30	*
Team members (across disciplines) reviewed and summarized the "lessons learned" from previous solar car teams	2.13	7, 30	
Our team made necessary adjustments to avoid the pitfalls stated in the "lessons learned" from previous solar car teams	2.05	7, 30	
Most of the frame of the vehicle was assembled at the time of the mid-semester review	2.57	7, 29	*
The team logbook was updated each week	2.45	7, 30	*
Most weeks the logbook was updated just before the weekly progress report	2.97	7, 30	*
During the first 6 weeks, the team met more than once each week (on average)	3.73	7, 30	*
After the first 6 weeks, the team met more than once each week (on average)	0.62	7, 30	
Team members (across disciplines) worked to calibrate the wind speed sensor with the anemometer	2.01	7, 30	
Team members (across disciplines) worked together to integrate and test the vehicle	1.11	7, 30	
Our team tested the vehicle on the pavement enough before the race day find	2.95	7, 29	*

and correct problems			
We were able to gather good data on race day	15.90	7, 30	*
On race day our lowest time from heats 1 and 2 was below 40 seconds	10.08	7, 30	*
On race day our highest time from heats 1 and 2 was over 40 seconds	4.14	7, 30	*
Our team had a member or members who did not participate/contribute very much	4.14	7, 30	*
I wish my group would have worked better as a team	1.98	7, 30	
The vehicle would have performed better if we had better teamwork	0.61	7, 30	
Our group worked well as a team.	2.75	7, 30	*
There was a high level of interdisciplinary interaction between most team members	4.48	7, 30	*

While individual item level analyses can be informative, often summary measures have more utility. Quite often a single global 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. In this case, the authors desired to create a summary measure that may be used as a predictive variable. In addition, the authors attempted to pilot a scale that could be applicable to other projects. For this reason, the authors conducted an exploratory factor analysis on the more global teamwork items and examined the internal consistency of the scale. The scale consisted of 5 items and yielded an  $\alpha = 0.74$  which is considered an acceptable level of internal consistency (reliability). The summary measure is the sum of the five items. The summary measure across the 37 respondents (one respondent omitted one of the items and thus was missing the summary measure) ranged from 11 to 20 with a mean=15.97 and standard deviation =2.15. The 5 item scale expands the range of variability as compared with most of the individual items. The 5 items included in the summary scale are listed below. 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 past experience, integration and testing. Thus, this measure could be adapted to pertain to many multidisciplinary projects.

Table 3 – Summary Teamwork Scale

Summary Teamwork Scale
Team members (across disciplines) discussed design tradeoffs during the project
Our team made necessary adjustments to avoid the pitfalls stated in the “lessons learned” from previous solar car teams
Team members (across disciplines) worked together to integrate and test the vehicle
Our team tested the vehicle on the pavement enough before the race day find and correct problems
Our group worked well as a team.

Finally, as an initial step toward validation the authors examined the predictive validity of the Summary Teamwork Scale in predicting the performance of students on their solar car project. Three outcome performance measures were used: a midterm walk through grade, the average speed based on two trials during the race day, and the final course average. While these three measures are not independent, at least one is a purely objective measure based on the performance of the solar car. To assess the predictive validity, a multivariate regression was conducted using the three outcome measures as the dependent measure. The summary teamwork scale was the independent measure. The purpose was to determine if a portion of the variability in the outcome measures (project performance) could be attributed to the assessment of

teamwork by students. The results suggest that the teamwork assessments were a significant predictor of performance on the project. The teamwork assessment accounted for 17% of the variance in the midterm walkthrough grade, 22% of the variance in the race results and 24% of the variance in the final grade. 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 multidisciplinary teamwork measure that the authors piloted. The Summary Teamwork Measure yielded high reliability and strong predictive validity. This summary measure can be adapted and generalized to other multidisciplinary team-based projects. The results documented the relationship between teamwork and the success of project outcomes.

While the results have implications for future iterations, the results also hold promise for the critical role that effective interdisciplinary teamwork plays in design and production environments. Next steps will continue validity 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. These responses will be examined qualitatively for validation purposes as well as to aid in design changes in the survey for the future. These next steps will be addressed in a forthcoming paper.

## Bibliography

- [1] Thompson, R.S., "Reliability, validity, user acceptance, and bias in peer evaluations on self-directed interdependent work teams," Doctoral Dissertation, University of Colorado at Denver, 2000.
- [2] *Criteria for Accrediting Engineering Programs*, published by ABET, Inc., Baltimore, Maryland, [www.abet.org/images/Criteria/E001\\_06-07\\_EAC\\_Criteria\\_12-19-05.pdf](http://www.abet.org/images/Criteria/E001_06-07_EAC_Criteria_12-19-05.pdf), 2005.
- [3] Musiak, R.E., Haffner, E.W., Schreiner, S., Karplus, A.K., Vollaro, M.B., and Grabiec, R.A., "Forging New Links: Integrating the Freshman Engineering Curriculum", in *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*, June 2001.
- [4] Northrup, S.G., Moriarity, J., Vallee, G., and Presz, W., "A Successful Interdisciplinary Engineering Design Experience." in *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition*, June 2003.
- [5] Felder, R.M., and Brent, R., "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria", *Journal of Engineering Education*, January 2003, pp. 7-25.
- [6] Davis, J.R., *Interdisciplinary Courses and Team Teaching: New Arrangement, for Learning*, American Council on Education and Oryx Press, 1995.

- [7] Powers, T.A., Sims-Knight, J., Topciu, R.A., Hadan, S.C., “Assessing Team Functioning in Engineering Education”, in *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition*, June, 2002.
- [8] Besterfield-Sacre, M., Shuman, L.J., Wolfe, H., Atman, C.J., McGourty, J., Miller, R.L., Olds, B.M., and Rogers, G., “Defining the outcomes: a framework for EC 2000. *IEEE Transactions on Engineering Education*, Vol. 43 (2), 2000.