Engineering Students and Training in Teamwork: How Effective?

Linda Schmidt, Janet Schmidt
University of Maryland
Carol Colbeck
Pennsylvania State University
David Bigio, Paige Smith, and Lee Harper
University of Maryland

Abstract

The motivating principle of the BESTEAMS (Building Engineering Student Team Effectiveness and Management Systems) project is to create a modular student team training program that can be integrated into any existing engineering undergraduate curriculum. Funded by a three-year NSF-Course, Curriculum, Laboratory Improvement (CCLI) grant, the BESTEAMS curriculum is comprehensive and developmental, offering three levels of instruction (introductory, intermediate, advanced) in three key areas of team functioning (personal awareness, interpersonal dynamics, and project management).

The purpose of this paper is to describe the results of student evaluation of the introductory level curriculum that has been introduced into the Clark School of Engineering's - Introduction to Engineering Design course (ENES 100). Students completed three team work modules presented by faculty trained in the module delivery during the 2001-2002 academic year. The first Introductory module related to personal effectiveness and increasing self awareness. Using the widely recognized Kolb Learning Style Inventory (LSI), the module shows students how knowing their own preferred learning style can give them insight into themselves as well as their teammates' view of educational and team tasks (N = 379 students). The second Introductory module (interpersonal dynamics) addressed basic communication issues including giving and receiving feedback, typical stages of team development, and brainstorming activities (N = 125 students). The final module on project management, covered personal time management in the context of team projects and included project definition, scoping and the creation of Gantt charts (N = 144 students).

1. The BESTEAMS Project: Modules for Team Training

BESTEAMS stands for Building Engineering Student Team Effectiveness and Management Systems. In addition to the University of Maryland, the current BESTEAMS partners include: Howard University, Morgan State University, and The United States Naval Academy (USNA). The diversity of partners is deliberate: one goal of BESTEAMS is to create a team curriculum that is appropriate in a wide range of different engineering schools, ranging from the historically Black to a military context, from public to private institutions, for men and women of all nationalities. The ultimate goal is to be a catalyst for a professional engineering environment that is welcoming and comfortable for all people.

BESTEAMS focuses on teaming as a means of bringing about permanent change in the engineering environment. Engineering project teams, ubiquitous in the profession, are becoming a cornerstone of the engineering education system. Team-based product design and development delivers increased productivity, significant time-to-market reductions and profitability gains.

The early work of the BESTEAMS partners was to develop and implement a prototype team training system called the Engineering Project Team Training System or EPTTS. EPTTS included segments on teamwork delivered through the "filter" of learning styles (using Kolb's Learning Styles Inventory, LSI[6]). Faculty-training workshops to teach engineering instructors to use EPTTS and companion materials on their own were developed. Nearly 900 engineering students in 20 different classes at four different institutions were trained by the BESTEAMS partnership in personal awareness using the Kolb LSI. These early efforts supported the belief that student training in proven personal and team dynamics methods improves the team experience for both faculty and students.[8]

2. Design of Curriculum Modules

As implied above, the creation of a successfully operating student team is not automatic. Good will or intention to be effective team members is not sufficient. Teams are collections of individuals who must learn to interact with each other and with the "team" as a whole. BESTEAMS identified three domains of team performance that are key to successful team functioning. These three aspects define the type of process training we have devised for engineering students and provide the basis for assessing team effectiveness. The domains are described in Table 1.

Table 1. BESTEAMS Engineering Student Team Training Curriculum by Module and Team Performance Domain.

Track	Personal	Interpersonal	Project Management
Introductory	Kolb Learning Styles	Feedback, Team Development & Learn Styles in Team Context	Individual Time Management & Project Scoping
Intermediate	Felder's Inventory of Learning Styles	Human Resource Management: Conflict Resolution	Project Organization Decision Management
Advanced	Leadership Styles	Negotiation & "Win/Win" Outcomes	Performance Breakdown Resolution vs. Completion

