TEAM BUILDING IN LOWER DIVISION PROJECTS COURSES

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Abstract *¾ Teamwork in lower division projects courses is increasingly common. To ensure student effectiveness in these teams, instructors must assume a facilitator role to nurture team process and progress. This paper describes team-building activities in two introductory engineering design/build projects courses at the University of Colorado at Boulder. The discussion is organized around developmental stages that teams typically pass through—forming, storming, norming and performing—with stage-appropriate reference to team needs, assessment and activities designed to build team skills. An evaluation of this team-building program is provided, based on skills self-assessment data gathered from students during one semester. Implications and suggestions for curriculum improvement are discussed.*

Index Terms ¾ curriculum development, design/build, freshman design, outcomes assessment, team building

INTRODUCTION

Teams are increasingly popular as a basic working unit in engineering education. Work teams are common in capstone design classes and are becoming increasingly prevalent in lower-division project courses. Teaming is an effective structure for meeting many educational objectives. Teams are well suited to the interactive learning style often preferred by underserved populations[1] and they introduce students to the realities of the engineering profession. Teams are also an effective structure for developing students' skills in accordance with several ABET EC 2000 outcomes including Criterion C, the ability to function in multi-disciplinary teams, and Criterion G, the ability to communicate effectively.

Teams require nurturing to develop for maximum impact. Without focused team building, teams can become ineffective, unable to meet their goals, dissatisfying and frustrating to members, and a burden to instructors. To build teams, instructors must continuously assess and stress team dynamics. The instructor must be aware of the dynamics within each team, including differences in social styles, relationships between the members, goals of individuals, and team developmental stages. Instructors can use this assessment information to make decisions about team intervention.[2]

TEAM BUILDING IN PROJECT-BASED COURSES

At the University of Colorado at Boulder, two, semester-long, hands-on courses introduce students to the engineering design process. The First-Year Engineering Projects course allows first-year students to design and build functional prototypes.[3] The specific projects that students build vary by section, but examples include assistive technology devices to help clients with disabilities, interactive learning exhibits for K-12 students, robotic vehicles and Rube Goldberg devices. The emphasis of the course is on learning the design process in a team-oriented, hands-on way, so the specific *product* is less important than the *process*. The Invention and Innovation course introduces sophomore, upper division and transfer students to product invention, including entrepreneurship and patenting. In both courses, student teams present their final products to the public at an end-of-semester Design Expo.[4-5]

Both courses emphasize teamwork, with the team component of the course comprising about 70% of the final grade. Instructors attend to team dynamics by employing numerous structured activities and using various assessment tools. The following section provides an overview of the team building activities in these courses. This section is organized by team developmental stages, according to the model specified by Tuckman.[6] This model specifies four stages of team development—*forming*, *storming*, *norming* and *performing*. Each developmental stage is described in terms of stage-specific team needs, as well as course assessment and team-building activities.

Stage 1: Forming

During the forming stage, team members are new to their teams and getting acquainted with one another as well as themselves as team members. At this stage, team members display socially appropriate behavior and interactions may be somewhat tentative, with members hesitant to take risks.

Teams have several important needs during this stage, which must be supported if they are to develop appropriately. Attention is first given to team selection. An appropriate mix of skills, styles and demographics ensures that a team has the homogeneity to get along with one another and the heterogeneity to cover the range of roles necessary for complicated projects. A Skills Assessment

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Inventory measures skills associated with specific course objectives at the beginning of the semester.

Stylistic differences are assessed through an interactive Social Styles workshop in which students self-assess *how others perceive them* in the communications process, categorizing themselves into one of four interactive communication styles: *driver, analytical, amiable* or *expressive*.[7] The preference of individual students to work alone or in teams is also considered. Typically, students who prefer individual work are spread among the teams rather than clustered within teams. Likewise, to balance technical skills and knowledge, students with significant hands-on tinkering experience, working with CAD, or using hand tools are spread among teams. Instructors also consider demographic variables when forming teams, attempting to avoid isolating students who are underrepresented in engineering at our institution—women and students of color.

