Teaming in Engineering Technology Education: Lessons Learned and Experiences that Work

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Abstract

The efficiencies and benefits of multi-disciplinary teams are leading to their more widespread implementation into business and the engineering world. However this mode of problem solving and goal achievement clashes with the American culture of rugged individualism and personal advancement. The need to introduce teaming into engineering education has been recognized for some time and is part of ABET requirements for certification. Best practices and assessment of instructional approaches that work remain an on-going need.

In Western North Carolina, teaming skills are highly valued with regional enterprises. The Six Sigma quality program at Caterpillar and TEAM Industries and a supervisor-less, team manufacturing structure at Selee are examples of the heavy reliance that regional firms place on well developed teaming skills from Western Carolina University graduates. Critical skills in positive interdependency, individual accountability, face-to-face promotive interaction, interpersonal skills, and group processing are essential proficiencies for companies relying on healthy team dynamics. Team structures have been created in several areas of engineering technology instruction at Western Carolina University. Among these are project management, parametric modeling and engineering design, and rapid prototyping and component design. In this paper faculty experiences are shared, feedback from industry is provided, lessons learned are described, and techniques that we believe are effective in this area of education are identified and presented.

Introduction

In the present global economy with stiff competition from abroad, the survival of most U.S. companies relies on the stimulation of innovation and creativity to generate new high margin, high value added products and processes for the marketplace. Short times to market and efficient product development processes are key ingredients to success. Concurrent interdisciplinary processing is commonplace. Teams and teamwork skills have been shown to be powerful assets in achieving business success. Without these skills, initiatives such as Six Sigma quality would lose their power and effectiveness.

Proficiency in working as a team has become a fundamental skill demanded of the graduating engineer. Beyond content competencies, businesses desire basic workplace skills, excellent listening and oral communications, creativity and problem solving skills, solid personal management, interpersonal skills including conflict management, and leadership and organizational effectiveness[1]. These skills are not explicitly taught in engineering curriculums where the focus has been on the content and analytical skills of the engineering disciplines. Industry and the Accreditation Board for Engineering and Technology however expect engineering graduates to have well developed teaming skills[2].

Feedback from industry suggests that teaming skills in engineering graduates fall short of the needed proficiency. Several deficiencies were identified in interviews carried out with business executives. Employees are uncomfortable with not being right all the time, which seriously impedes consensus building. Many employees are not capable of straight communication on issues and keeping the communication from being personal. Helping others succeed and coaching fellow team members are uncommon skills in the work force. Team self assessment is largely unsuccessful, and a fear of retaliation is a major barrier. A general negativity toward team activity is also exhibited at the college level. As noted by Buckenmyer, “the announcement that there will be a team project is received with moans, complaints, or other indications of displeasure”[3]. From informal samples, less than 20 percent of students report favorable and positive experiences with team activities. The reasons reflect the workforce experience and include lack of cohesiveness, lack of mentoring and guidance as if teaming skills are presumed to be natural, unequal contribution of team members, and lack of clarity in the objectives and assignments. It is common for students to be faced with four to five simultaneous team projects, which require extensive, difficult-to-schedule, out-of-class face time with team members. To compound these barriers, the American pioneering roots and culture grows and rewards strong individual effort and personal independence. Buckenmyer suggests that Generation X even appears at times to be anti-team. They are strongly influenced by information technology saturation and the visual stimulation of the world in which they have grown[3].

In other words the economic climate is challenging, and the workplace is expecting well-developed teaming skills to successfully compete in the global marketplace. Many of the required skills are missing in new engineering graduates, and educational institutions are attempting to address these deficiencies despite a culture of self sufficiency and poor prior teaming experiences. In this context, we hope to contribute to the advancement of engineering curriculums that foster the growth of teaming skills by sharing our experiences and stimulating the creation of new approaches to strengthen this effort.

Background to Cooperative Learning

The work of Johnson, Johnson, and Smith is the most recognized reference in the field of cooperative learning[4]. In their model of learning, there are three fundamental learning structures: competitive, individualistic, and cooperative. In the competitive model, a negative interdependency between learners is created--the “I win, you lose” scenario. In the individualistic learning structure the student is unrelated to other students. Finally a cooperative structure maximizes learning of both self and others, or simply, “we sink or swim together.” These three structures for learning were evaluated with respect to the learning outcomes of achievement, interpersonal relationships and psychological health. The cooperative learning structure clearly produced the best outcomes. This work suggests that a structure strongly favoring cooperative learning while retaining some elements of competition would create a highly productive learning environment. This view is supported by a survey of students in large classes that identifies "other students" as the second-most frequently cited factor contributing to their learning[5].