2.1 Curriculum Domains

The first domain critical to successful teaming is "Personal" knowledge, skills and abilities. Individuals must know themselves in order to work effectively as part of a team. By knowing their personal strengths and weaknesses, team members can choose tasks for which they are best suited and thereby contribute effectively to a positive team outcome and product. While psychological literature provides many theories that can be used to learn about personality (e.g., Kolb, Jung), without this information, people often rely on stereotypes to make judgments about themselves and others.[4] To help students use an “attribute filter” which teaches them about themselves and others in an educationally useful, rather than stereotypic manner, we piloted the Kolb LSI in the early EPTTS curriculum. Based on these efforts, we adopted the LSI as the basis of the Introductory Level BESTEAMS Personal Module. Subsequent modules expand the personal domain as described below:

> *Personal – This domain includes skills fundamental to successful interaction in complex personal and technical projects, self-understanding of how individuals prefer to learn, personal strengths, and how to maximize them.*

The second critical domain, “Interpersonal” builds on the Personal domain. In our prototype work, we effectively used the Kolb as a springboard to an appreciation of individual differences and their impact on team performance. Beyond the introductory level, material on more complex group dynamics and conflict resolution is presented in the intermediate and advanced modules:

> *Interpersonal – The basic mode of operation of any team is interactions between individuals. Appreciation of the diversity of learning styles and performance modes is necessary for success. Communication skills are the fundamental tools that need to be mastered in this domain.*

The third key domain is the “Project Management"—not only in the sense of producing a quality team product that meets the customer specifications,[5,7] but in terms of managing the *team processes* required to produce the outcome or product. The importance of this domain became clear when we observed student teams with satisfactory interpersonal group dynamics, but poor engineering team projects. Conversely, we have had student teams that did not function well, yet produced strong engineering products. Thus we developed team training materials to teach our students how to manage the project itself (key project management skills).

> *Project management-- Refers to guiding the complex activities of a team of people to produce a specific product. Tools and techniques associated with managing activities to optimize the team process and product are taught in this domain.*

2.2 Developmental Nature of the Curriculum

The general content of the three domains of the BESTEAMS curriculum has been outlined previously. A second major characteristic of the BESTEAMS model is its developmental nature. Later modules build on earlier ones. In the ideal engineering educational setting, the Introductory level modules in each of the three tracks are taught to first-year students just beginning team projects. The intermediate modules are geared to sophomores and juniors who have had more experience on engineering project teams. Finally, the advanced modules should be taught to students as they approach the completion of their senior capstone team experience. While this is the "ideal," the independence of the modules allows faculty members to "pick and choose" the modules they feel are most appropriate to a given project or class. Initially, we worried about redundancy, both in terms of students being exposed to the same module twice or overlap in terms of the material across levels of the curriculum. However, in practice, "one shot learning" is not usually effective for subject mastery. Depending on the circumstances, an individual student may benefit more from seeing the material a second time, perhaps because of the particulars of the team experience in that class or his/her own personal receptivity to the material. Also given the typical time lag between training sessions, some redundancy acts as a "refresher" for the material. In sum, the BESTEAMS model is designed to move the student's understanding from simple to more sophisticated understanding of self/team dynamics in the context of an engineering team project.

3. Current Status of BESTEAMS Introductory Modules

BESTEAMS impacts the University of Maryland and its partner schools only to the extent that faculty teach the modules in their classes and students participate in the training. Therefore, participation levels provide the most basic indicator of BESTEAMS impact. During the 2001-2002 academic year, BESTEAMS trained over 40 faculty members who, in turn, delivered Introductory Modules to 1270 students.

Across all BESTEAMS partner schools, a total of 18 faculty implemented at least one BESTEAMS module in fall 2001, and nine faculty implemented at least one module in spring 2002. Several of faculty who taught courses including BESTEAMS modules in fall 2001 also included them in their spring 2002 course.

Most of the faculty implementing modules were at the University of Maryland (13 in fall 2001, eight in spring 2002) for two reasons. First, BESTEAMS already had a history of implementation at Maryland from the pilot projects. Second, BESTEAMS became an official part of the curriculum for ENES 100, the introductory design course required of all first year engineering students at Maryland. This course is taught in small sections of 36-42 students at this large research university. Faculty teaching the required first year introductory courses at Howard University and Morgan State University also used BESTEAMS modules in 2001-2002. At these smaller schools, almost all first year engineering students enroll in one or two large course sections (120-170 students) taught either by one professor (Morgan State) or by a team of professors, including one with BESTEAMS training (Howard). The USNA does not have an analogous required introductory course for all engineering majors. Students begin work in their majors during their second year. Therefore during 2001-2002, three USNA faculty began BESTEAMS implementation in introductory courses for two of the USNA's five engineering majors (mechanical engineering and ocean engineering).