Taken together, these variables are carefully evaluated when forming teams. Since teams are formed after initial class-wide team dynamics and group problem solving workshops, the instructors have time to carefully observe the students in action, and can pinpoint those students who naturally gravitate towards various team roles with a high degree of accuracy.

A second need of teams during the early formation stage of team development is the opportunity for interaction. Early in the courses, students participate in Team Dynamics exercises, a series of physical and mental activities designed to get members acquainted, build trust and introduce team problem solving. Students quickly learn each other's names, balance each other on logs, juggle balls and work together to solve challenging logic games. These structured activities help alleviate the initial hesitancy that can characterize teams, and help teams learn to work together in a fun, low-risk context. They also emphasize the importance of committing to team goals and avoiding non-productive, attention-getting behavior.

Another important need during the forming stage is the opportunity to *practice working as a team.* In these two courses, the teams complete an introductory, two-week design and build project using limited materials such as foam core or PVC pipe. Instructors assess team performance, and teams are given an opportunity to self-assess their performance as well. This activity provides teams with the experience of setting goals, fulfilling roles, brainstorming design alternatives, and constructing a project without the concern of going seriously off-track. Peer evaluation at the end of the initial project is a powerful tool, providing each team member with an opportunity to quantitatively evaluate the contribution of his or her team members. This evaluation typically accounts for 5% of the course grade and, thus, is taken seriously by students. Instructors meet one-on-one with each student to provide anonymous feedback. We find this is often a turning point in individuals' experiences, as students genuinely want to succeed but don't often know how to be a successful contributor to their team.

Stage 2: Storming

After teams have spent a period of time working hard to be pleasant to each other, the "kid gloves" come off. In the storming stage, team members begin to struggle for control, jostling for various roles and coming into conflict with each other. Teams members may blame one another for problems, applying judgmental labels and splitting into competing or warring factions. Although stressful, this is a necessary stage of group development that can generate helpful creative tension in the team.[8]

During this stage, teams need to learn to clearly identify their problems. The SYMLOG assessment tool is one approach to help teams learn to identify their problems. SYMLOG is an acronym for *systematic, multi-level, observation of groups.* In this assessment approach, team members rate their team performance on 26 problems common to work teams. Team ratings are averaged and results are presented to each team along with normative data for each problem. Teams are asked to pick two problems that concern their team the most, and develop an action plan to address these issues.[9]

Teams need a safe forum to express their thoughts and feelings, as well as to learn to resolve conflict. In these two courses, teams participate in a weekly project meeting that includes the opportunity to review, assess and process their team performance with the instructor. Skills assessment and social styles can be reintroduced at this time to help teams better understand *and value* the strengths of individual differences, the variety of roles in the team, and the relationships between individual differences, roles, and conflict. Use of this forum helps to negate one of the chief dangers in engineering design teams—the tendency to avoid discussing team process. Teams that avoid discussing problems can become stuck in the storming stage as conflict festers beneath the surface or builds until it explodes, damaging both relationships and the ability to achieve team goals. During these times, instructors should be prepared to intervene outside of the formal structure of the class, spending focused time on a specific team's process and taking an active role in conflict resolution. If facilitated effectively, teams emerge from the storming stage with a greater ability to be direct with one another and more accepting of each other's strengths and weaknesses.

Stage 3: Norming

Teams can use the skills gained in the storming stage to begin *norming*—developing expectations about what should and should not take place in the team. These norms form a baseline reference against which team members can regulate their behavior.

During the norming stage, teams most need clarification. Team meetings are used to clarify team rules

and roles assumed by each team member. The danger in this stage is that norms can be developed non-verbally and without equal participation. Norms may institutionalize behavior that is ineffective or can consistently marginalize team members into minor roles. For example, women in engineering design teams are often assigned undervalued roles, such as report writing or preparation of presentations. While these are important tasks for team success, they are not valued equally with actual construction of products. Instructors use team meetings to make norms explicit, discussing team rules and covert expectations. Instructors may also assign or rotate roles, giving team members the experience of contributing in areas other than those that are customary or comfortable for them.

