Building Successful Student Teams in the Engineering Classroom

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Introduction

Over the past twenty years industrial organizations have undergone many changes in the area of work performance. Teamwork, as a vehicle for work performance, continues to emerge as an industrial phenomenon. When utilized effectively teamwork has been shown to lead to an increase in productivity, a reduction in costs, a rise in employee involvement and a flattening of the organizational structure. The movement towards teamwork has taken on the proportions of an avalanche roaring through firms and it has become the single most consistent strategy for continuous improvement in quality and competitiveness in most organizations [17].

Employers look for more than technical skills when assessing the professional competence of engineers during the hiring process [7], [23]. A study conducted by the American Society of Mechanical Engineers (ASME) found that mastery of teamwork and communication skills were the top desirable attributes of graduating engineering students [1]. Unfortunately, some employers do not think new engineers possess these skills [1], [23]. Most employers report that new engineers entering the industry are astute and well prepared but also believe that improvements need to be made in areas such as public speaking and presentation skills, report writing and the ability to work in teams. These skills, along with interpersonal interaction and conflict mediation, were coined "performance skills" by Seat and Lord and are becoming increasingly essential for recent graduates seeking employment [23].

Background

Despite industrial trends and employers' expectations, a gap exists between the mastery of performance skills expected and those demonstrated by new engineering graduates. Employers expect college students to possess these skills and often complain that college graduates have not learned the team approach to problem solving [9]. Employers, along with the Accreditation Board for Engineering and Technology (ABET), expect better preparation in these areas to be incorporated into the engineering curriculum at the college and university level [5], [9].

Unfortunately, many colleges and universities have not been able to keep up with industry's demand to incorporate activities to enhance teamwork and performance skills into the engineering curriculum. Some schools have successfully provided opportunities for students to hone their performance skills but many remain heavily focused on theoretical training and do not place much emphasis on the practical aspect of the engineering profession and the development of performance skills [9], [23].

Many faculty and administrators tend to focus on theoretical training because of their discomfort with and lack of preparation for effective management of the team experience and the problems related to team organization and management. Buckenmyer observed that an announcement that there would be a team project was frequently received with moans, complaints or other indicators of displeasure [3]. Upon further discussions with students the following reasons for their negative attitudes toward teams surfaced: teams did not work well together; they were a collection of individuals rather than a united entity; members were unclear about expectations for the team; some members became free riders or social loafers; group members did not know how to build a team or handle conflict within the team; teams did not know how to choose a leader; and teams failed to make definite work assignments for members or establish specific due dates.

Jones indicates that a well-structured, robust system for developing teams can overcome the flaws in the traditional classroom model and can energize the learning process; while an improperly structured team system can undermine the goals of education [13]. Furthermore, the inappropriate use of teams can not only undermine the educational process, but also foster an attitude of contempt amongst students towards future teaming experiences. Buckenmyer states that, "What is taught poorly in college may contribute later to poor performance on the job." [3]

It is well reported that organizations that effectively use teams spend long hours and millions of dollars training individuals, teams, team leaders and managers. For example, Motorola has reported spending about $30 million a year on training, mostly on teams [3]. Unfortunately, very little formal training has been provided in the engineering classroom. Teams in the business world develop the ability to deal with their internal problems, but this takes time and time is precisely what a student team does not have.

Unlike business teams, students have a limited time in which to form teams and complete their task. Whereas, in the business environment, team members are typically with the same company or department for quite some time which allows for the existence of personal interconnections that precede and supercede teams [3]. Also, there are typically incentives to foster high commitment and actions taken to deal with non-performers immediately. Furthermore, people are allowed to build reputations as team players. Conversely, in educational teams many students don't build reputations or relationships and there is a lack of continuity to the teaming process.

To address these concerns, a number of scholars have called for a paradigm shift in teaching methods. The most com-

mon shift has been moving from instructor-centered to student-centered methods. One method of creating this shift has been active learning. Active learning has been defined as anything in which students do something in the classroom other than watch or listen to the instructor.

Cooperative learning, the most common approach to active learning, is a pedagogical approach that involves students working together in small groups to accomplish shared learning goals and to maximize their own and each other's learning [12]. Research on the use of cooperative learning at the college level has focused on three broad categories of outcomes: individual achievements, positive interpersonal relationships and psychological health.

Previous studies show that cooperative learning promotes a significantly higher level of individual achievement than either competitive or individual learning and encourages the development of positive relationships. Springer, Stanne, and Donovan found that small-group learning had a significant and positive effect on undergraduates' achievement, persistence and attitudes [24].

The Johnson, Johnson and Smith model of cooperative learning is the most commonly referenced and used model in the engineering education environment [12]. Their model, which requires a lot of structure is, centered around five basic elements: positive interdependence, individual accountability, face-to-face interaction, interpersonal and small group skills and group processing.