Additional administrative staff and undergraduate students were involved in delivering BESTEAMS modules at the University of Maryland during 2001-2002. Administrator participation (six during 2001-2002) derived from at least two elements of the school's and the project's history. First, academic administrators as well as faculty teach ENES 100. The success of ENES 100 over the last decade is due - at least in part - to the expectation that faculty and chairs from all engineering departments teach the introductory course. Over the years, the dean, associate deans, and department chairs have encouraged faculty participation by taking their own turns. This legacy of broad-based faculty and administrator participation in teaching ENES 100 ensures that a substantial number of faculty and administrators are now being exposed to BESTEAMS as the modules become a required part of the course curriculum. The second reason for administrator implementation of BESTEAMS is that in addition to engineering faculty, the staff involved in the development, implementation, and direction of BESTEAMS includes administrators whose expertise is in areas other than engineering (e.g., psychology, assessment, education.)

3.1 Students Trained by BESTEAMS

At least 1287 students enrolled in courses in which BESTEAMS modules were implemented during 2001-2002, as shown in Table 2. With few, if any exceptions, the students enrolled during spring 2002 were not the same as students enrolled during fall 2001. Almost all students were enrolled in the required first year introductory engineering courses at their schools (Maryland, Howard, and Morgan State) or introductory sophomore courses in their major (in mechanical engineering or ocean engineering at the USNA). Ten Howard upper-level students, and 25 Morgan State mid-level students participated in pilot implementations of project management modules delivered by one of the Maryland BESTEAMS directors.

Table 2. Number of Undergraduate Students Enrolled in Courses Using BESTEAMS Modules in the 2001-2002 Academic Year

	Unduplicated Total		# of Women		# of under-represented minorities	
	Fall	Spring	Fall	Spring	Fall	Spring
University of Maryland	446	246	83	45	64	33
Morgan State University	240	55	*	*	*	*
Howard University	170	10	*	*	*	*
US Naval Academy	120	0	*	*	*	*
Total Undergraduate students	**976**	**311**				

* Numbers of women and under-represented minorities participating at partner schools unknown.

Only the University of Maryland was able to provide actual counts of women and underrepresented minorities enrolled in courses using BESTEAMS modules. However, based on interviews with the partner school coordinators, it may be safe to say that most of the students participating in BESTEAMS at Morgan State and Howard (both historically Black institutions) were underrepresented minorities but most of those participating at the USNA were not. The numbers of women participants were more difficult to estimate.

4. Student Evaluation of Training

All students who participated in the BESTEAMS faculty led training were asked to complete an evaluation of their experience. Students were given a brief survey at the conclusion of their training session. Questions included their general background with training in team work skills, their assessment of the impact the current training would make on their work in teams, as well as feedback on the characteristics of the training itself. Demographic information was available for a subset of the trained students (Table 3) representing roughly 50% of the trained students. For this group, the data were analyzed by gender, ethnicity and type of engineering major.

Table 3. Number of UM Undergraduate Students Evaluating BESTEAMS Modules 2001-2002			
Module	**Student Evaluations Reported**	**Matched Demographic Data**	**% Complete Records**
Kolb Learning Styles	379	166	43.8%
Interpersonal Effectiveness	125	62	49.6%
Project Management	144	76	62.8%

In an effort to streamline the evaluation process, demographic data was not included on the module evaluation forms. The intention was to collect demographic data by matching student identification numbers to the institutional databases. This proved to be problematic. The differences shown in matching demographic data to evaluation data is due to variation in form completion rates.

As noted in the Table 4, the average rating for each student evaluation question related to the quality of the training (Q1 through Q5) is on the agreement side of the neutral response. Stronger positive responses are found in the questions Q4 and Q5 that asked students to rate the perceived usefulness of the training for team work and their ability to transfer their training into the team settings. Theses results are consistent across training modules in each domain.