If facilitated effectively, the norming process can lead to team cohesion, which can be defined as, ". . . the attraction and connection of group members to one another and to the group."[10] This level of connection is a necessary precursor for the efficiency and coordination necessary in the performing stage. Cohesion is the natural result of a clear set of team norms, developed openly, with equal participation from all members. When everyone knows and is committed to team norms, the likelihood of that team functioning as a single cohesive unit is dramatically improved.

Stage 4: Performing

Organized and committed, teams are now ready to perform. High-performance teams are characterized by their productivity—the ability to solve problems and achieve goals. Instructors with high-performance teams in their courses now reap the rewards of past support and are motivated to provide the additional support to see these teams through to success.

During the performing stage, teams thrive on accountability. Design projects are complex and long, requiring much iteration. Milestones and evaluative feedback help keep the projects on track and provide the satisfaction and rewards that accompany accomplishment. Periodic design reviews and oral presentations provide the opportunity for the team to self-assess and receive feedback from the instructor and other classmates. Peer evaluation assessment is again conducted by asking team members to anonymously split a hypothetical $1,000 bonus among all members of their team, including themselves, and provide written rationales for their ratings.

Performing teams also need to develop increased autonomy. Although structured accountability and support are readily available, teams spend the majority of class time working independently without external structure. During team meetings, instructors strongly encourage team members to become familiar with each other's schedules, establish means of contacting one another, and schedule their own meeting times outside of the classroom. Teams are required to develop a project timeline, which is regularly reviewed.

Finally, performing teams need a sense of closure, an opportunity to put everything together and make sense of the semester's accomplishments. These projects courses address the need for closure via several activities, most notably, the Design Expo—a day-long presentation of the project to the public. Projects are judged and winners receive low-cost, high-prestige awards. Team members make a final product presentation in class, and submit a final design report. They also submit a final peer evaluation that counts an additional 5% of their course grade.

AN EVALUATION OF TEAM BUILDING ACTIVITIES

The First-Year Projects and Invention and Innovation courses place great emphasis on course evaluation and improvement. Student skill development is assessed pre-semester and post-semester via the Skills Assessment Inventory, a 60-item assessment of the overall course objectives. Students self assess their skills on a five-point Likert-type scale with choices ranging from strongly disagree to strongly agree. One sub-scale of both inventories is the Teamwork Skills scale. Scales for both courses share 10 items, and the First-Year Projects Teamwork Skills scale has an additional five items designed to assess entry-level team skills.[11] In the list below, these items are associated with the four team developmental stages—*forming*, *norming*, *storming* and *performing*. Although the Teamwork Skills scale items were developed specifically to assess course learning outcomes, they can be tied to team developmental stages to illustrate the progressive development of teamwork skills, from "hanging out" with other students to leading them. Items present on both the First-Year Projects and Invention and Innovation inventories are marked with an asterisk (*).

Stage 1: Forming

1. I have found a group of people in the College of Engineering with whom I like to hang out.
2. I have found a group of people in the College of Engineering with whom I can study.
3. I am familiar with my strengths and weaknesses as a team member.*

Stage 2: Storming

4. I understand the different roles played by team members.*
5. I understand how to work with people who have a style of work different from my own.*
6. I am skilled at resolving conflicts between team members.*

Stage 3: Norming

7. I prefer to work in a team rather than work alone on a complex project.*
8. I know how to support the leadership of the team.

