Using Self-Assessment to Evaluate the Effectiveness of an Engineering Management Course with Cross-Functional Teams

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Abstract

A self-assessment tool was used to measure the effectiveness of an undergraduate capstone course in systems design/engineering management taught at Rutgers University. To quantify the impact of the course, a self-assessment behavior-oriented survey was used called the Team Developer™, which measured the student team members on several cognitive and behavioral skills. The foundation of the course was built around an industry simulation. Students were organized into teams or "companies" that had to develop a proposal to win a contract from "NASA" for development of a colony on Mars. Lectures were given by interdisciplinary faculty from throughout the university, industry, and the NASA community on the engineering disciplines needed to develop their subsystems and the engineering management and proposal skills needed to design, integrate, and draft a proposal to win an engineering contract. This course allowed students to use innovative design principles to solve complex problems and strengthen this with engineering management and business skills. The Team Developer™ showed a positive impact of the course on the student's behavior and activities in the four areas of collaboration, communication, decision-making, and self-management. Rutgers University recognized this course in 2000 with its award for Excellence in Academic Creativity and Innovation.

Introduction

In business, one of the keys to success is customer satisfaction. In academia, students are customers of the institution for which they are attending. Common in academia is the use of course evaluations to assess the value of a course and its impact on the student, the customer. Unfortunately, these do not equate the value of personal growth to the student and do not truly associate the full impact of a course. This paper will discuss an innovative industry simulation course taught at Rutgers University using cross-functional teams and how a self-assessment tool, the Team Developer™, was used to determine the added value to the student and the effectiveness of the course in four behavioral skills: collaboration, communication, decision-making, and self-management.

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Background and Motivation

Most courses in engineering education are offered as part of a curriculum for a student to meet the requirements for graduation and the effectiveness of a course or technical and scientific growth is measured through standard testing and grading mechanisms. Few courses are offered that are at the discretion of the student to enhance their personal growth; therefore, there is little emphasis placed on measuring the impact a course may have on a student's cognitive or behavioral growth. Wilde stated in 1983 that, "The route from school direct to university for an engineering degree without practical experience in the industrial environment does not give the young engineer the basic skills, knowledge or attitude required for a career in engineering design."[1] A common practice in engineering curriculum at most higher education institutions is the use of simulations or design projects to give students hands-on and real-world experience with the objective of not only teaching the application of engineering principles, but behavioral skills in a team environment. Cowan showed the value of group learning in engineering courses can halve the failure rate.[2] Still, these courses are evaluated with traditional tools. McGourty states that the Accreditation Board of Engineering and Technology (ABET) criteria encourage institutional assessment efforts to focus on the measurement of student learning outcomes in a systematic and valid manner. McGourty goes on to state "few educational institutions have a comprehensive system for measuring program results in terms of student learning outcomes."[3]

One of the more common tools used to determine personal growth is through the use of self-assessment. The purpose of self-assessment is to be able to measure the current state against a model or measure and provide a means to identify future improvements.[4] This study used the Team Developer™ self-assessment tool because it measures four behavioral skills important to cross-functional teams and engineering management. It was also a measurement of skills considered important to real-world learning and engineering design teams. The Team Developer™ has been successfully used in the classroom to provide students with feedback on their developmental effectiveness in specific cognitive and behavioral skills. Students rate themselves on behaviors they have found to be important for engineers in a team environment. The Team Developer™ provides students and educators with feedback based on the observation of specific behaviors rather than subjective overall impressions. It also allows educators to tailor curriculum to specific needs.[5] To learn more about the Team Developer™ see *Tools and Tactics of Design, The Team Developer: An Assessment and Skill Building Program: Student Guidebook* (Dominick, et. al., 2001, ISBN: 0-471-40384-9) and *Tools and Tactics of Design* (Dominick, et. al., 2001, ISBN: 0-471-38648-0).

Course Description

The course was an industry simulation set in the future. The simulation emulated, as closely as possible, the experience of working as a member of an aerospace industry proposal team. For the simulation, the class was formulated into companies (teams) of five students that develop a proposal to win a contract from "NASA" for design of a settlement on the surface of Mars where over 19,000 people would live. Each team then had cross-functional responsibilities in the areas of Operations Engineering, Systems Engineering, Automation Engineering, and Human Engineering to propose a design that could integrate these subsystems into a functioning colony. To encourage communication and collaboration within the team, the companies were organized into a President, responsible for systems integration management, and four Co-Vice Presidents with accountability in two of the functional areas. Lectures were given by university faculty, experts from industry, and members of the National Aeronautic and Space Administration (NASA) community in a variety of science and engineering areas. Table 1 is a sample of lecture topics given in both technical and social sciences. The topics of lectures dealing with the technical and human side of developing an engineering proposal were designed to give the students a solid grounding in the material they would need to complete their industry simulation.