According to Johnson et al, there are five basic elements to team dynamics including positive interdependence, face-to-face promotive interaction, individual accountability, interpersonal and small group skills, and group processing[4]. Fundamental to positive interdependence is the concept of "all for one, one for all". Each member of the team depends on the other team members for success. Face-to-face promotive interaction includes the coaching, explaining and counseling functions that have been noted as deficiencies in the workplace. It is the group effort that counts. The frequent complaint of unequal contribution to the team effort stems from a lack of individual accountability. The acceptance of peer feedback given in a constructive manner is a key element for improving team performance. For instructors, assessment of individual performance becomes a challenge. Interpersonal and small group skills encompass a broad range of skills including leadership, decision-making, consensus building, conflict management, and accurate communication. Group processing skills ensure that the team can assess how well it is doing relative to its goals and maintain working relationships with team members. Acknowledging contributions and taking corrective action results in continuous improvement of the team's performance. Adams[6] has also given an excellent summary of cooperative learning in engineering.

Approaches

In this section we describe our approach to team learning relative to the life cycle stages of a team: its formation, chartering, assessment, and coaching/monitoring. We have adopted two methods to forming the team, random selection and faculty assignment. In choosing either approach, it is essential that fairness be maintained. Random selection is particularly successful when the class members are of similar level of competency and where competition between teams in grading is not present. Random selection closely resembles the real world where availability of personnel often determines team makeup. Forming teams by the faculty assignment is particularly effective in ensuring diversity of talents, culture, and performance levels. This balancing of team capabilities is particularly important when teams will be competing against each other to accomplish the same team objective.

The root of many complaints to team activities resides in the lack of consensus on and commitment to the team's achievement objectives. Class team projects are usually drawn together by the vague class assignment. The team charter should include the target level of achievement or grade, completeness and a code of conduct and performance. This written charter signed by the team clears the air for effective group processing. This device is useful for long duration projects and probably not worth the effort to formalize it for short ad hoc teams. Initially making the team members aware of their commitments and reinforcing that awareness is always appropriate.

Easily the most important aspect of performance assessment is that it be clear and upfront to the team. In most of our team activities we have at least two and sometimes three dimensions to the grade. Grading approaches include a team grade given to all team members, an individual performance grade where the complexity of the project allowed for subtasks by individual, and a self assessment rating done by the team members themselves. For self-assessment, all members of the team are asked to rate all the team members including themselves. Two different approaches have been used. In the first approach the student is asked to rate from one to ten each team member's contribution including his/her own across several factors. Alternatively team members are asked to rate everyone's contribution relative to each other. For example, if it is a four-member team, then each member is given a rating from one to four but no two members can have the same rating. This avoids the tendency to rate everyone the same, which minimizes any differentiation in performance between team members.

Finally, teaming skills are acquired skills and are not natural to U.S. students. Coaching, mentoring, and monitoring by the instructor are essential to successful teams. Faculty members act as both models and facilitators while teaming skills are being learned. Particular attention is needed for conflict management when teams become dysfunctional and intervention is required. The facilitator must resist the temptation to dissolve a dysfunctional team, which would circumvent the learning process.

Special attention needs to be given to the constraints arising from a student population with jobs while following a course of instruction. At Western the vast majority of our students are in this category and scheduling time for team working is challenging. We have found that students overcome this barrier once they are convinced of the value and benefits of working as a team. We allocate a portion of class time to team activities, provide access to a team study room with computer for team gatherings, and provide dedicated team specific chat rooms. The primary goal is to enhance communications. Faculty should be attentive to these problems and aid the team in developing solutions.