9. I am comfortable asking my team members for help.*
10. I know the team roles that I am most effective at performing.*

Stage 4: Performing

11. I am comfortable working in a team on a long-term project.*
12. I know how to work cohesively with a team of people toward a common goal.*
13. I can write a team report for a project.
14. I know how to carry on multiple responsibilities for a project.
15. I am effective at leading a team.*

At the beginning and end of the fall 2001 semester, 162 First-Year Projects and 14 Invention and Innovation students completed the Teamwork Skills scales. Repeated measures, multi-variate, analysis of variance procedures were run on both sets of data. These procedures test the data on two levels, providing information on significant pre-test/post-test differences on the Teamwork Skills scale as a whole and a breakdown of the pre-test/post-test differences for each individual item of the Teamwork Skills scale. For the First-Year Projects course, there was a statistically significant difference between the pre-test and the post-test assessments on the Teamwork Skills scale ($p<.05$). Compared to the pre-test assessment, students scored themselves significantly higher on the Teamwork Skills scale at the post-test. When comparing individual Teamwork Skills scale items, twelve of 15 individual items also gained significantly. Mean differences between the individual items on the First-Year Projects Teamwork Skills scale are graphed in Figure 1. Solid bars indicate statistically significant changes on the post-test; lined bars indicate non-significant changes. The possible range of scores represented by the bars is from one to five. The numbers beside the bars correspond to item numbers in the inventory list above.

For Invention and Innovation students, the data analysis must be interpreted with caution; a larger sample size than 14 is required for confidence in the robustness of the findings. These results are offered as tentative support for the findings from the First-Year Projects Skills Assessment Inventory. For Invention and Innovation students, there was a statistically significant difference on the overall Teamwork Skills scale between the pre-test and post-test ($p<.05$). Similar to First-Year Projects students, Invention and Innovation students perceived themselves gaining significantly on the Teamwork Skills scale across the semester. When analyzing the differences between individual items, three of 10 individual items also showed significant gains—item 3, item 5, and item 10 from the inventory list above. Mean differences between the individual items on the Invention and Innovation Teamwork Skills scale are graphed in Figure 2. The numbers beside the bars correspond to the ten Invention and Innovation Teamwork Skills scale items provided in the inventory list above.

For both courses, all Teamwork scale items associated with the forming stage of team development increased significantly between the pre-test and post-test. This indicates that students perceive themselves gaining in the basic skills of teamwork, learning to relate with one another and gaining familiarity with individual differences. Basic skills are an important focus of these introductory courses, as most of the formal team building exercises take place as teams are formed and prior to starting the main design project. The development of fundamental teamwork skills is one of the major reasons for the vertical integration of the team structure downward into the earlier semesters. The college does not want its students to first experience basic teamwork skills in capstone courses, or worse, while on their first professional job.

Two of three items associated with the storming stage of team development increased significantly during the semester in both courses. Students reported gains in their understanding of the roles played by group members and in their skills at working with others who have different styles. Acceptance and skill regarding working with others who operate differently is an important sign of student maturity. These are skills that most differentiate a novice from a more seasoned team player. Without an appreciation for individual differences, team members often get stuck stereotyping and making scapegoats of others, which drains energy and hampers team productivity. Students did not report significant gains in conflict resolution skills in either the First-Year Projects or Invention and Innovation course. Conflict resolution skills are difficult to develop, especially for engineering students who frequently report an introverted and analytical style that is uncomfortable with emotional conflict. Students in these courses often avoid confronting conflict in their teams, not addressing issues until emotional turmoil reaches a critical point. Instructors can assist with the development of conflict resolution skills by modeling effective conflict resolution and encouraging team members to resolve conflict early.