Table 1: Course Lecture Topics

Technical	Social Science
What is Bioregenerative Life Support	Company/Organizational Structure
BLS Research around the World	Project Management
Past/Future NASA Exploration Missions	Group Interactions/Crew Dynamics Exercise
Mission Scenarios for Exploration of Mars	Proposal and Business Plan Writing
The Moon and Mars	How to Make a Good Presentation
Robotics for Space Exploration	Time Management
Gravitational and Space Biology	Leadership Styles
Why Grow Plants in Space?	
Evolution of Food Systems for Space	
Food Nutrition and Processing for Space	
Waste Processing and Resource Recovery	
Systems Studies and Modeling	
Engineering Design Basics	

The proposal would have to support the design of an overall structure, define sources of construction materials, specify vehicles used for transportation, determine sources of electrical power and water, design computer and robotics systems, specify allocation of interior space, show examples of pleasant community design, and provide estimated costs and schedules for completion of the project. The Simulation concludes with the team's presentations of briefings describing their designs to a panel of expert judges. These experts were volunteers from the university and NASA community. The end results of the course were to teach optimism for the future, technical competence, management skills, knowledge of environments and resources in space, appreciation for the relationship between technical products and human use, ability to work in teams, and techniques for preparing effective documentation. It required that students integrate their knowledge of and utilize skills in space science, physics, math, chemistry, environmental science, biology, computer science, engineering, writing, speaking, art, and common sense. Students were graded on a mid-term exam, reading assignments, company proposal, and company presentation.

The criteria for the winning proposal were defined to the students as:

1) The Basics: win the same way any company wins a proposal simulation
    a. Create a design that meets the customer's requirements
    b. Show in your presentation that your design meets the requirements
2) Customer requirements are described in the Request for Proposal (RFP)
    a. RFP describes exactly what the customer desires
    b. Winning design should address every issue or point included in the RFP

    c. Plenty of latitude for innovation: show how your design meets the RFP
3) Communicate your design in the presentation
    a. Best design in the world is worthless if you don't communicate it
    b. Think about the briefing and charts as soon as you start the design process
    c. Make sure your presentation shows that your design meets RFP requirements
4) Although innovation is encouraged, feasibility is essential
    a. Justify any technologies assumed in your design which exceed those described in the simulation materials
    b. Judges are engineers working in NASA and the aerospace industry--base your design on the level of existing technology defined by the Simulation organizers, laws of Physics, and common sense

Students were provided with resources both for their systems design and in learning. To subject the students to alternative learning and business tools, a web-based communications and management module that enabled students to use Internet technology to manage their projects was developed. This allowed for project scheduling, task management, instant messaging, and file sharing. Additionally, video conferencing and distance learning technologies were incorporated into the class to reach out to expertise throughout the country for guest lectures. This course allowed students to use innovative design principles to solve complex problems and strengthen this with engineering management and business skills. Rutgers University recognized this course in 2000 with its award for Excellence in Academic Creativity and Innovation.

Methods

Over two semesters, 35 students were surveyed from seven teams of five students per team. Students were asked to complete a behavioral survey, the Team Developer™, after all course requirements had been met and before final grades were distributed. Students were asked to think back to the work they performed on the semester project. Using the questionnaire, they were to rate themselves on how frequently they engaged in each of the specified behaviors and activities listed (1=Never, 2=Rarely, 3=Sometimes, 4=Frequently, and 5=Always). They were informed that the information would remain confidential and responses were to be based on actual behavior. The survey consisted of 32 randomly ordered questions with eight questions related to four behavioral skills measured in the Team Developer™: Collaboration (CO), Communication (CM), Decision Making (DM), and Self Management (SM). Results were shared with the students as a form of personal feedback and self-growth.

Results

The survey results were favorable in showing the student's application of the behavioral skills measured. Table 2 shows the mean scores for each of the teams in the four behavioral skills and the overall mean scores across teams (T#) and behavioral skills. Most team scores were high in each skill. Only T4 scored below 4.0 in all of the behavioral skills with a low of 3.41 in SM and a high of 3.66 in CM. All other teams scored 3.68 or higher, and T3 had the highest score of 4.48 in CO. The overall score for teams and skills were also positive with overall team scores greater than 3.49 and overall skill scores greater than 3.80. These results show a positive indication of the student's use of the four behavioral skills within the course.