Table 4. Summary of Student Evaluations of BESTEAMS Introductory Modules (Rating Scale: 5 = Strongly Agree to 1= Strongly Disagree)			
Training Evaluation Question	**Kolb Learning Styles** (N = 379)	**Interpersonal Effectiveness** (N = 125)	**Project Management** (N= 144)
Q1: The materials covered in this class were useful to me.	3.57 (0.87)	3.51 (0.88)	3.63 (0.93)
Q2: The handouts (if any) were useful	3.51 (0.97)	2.70 (1.51)	3.27 (1.19)
Q3: The group exercises (if applicable) helped me to really understand the material.	3.10 (1.26)	3.23 (1.14)	3.13 (1.45)
Q4: I think this material will help me to become a more effective team member	3.42 (1.04)	3.72 (0.88)	3.77 (0.88)
Q5: I understand the key concepts of today's workshop well enough to apply them in my team.	3.91 (0.90)	4.13 (0.74)	4.24 (0.70)
Q6: This was a positive learning experience for me.	3.80 (0.91)	3.71 (0.95)	3.76 (0.84)
Q7: I enjoy working in teams	4.07 (0.91)	4.06 (0.87)	4.01 (0.97)
Q8: I have received formal training on teams in the past.	2.96 (1.37)	3.12 (1.29)	3.33 (1.27)

Other observations possible from the data in Table 4 are that students considered the training experience to be a positive use of class time (Q6) and recognize that they were accumulating training throughout the course by virtue of the modules (Q8). Finally, students reported agreement (Q7) with the statement, "I enjoy working in teams."

A smaller set of data was identified that matched the student evaluations with the available demographic information (Table 3). Only the BESTEAMS Kolb Module matched data set was sufficiently large to consider by demographic differences (gender, ethnicity, and academic major within engineering).

Data from Table 5 shows trends toward differences in response by gender and ethnicity both varying, for questions Q3, Q7 and Q8. (There were no statistically significant differences in the average rating by student group in any case.) The data show that the responses to the item relating to "usefulness of the group exercises" vary within each module. Women tended to rate them lower than men. Ethnic minority students tended to rate them higher than majority students.

Table 5. Demographic Summary of Student Evaluations of BESTEAMS Kolb Learning Styles Module
(Rating Scale: 5 = Strongly Agree to 1= Strongly Disagree)

Training Evaluation Question (Summarized from statement in Table 4.)	Kolb Learning Styles Evaluation by Gender (N = 161)		Kolb Learning Styles Evaluation by Ethnicity (N = 166)	
	M = 135	F = 26	Majority N =140	Minority N = 26
Q1: Useful material covered	3.62 (0.82)	3.40 (0.76)	3.54 (0.81)	3.88 (0.71)
Q2: Useful handouts	3.48 (0.92)	3.38 (1.20)	3.48 (0.95)	3.46 (1.03)
Q3: Useful exercises	3.13 (1.22)	2.85 (1.54)	3.01 (1.28)	3.38 (1.17)
Q4: Material helpful	3.43 (1.01)	3.38 (1.10)	3.39 (0.98)	3.50 (1.21)
Q5: Can apply concepts	3.93 (0.92)	3.96 (0.72)	3.93 (0.90)	3.81 (1.10)
Q6: Positive Learning	3.74 (0.92)	3.69 (0.79)	3.73 (0.79)	3.73 (1.31)
Q7: Enjoy working in teams	4.11 (0.88)	3.77 (0.86)	4.10 (0.81)	3.81 (1.23)
Q8: I Received formal training	3.02 (1.39)	2.46 (1.45)	3.04 (1.41)	2.46 (1.30)

The responses to "I enjoy working in teams" (Q7) tended to be lower for women and minority students than for men and majority students, respectively. Again, the difference in sample means is not statistically significant. However the ramifications of a trend like this warrant further study

and data collection with additional samples of students.
The responses "I received formal training in teams" (Q8) suggests that more majority men have received such training compared to women and minorities. It is possible that majority, male students are referring to training opportunities that they have experienced outside the formal classroom. Perhaps asking more specific questions related to other team training experiences would help explain this finding.

Although data were available by academic major, the subsets were increasingly small. Only three majors had greater than 30 students (Aerospace, Computer, and Electrical Engineering). However, the responses to the student evaluations across these majors varied much less than the differences displayed within Table 5 for gender and ethnicity. This is not surprising since the students are in their first year, are in interdisciplinary teams, and have not differentiated their skills and engineering approaches yet. Perhaps we can also tentatively assert that there is no predetermined bias against team training by academic major at this early point in a student's engineering career.