Observations and Examples

Team activities have been incorporated into parts of the Engineering Technology curriculum at WCU. Team projects are part of our courses in Project Management, Rapid Tooling and Prototyping, and Parametric Modeling in Engineering Design, each with different approaches to developing teaming skills and assessing performance. In our Project Management class, five teams of juniors and seniors were formed randomly by the luck of the draw. Each team of three students selected a unique project that was used as the vehicle for exercising project management techniques. There was no explicit team-to-team competition although comparison was unavoidable. Each member of the team received the same grade on their team project. In addition each member of the team was asked to rate the each member's individual contribution to the project. Contribution was rated according to five factors: willingness to cooperate, attendance and participation at meetings, punctuality, knowledge of subject, and overall contribution to the project. For these teams with three members each, they were asked to give each member a rating from one to three and no member could get the same rating. A sample of this self assessment form is given in figure 1. At the top, the figure contains the instrument that the team member filled out. The table at the bottom is the composite rating collated by the instructor. With five factors and teams with three members and a rating scheme where 1 is the highest and 3 is the lowest, the perfect rating that a team member could receive is 15 and the poorest rating corresponds to a rating of 45.

Individual Team Member Rating Form

Team Contribution Rating						
Team #1	**Name**	**Willingness to cooperate**	**Attendance and participation at meetings**	**Puntuality**	**Knowledge of the subject matter**	**Contribution to the project**
Team Member 1	Joe Smith	1	2	2	1	1
Team Member 2	Sally Jones	2	3	1	2	3
Team Member 3	Sam Short	3	1	3	3	2

Rate contribution to the team effort from 1 to 3 with 1 being the most contribution and 3 being the least

Additional comments:

Composite Team Contribution

Team Contribution Rating							
Team #1	**Name**	**Willingness to cooperate**	**Attendance and participation at meetings**	**Puntuality**	**Knowledge of the subject matter**	**Contribution to the project**	**Composite Rating**
Team Member 1	Joe Smith	3	5	5	3	3	19
Team Member 2	Sally Jones	6	6	4	7	8	31
Team Member 3	Sam Short	9	7	9	8	7	40
		18	18	18	18	18	

Figure 1. Self assessment instrument for team participation and contribution. Top, the individual assessment form and bottom, faculty consolidated team member rating. A composite rating (the sum of all the factors) is shown at bottom right

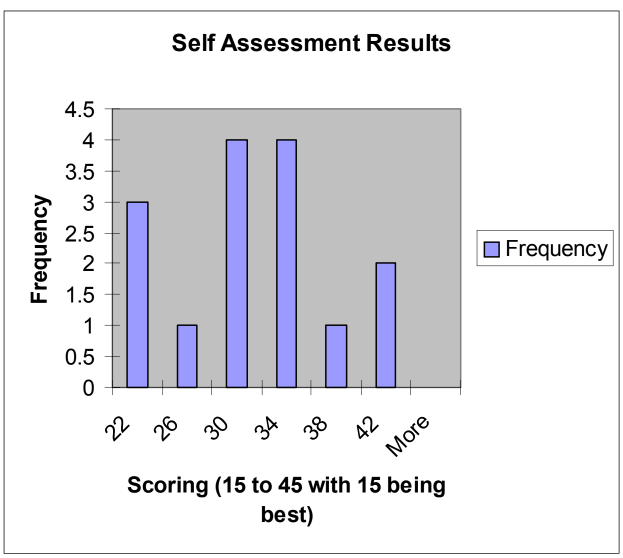

Figure 2 Self Assessment Data for Project Management Team Contribution

The results of this rating process are shown in figure 2. As the figure indicates, three students (with composite rating less than 22) in the view of their team members contributed more to the team performance than did the other members of the team. Two other students with composite rating higher than 42 were sub-par in their contribution to the team effort. From a faculty point of view, this enabled the instructor to clearly identify and appropriately reward extraordinary contribution at both ends of the spectrum. This is the result of only one class and any broad conclusions are not possible. Nevertheless the results suggest an encouraging direction for exploration.

In the laboratory sections for a junior/senior level Rapid Tooling and Prototyping class, each section was formed into a team. Each team, which varied in size from 9 to 14, was given the same assignment of completing a working prototype of a Roots Engine and designing a process to produce the engine. The project deliverables were specific and included drawings and process descriptions. In this semester long project, the complexity of the project allowed for individual students to have component responsibility within the context of a team effort. Furthermore the teams were informed that they were competing against the other teams for a final grade that would be composed of the team grade, the individual grade and the self-assessment rating. The self-assessment criteria was based on a score of one to ten and not rated relative to each other. The performance of the three teams varied widely with one team being outstanding and one team performing poorly. Two of the three teams consisted of some students with cooperative or industrial experience. Team leaders for these two groups were able to apply prior experiences and keep the project moving toward the overall goal. The third group, however, functioned as a non-cohesive group and only focused on individual responsibilities. Not surprisingly, the two teams with leaders having prior industrial experiences outperformed the third.