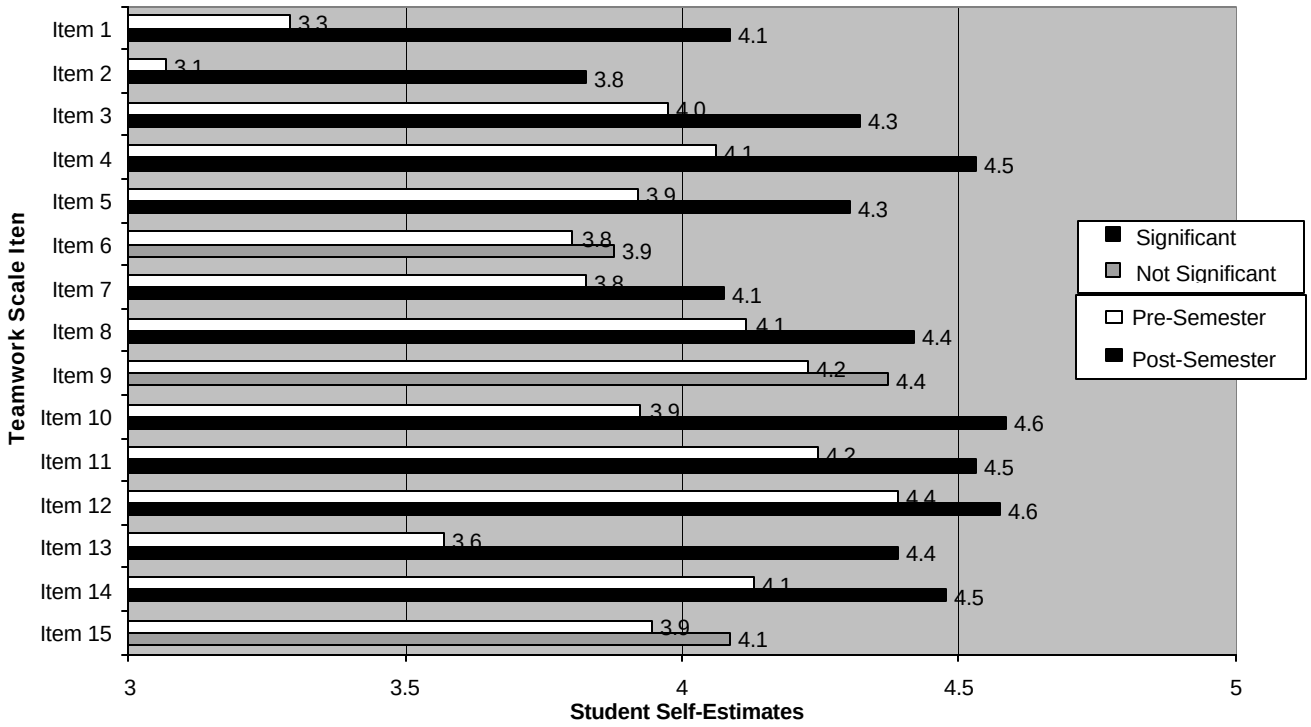

FIGURE. 1
COMPARISON OF PRE-SEMESTER AND POST-SEMESTER MEANS FOR THE FIRST-YEAR PROJECTS TEAMWORK SKILLS SCALE.