5. Discussion

This paper will conclude by making general observations about implementing team training into the undergraduate engineering curriculum including obtaining faculty buy-in and "lessons learned."[9] The discussion is greatly assisted by a recent evaluation report written by our project's external evaluator, Dr. Carol Colbeck.[2] In this report, she notes that one of the key factors in determining whether or not team training is integrated into an institution's curriculum is whether the locus of *decision-making about teaching and curricular issues is top-down from administrators or bottom-up from faculty.*

Implementing BESTEAMS type training involves convincing faculty and administrators to devote class time to new material, and energy to learning the material themselves as a prerequisite to conveying it to students. Successful implementation may depend on convincing the right people in a given engineering school – those who are influential because of position or reputation – that training in teamwork will benefit their students and, by extension, their school. The four schools involved in the BESTEAM partnership include two in which decision making is more likely to happen from the top down (USNA and Morgan) and two in which the locus of decision-making is primarily bottom-up (Maryland and Howard). The experience of both types of institutions are described below.

Enlisting the support of key administrators is necessary for getting BESTEAMS training started at *top-down schools*. The USNA, with military structure superimposed on academic culture, provides an extreme example of top-down decision making, as illustrated by comments by the local coordinator and faculty implementing BESTEAMS modules at the Academy. If the “chain of command thinks it’s a good idea,” faculty members are more likely to implement BESTEAMS modules in their classes.

In contrast, at *bottom-up schools*, one key to successful BESTEAMS implementation may be identification and recruitment of well-respected and influential faculty. By influencing "opinion leaders," more informal buy-in among their faculty colleagues may occur. Getting to opinion leaders may involve exposing them to the worth of BESTEAMS training by conducting abbreviated training or information sessions at dean's or chairperson's meetings or their equivalent.

A second major factor in the adoption of the BESTEAMS curriculum lies in the importance of teamwork itself in the engineering school's curriculum. The ways in which faculty and students interact with themselves and each other, and the extent that an engineering school promotes teamwork are also likely to affect the initial success of BESTEAMS. However, despite institutional differences such as these, because of recent revisions in accreditation criteria for undergraduate engineering programs,[1] the climate for group work has become more positive. Indeed, "the ability to function on multi-disciplinary teams" is now a *required* student learning outcome for graduates with a bachelor's of science in engineering degree and instructing and documenting engineering students' performance as team members has become a priority for all schools of engineering. Thus, the degree to which an engineering program is focused on ABET accreditation and measurement of student outcomes may influence its investment in team training for both faculty and students.

Colbeck articulated a number other issues that influence how likely an institution is to implement a BESTEAMS type training program on its campus. Among these factors are the organization of the curriculum and the number of "core courses" where team training can be implemented to maximize student exposure; the variety of student needs and discipline specific differences that impact uniformity of team training; faculty members own comfort level with so called "soft skills" versus "technical" material, and finally, the resources available to support the costs (both in terms of time and money) of providing BESTEAMS materials and training.

In sum, our experience at the half way point in our three year NSF grant in implementing the BESTEAMS curriculum material at four very different engineering schools is largely positive. Faculty and student feedback has been reasonably good, with some preference for project management training. Under "lessons learned" we would re-emphasize the factors articulated by Colbeck. Using UM as an example, we benefited from a recent ABET EC 2000 visit and the external mandate to pay attention to teamwork training for our undergraduates; the existence of ENES 100 as a required course for all first year students where the introductory modules could be taught; the ENES 100 infra-structure support which goes beyond that provided by BESTEAMS; as well as an increasing tradition of conducting team training as an integral part of this course. On the other side of the coin, difficulties in implementation have included unequal training of students due to differences in faculty selection of modules, lack of faculty comfort with the teamwork materials, as well as lack of reinforcement of the material throughout the course.[10]

6. Future work

The BESTEAMS partnership has recently completed the pilot testing of the Intermediate level modules at UM. Preliminary training materials are now available for the three key aspects of team work at this level. Training in these new modules to faculty and students at our partner schools will commence shortly. We are introducing intermediate training into classes required by a high percentage of engineering majors: statics, dynamics, and strength of materials. At this level, our approach has been to ask faculty to teach *one* module in each of these courses, after "front loading" the first year students in ENES with all three of the Introductory modules. Assessment of the Intermediate modules will occur in a manner similar to the Introductory modules. Students who are trained in a module will complete a brief survey rating the strengths and weaknesses of the particular module. Their feedback will be incorporated into the final versions of the teamwork modules. Initial work has commenced on developing the material for the Advanced modules and piloting these modules will begin in fall 2003. Finally, papers and conference presentations will continue to be written to document and share the evolution the BESTEAMS team training materials for engineering students and faculty across the nation.