The first element, positive interdependence, deals with the fact that each student believes that he or she cannot succeed unless the other group members do (and vice versa) and that their group mates' work benefits them just as their work benefits the others. The second element, individual accountability, comes into play when educators assess individual students' performance and give feedback to them and the other group members. The group needs to know which of its members need more assistance, support and encouragements to complete assignments. The third element, face-to-face promotive interaction, involves group members helping, supporting and praising each other's efforts to learn. The fourth element, interpersonal and small group skills, deals with the fact that students must have the necessary social skills to function effectively. Those skills include: leadership, decision-making, trust-building, communication and conflict management. The last element, group processing, involves students' assessment of how well they are achieving individual and group goals and maintaining effective working relationships within their groups.

Cooperative learning can occur via peer instruction or teamwork [15]. For many faculty, teamwork has become the vehicle for implementing cooperative learning. Unfortunately, many faculty lack the necessary skills to lead, manage, evaluate or train students working in teams [17] [18], [25]. In the case of most faculty, their expertise rests in their technical specialty. As a result or consequently, students do not receive sufficient training or feedback to learn or master teaming skills. In many cases faculty just stick 3-5 students together, call them a team, assign a task and expect results. If lucky, students will complete their task, but it is unlikely they will develop good teamwork skills. What exactly constitutes good teamwork skills?

While the authors of this paper recognize and value the importance of cooperative learning and encourage faculty members to build cooperative environments, many colleagues do not. While knowledgeable in their subject matter many engineering faculty have little or no training in developing, implementing and evaluating teams. Furthermore, many do not fully understand the value of teams or cooperative learning and are not willing to change the structure of their course so that it is cooperative. In an effort to encourage a more effective use of teaming strategies and to assist faculty in getting started this article was written. It summarizes best practices obtained from focus groups with faculty using teams and a summation of the literature on effective teams.

Successful incorporation of teams into the engineering classroom will occur when faculty members can:

1. clearly distinguish between teams and groups
2. determine the appropriate size and composition
3. provide a clear understanding of different team member roles
4. provide training
5. develop effective team evaluation strategies
6. promote effective communication within the team and between team and faculty member
7. aid students in the development of clear goals

Distinguishing Between Teams and Groups

Although similar in nature, groups and teams are not the same. It is advantageous for faculty members to build teams in the classroom rather than groups. This section will assist in distinguishing between the two terms. Teams can be defined as a collection of individuals, empowered to take the responsibility for planning, making decision and performing task as assigned. Furthermore, a team consists of two or more people for the purpose of acquiring the necessary skills required to perform a task, which may not likely be achieved by one person alone.

Similarly, a group consists of two or more people interacting for the primary purpose of sharing information and making decisions about a given area of responsibility. Members of a group may or may not be interdependent on each other while members of teams are interdependent on each other and must rely on each other to achieve team objectives. Additionally, members of teams are required to work towards achieving a shared goal in a demanding and rigorous manner where as group members may have a common goal but are not subjected to the more demanding requirements that exist in a team environment.

Teams typically exhibit synergy that allows for an overall level of performance, which is greater than the sum of individual contributions. Whereas, groups typically do not perform at this same level. Groups merely engage in collective work, which produces outputs no greater than the sum of each member's individual contribution.

The team performance curve, Figure 1, provides a visual view of the relationship between team effectiveness and performance impact. As the curve illustrates performance impact is highest when team members are more effective. The curve identifies 5 stages of group and team de-

velopment, working groups; pseudo team; potential team; real team and a high performance team.

Working groups are groups for which there is no significant performance need or opportunity that would require them to become a team. Members interact to share information, best practices and perspectives within their area. The pseudo team is a group for which there could be a significant, incremental performance need but is not focused on collective performance and is not really trying to achieve it. In this situation the sum of the whole is less than the individual parts. The potential team is a group for which there is a significant performance need, and is really trying to improve its performance impact. It is believed that the steepest performance gain comes between a potential team and a real team. A real team is a small number of people with complementary skills who are equally committed to a common purpose and their performance impact is relatively high. The high performance team is a group that meets all the conditions of real teams and has members who are deeply committed to each other's personal growth and success. The high performance team outperforms all other teams and outperforms all reasonable expectations given its membership and team members have a sense of mutual accountability.

In the classroom setting faculty members should strive to build real or high performance teams. Each of these types of teams focuses on collective performance and in the clasroom setting that is an expected outcome. Emphasis on performance is the primary force that moves a group toward a team.

As evident from the performance curve below, understanding teams requires a cumulative and progressive set of experiences. When considering teams in the classroom, student teams may consist of diverse individuals with different levels of communication and teaming skills.