The competitive teams approach provided students a more realistic experience involving group dynamics, time management, and goal completion. This approach needs refinement before the next implementation cycle. Based on feedback from students and observations by instructors, we recommend conducting a compressed team empowerment component early in the semester. Students should be given specific goals and objectives and required to clearly define their mission and responsibilities. Task assignments should be made early, and project review periods scheduled regularly throughout the semester. Overall, the competitive approach was successful in projects where components and sub-assemblies are combined into a final working prototype. This approach will continue to be refined in our prototyping classes.

In our third example, team concepts were introduced into a Parametric Modeling in Engineering Design class composed primarily of freshmen and sophomores majoring in Engineering Technology. Generally these students have not been previously exposed to team concepts. Students were introduced to informal group processes first, by being required to complete a team project in the first two weeks of class. The first assignment requires an ad hoc group of three to be assembled randomly. The project criteria were then distributed and the team itself designated the role of each member. Then, the project was completed and students were allowed to evaluate the effectiveness of the team as a whole, and team members' contributions. The facilitator also graded the team on the problem's solution by using a rubric, as well as grading each member's individual contributions.

As the semester progressed, more formalized types of group processes were introduced in the class. By semester's end, the students were expected to complete a complex design project where parts are designed and integrated in a team effort. This final project, which Johnson et al[4] describes as "formal" cooperative learning, required the team to complete an assembly from several individual component parts. The teams were selected by the instructor to ensure diversity of talent, culture, and performance level. Each team of four was assigned a number of small component parts of an assembly, varying in difficulty. The team structure allowed for group roles to be self-assigned, therefore each group leader had the opportunity to distribute assignments according to ability. Upon completion of the project, each component part was integrated into the final assembly. If the parts were correctly modeled, and tolerances were correct, the final assembly would be a perfect fit. Obviously, if there were problems with individual parts, it would become evident. Assessment of the project was completed by both team members and the instructor, as it was in the first assignment. Based upon feedback received, and observation by the instructor, the project was a success. However, it is suggested

that pre-instructional planning time and post-project group processing time be integrated into the class.
The self assessment instruments used throughout the class were kept simple due to the maturity of the students in teaming. Students were asked to allocate $100 to team members in proportion to their contribution to the project. Contribution was described as attendance to meetings, relevant contribution to discussion, organization etc. In a second instrument, each team member was asked to rank all team members including themselves from greatest contribution to least contribution. No ties were allowed. Finally students were asked to assign grades to each team member including themselves assuming that 100 is the grade a team member would get for their fair share of the work. Grades as high as 200 and a few as zero could be assigned.

Conclusion

Proficiency in teaming skills must be one of the desired learning outcomes from any engineering technology program. Teaming skills are particularly highly valued with regional enterprises in Western North Carolina, as evidenced by feedback received from those industries. Western Carolina University has begun to integrate the development of these skills into the ET curriculum. Teaming activities has resulted in several promising implementations and has indicated possible directions for improvement. The following highlight our observations and recommendations:
1) Combining all three learning structures of cooperative, competitive, and individualistic learning into lab section instruction can create an environment that closely resembles the real world.
2) The technique of using a self-assessment rating system, which compares and rates contributions relative to each team member, seems to identify low and high performers in the team.
3) Courses that use teams should include explicit dedicated time for teaching teaming skills.
4) Pre-instructional time is very important to the success of the team activity and should be allowed for in all situations.
5) Post-project group processing/debriefing allows for assessment of team results, as well as social interaction, and must be included into class time allowances.

Clearly, the implementation of teaming into the Engineering Technology curriculum at Western Carolina University is a work in progress. However, strides have been made toward integrating the team concept into many classes. The three cases presented illustrate varying levels of involvement and results. Important lessons were learned and will be used to further develop these individual classes, and to serve as models for others. Hopefully, by sharing our experiences, we will contribute to the advancement of other engineering technology curricula that foster the growth of teaming skills and stimulate them to create other approaches to strengthen this effort.

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