Acknowledgements

The authors would like to acknowledge support for this research received from the following sources: the National Science Foundation Grant No. 008079 fro the Division of Undergraduate Education, The A. James Clark School of Engineering, the colleges of engineering at our partner institutions: Howard University, Morgan State University, and the United States Naval Academy, and, lastly, the Department of Mechanical Engineering of the University of Maryland

Bibliography

[1] Accreditation Board of Engineering and Technology (ABET), (2000) Engineering criteria 2000, Engineering Accreditation Commission, Baltimore, MD, 2000.

[2] Colbeck, C.L. (2002) Evaluation of the National Science Foundation Undergraduate Course and Curriculum Development Program BESTEAMS Project: Year One Report (unpublished report).

[3] Colbeck, C. L. (2002) Assessing institutionalization of curricular and pedagogical reform. Research in Higher Education, 43(4), 397-421.

[4] Felder, R., and Silverman, L. (1988) Learning and Teaching Styles in Engineering Education, Journal of Engineering Education, 78(7):674.

[5] Gido, J. and Clements, J.P. (1999) Successful project management, Cincinnati, OH: South-Western College Publishing.

[6] Kolb Learning Style Inventory, (1985) McBer & Company.

[7] Marmel, E. (2000) Project 2000, Foster City, CA: IDG Books Worldwide, Inc.

[8] L. Schmidt, L., Mead, P., Natishan, M., Lathan, C., Brown, S., Goswami, I. and Mouring, S. (1999) "BESTEAMS: Building Engineering Student Team Effectiveness and Management Systems, CD-ROM_ Proceedings 1999 ASEE Annual Conference & Exposition, Charlotte, North Carolina, June 20-23.

[9] Stark, J. S. & Lattuca, L. R. (1997) Shaping the college curriculum: Academic plans in action. Boston: Allyn and Bacon.

[10] Van Aken, S. (2001) University Leadership Development, Virginia Tech, Blacksburg, VA.

Biographical Information

LINDA SCHMIDT, Ph.D., Associate Professor, Mechanical Engineering, Clark School of Engineering, University of Maryland College Park. Dr. Schmidt is the Principal Investigator of the BESTEAMS project. In addition to team training, she is interested in engineering design processes, facilitating the success of women and minorities in engineering and advises the local chapter of Phi Tau Sigma.

JANET SCHMIDT, Ph.D., Director, Student Research, Clark School of Engineering. Dr. Schmidt a co-PI of the NSF sponsored BESTEAMS grant. A licensed psychologist, she is responsible for administering and assessing the project. Her other interests include promoting the success of women and minorities in science and engineering as well as and assessment activities related to ABET accreditation.

CAROL COLBECK, Ph.D., Director and Associate Professor, Center for the Study of Higher Education, The Pennsylvania State University. Dr. Colbeck is the external evaluator for the BESTEAMS project and has published extensively on the topics of innovation in engineering education.

DAVID BIGIO, Ph.D., Associate Professor of Mechanical Engineering, the Clark School of Engineering, the University of Maryland. A co-PI of BESTEAMS, Dr. Bigio is responsible for outreach, team training, and module development. His interests include entrepreneurial aspects of engineering education and fluid mechanics.

PAIGE SMITH, M.S., is Director of the Women in Engineering Program at the University of Maryland. She provides leadership in recruiting and retaining women engineering students for the college. Her current research focuses on engineering design teams and project management. She is completing a doctorate in Industrial and System Engineering.

LEE HARPER, M.S., is the Coordinator of Education for the Institute of Systems Research at the Clark School of Engineering. She is a member of the BESTEAMS group and conducts module training. She is currently completing a doctorate in Educational Leadership.