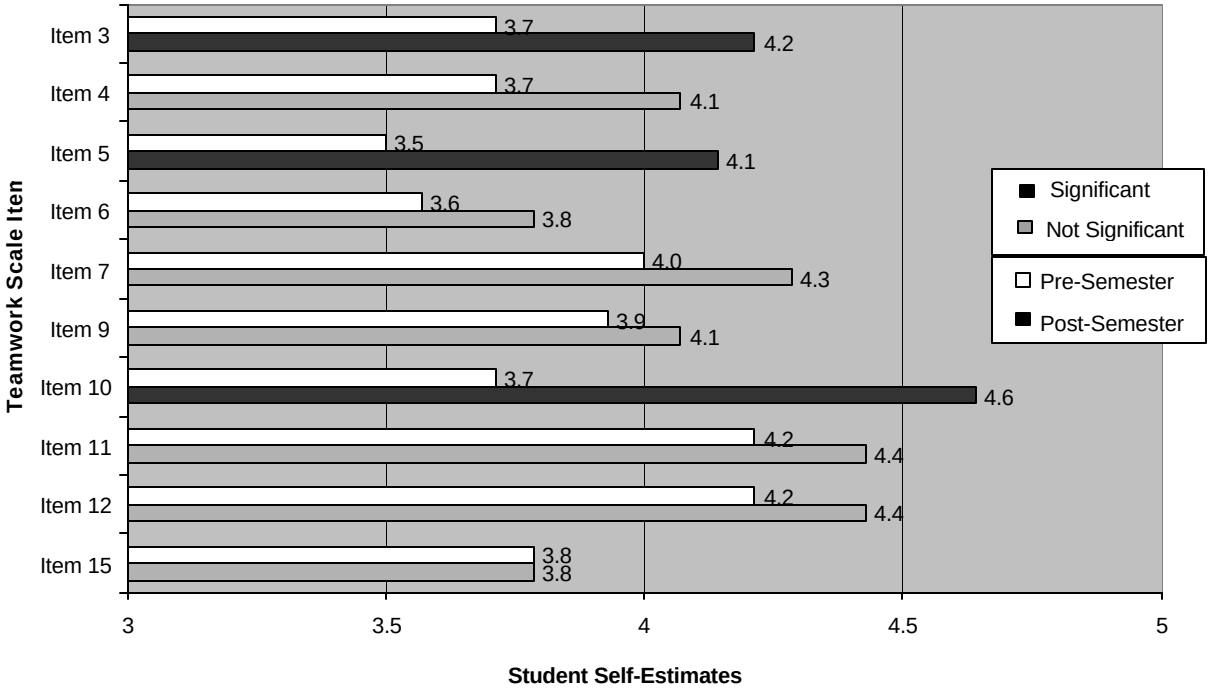

FIGURE. 2
COMPARISON OF PRE-SEMESTER AND POST-SEMESTER MEANS FOR THE INVENTION AND INNOVATION TEAMWORK SKILLS SCALE.

Three of four items associated with the norming stage were significant for First-Year Projects students. Students reported an increase in their preference for working in a team and their ability to occupy roles and support others in their roles. Experience with a variety of roles is an important part of the norming process as students become familiar with and develop commitment to all facets of the team structure. Familiarity and commitment allow the team to function cohesively as a unit.[12] Students did not report significant gains in skills associated with asking one another for help—a crucial element in the process of developing cohesion. Engineering teams often experience more difficulty than others while developing this skill. This can, again, be attributed to stylistic issues as engineering students are frequently characterized as independent. Without intervention, it is common for one team member to attempt to take over the team and monopolize the project because s/he does not trust the other members enough to ask for help. Instructors can intervene in team meetings to help a group delegate and follow-up on tasks. Once team members learn that they can rely on one another, they become open to asking each other for assistance.

First-Year Projects students reported significant gains in four of five items associated with the performing stage, reporting improvement in writing team project reports as well as working long-term and cohesively toward a common goal. These advanced teamwork skills serve students well as they move to upper-division courses. However, first-year students did not report significant gains in their skills at *leading a team*. In student teams, members typically enter the course with a wide range of leadership skills and experience; an adequate team leader emerges as needed. Thus, many students do not gain experience with the leader role and do not develop their skills in this area. The lack of leadership skills becomes a problem when students graduate. Industrial teams are increasingly multidisciplinary in which members with diverse agendas compete for influence. To be effective and promoted, practicing engineers must be able to gain influence and lead others. Instructors can potentially affect the development of leadership skills by assigning and rotating roles.[13] This opportunity often presents itself to the instructor when two team members are engaged in dominance battles or no leader has emerged.

SUMMARY

A team structure is increasingly present in introductory engineering courses as education programs emphasize the development of teamwork skills in the curriculum, reflecting the professional world of engineering. Implementing team structures alone is not sufficient for *building skill* in this area. Students often find teamwork to be the most challenging component of the engineering projects courses. Our experience is that teams must be *facilitated* for members to be satisfied and team-based projects to be successful. One approach to mentoring successful teams is to organize assessment and team-building activities around team needs specific to each of four stages of team development—*forming, storming, norming* and *performing*. Comparison of student self-assessment, evaluative data for pre- and post-semester teamwork skills reveals that students report significant gains overall across the semester in a myriad of teamwork skills, with the exceptions of conflict resolution, leadership skills or skill at asking other members for help. This knowledge can assist instructors in providing support and curriculum to develop tomorrow's leaders.

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