Table 2: Mean Scores for Teams in Four Behavioral Skills

	T1	T2	T3	T4	T5	T6	T7	*Overall*
CO	4.28	4.18	4.48	3.56	4.33	4.40	4.05	4.18
CM	3.95	3.85	3.95	3.66	4.04	4.33	3.80	3.94
DM	3.98	4.10	3.48	3.34	4.10	4.03	3.68	3.81
SM	3.78	3.93	3.80	3.41	3.75	4.43	3.50	3.80
Overall	4.00	4.01	3.93	3.49	4.06	4.29	3.76	3.93

To support these findings, an analysis of variance (ANOVA) was performed on the mean scores between teams and skills to determine if there was consistency across teams, skills, and semesters (Table 3). This analysis would help to build validation for the course format and the instructor's methods. CO was the only behavioral skill that showed consistency between teams, while the other behavioral skills demonstrated less significance between the means. Therefore, the results of the ANOVA cannot validate the course format or instructor's methods across teams, skills, and semesters. The ANOVA does demonstrate that further investigation may be needed to create more consistency in the coarse format and methods.

Table 3: ANOVA of the Mean Scores between Teams and Skills

ANOVA	*F*	*F Critical*
Between Teams – CO	6.72	2.29*
Between Teams – CM	1.99	2.29
Between Teams – DM	4.96	2.29*
Between Teams – SM	6.33	2.29*
Between Skills – Overall	2.53	3.01
Between Teams – Overall	4.41	2.57*

$\alpha = 0.05$ * statistical difference between the means

Even with this variation, the overall team and skill scores were favorable (overall team > 3.49; overall skills > 3.80). While the results show that the students perceived themselves as using these skills, without a before and after comparative score the study cannot show the developmental impact on the students. It can only affirm the use of the skills.

Conclusions

The objective of this paper was to show how a self-assessment tool could validate the effectiveness of an engineering management course with cross-functional teams. The self-assessment showed that the students perceived themselves as using these skills to accomplish the project. While the scores were favorable (overall 3.93), there was inconsistency across teams, skills, and semesters. As mentioned earlier, the Team Developer™ provides not only the students, but also the educators with feedback based on the observation of specific behaviors. As an educator, the optimistic objective is to transfer to every student equally the knowledge and skills related to the course material. The results of this study show that further work could be done to address some of these behavioral skills and how they impact the student.

In the future, adding a self-assessment at the mid-term of the class, so the students could measure their development throughout the semester, could enhance this study. The current design only allowed for a student to measure themselves against an already perceived opinion of themselves. This is also a challenge with the survey. Students could have a high opinion of their abilities in the four behavioral skills tested, which would skew the measurement. They may have a tendency to answer the question how they perceived they should and not how they truly acted. A solution to this would be to add a peer or 360-degree assessment tool to balance an individual student's personal opinion. One of the original objectives of this study was to identify behavioral skills that may be associated with a winning proposal team. Unfortunately, the results gave no indication as to what set the winning teams aside from the others, as higher scores did not equate to winning proposals. The effectiveness of a team may be more tied to the performance and validity, which were not directly measured in this study.[6] This study was attempting to validate the non-scientific and technical value of an engineering management, cross-functional team course and not a team's performance or validity. Further research could look into additional behavioral skills, or the addition of a peer or 360-degree assessment, which may reveal some of the variance in the teams not shown in this study.

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BRIAN J. SAUSER holds a B.S. from Texas A&M University in Agriculture Development with an emphasis in Horticulture Technology, a M.S. from Rutgers University in Bioresource Engineering, and a Ph.D. from Stevens Institute of Technology in Technology Management. He has worked in government, industry, and academia for more than 10 years as both a researcher/engineer and director of programs. He has managed an applied research and development laboratory in life sciences and engineering at NASA Johnson Space Center, was Program Director of the New Jersey – NASA Specialized Center of Research and Training, where he managed a multi-institutional, multi-disciplinary science and engineering research center working to generate new knowledge and technology for life support systems, and was a Project Specialist with ASRC Aerospace responsible for managing technology utilization and assessment, and commercial partnership development at NASA Kennedy Space Center. He is currently a Research Assistant Professor at Stevens Institute of Technology in the Systems Engineering and Engineering Management Department.