Composition and Size

As faculty members introduce teaming concepts into the classroom, they are encouraged to pay close attention to team formation and team size. The primary formation strategies are student self-selection or faculty assigned. The faculty-based methods are highly recommended as they provide a more realistic approach to formation and research shows that faculty assigned teams perform better [8]. Self-selection occurs when students are allowed to pick their fellow team members. In most cases students pick their friends and teams made up of friends tend to work rather poorly together because of members inability to be tough with each other.

Faculty assigned occurs when faculty members either randomly or by some other methods assign team members. Random methods include counting off by 1,2,3, assigning teams by color of shirt or birthday month. Other methods might include the use of personality tests, such as Myers-Briggs, DISC Profile, and Kolb Learning Styles. In the workplace, it is very seldom that individuals chose their team members. In most cases they are randomly assigned and you are left to deal with the lot you have.

Faculty members might also consider students' past teaming experiences, major, work schedules, past conflicts, academic performance (GPA) or proximity to campus (on-campus or commuter student etc) when forming teams. When considering student's GPA, the recommendation is to divide the GPA's into four quartiles and place one student from each quartile on a team. This can be beneficial to the weaker student as well as the stronger one. Considering work schedules and proximity to campus will help when students attempt to schedule meeting times outside of class. While these issues are important they to do not account for the random nature of practical teaming experiences.

Another important issue to consider when forming teams is whether or not special consideration should be made based on race, ethnicity or gender. There is a concern that members of under-represented groups should not be isolated. Felder and Brent recommend observing restrictions early in the curriculum, when minority and women students are at greatest risk, and then relaxing it later, when the priority is to prepare the students to enter the workplace where isolation will be a fact of life [6].

There is no magical number relative to team size. The appropriate size should depend on the task the team is about to

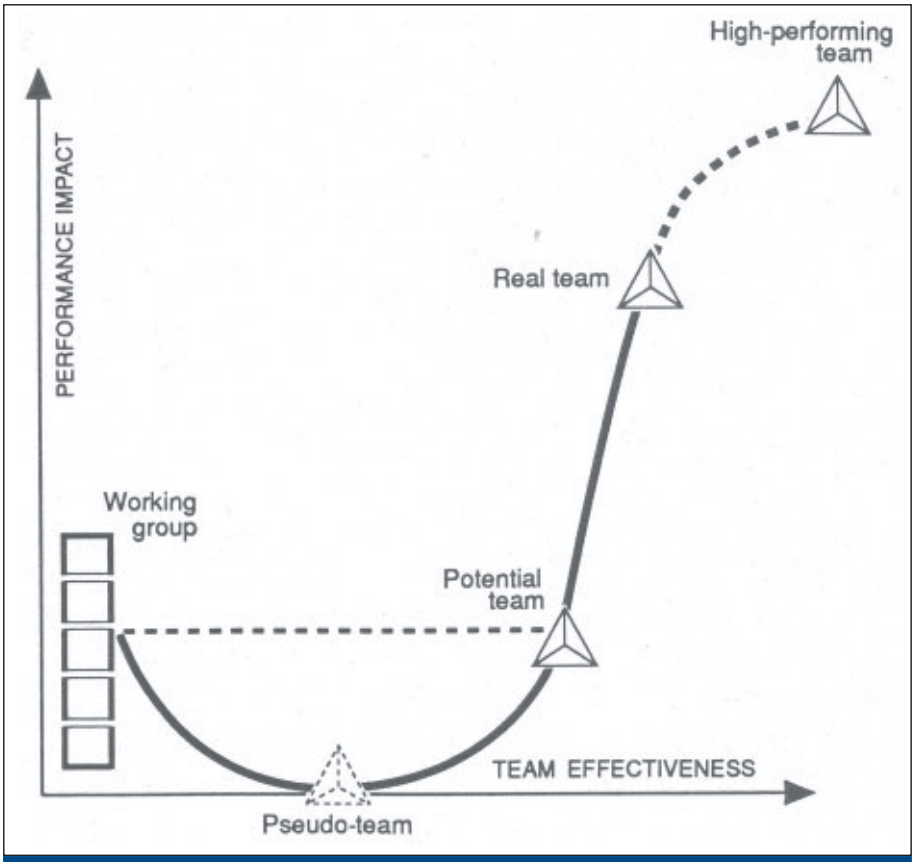

Figure 1. Team Performance Curve

perform. Researchers who study teams offer a variety of figures ranging from as few as 3 to as many as 12 for proper team size. Woods suggests using the "7 plus or minus 2 rule [18]." He suggests that humans have the capacity to keep about 7 plus or minus 2 items straight at one time and say this is also true for team size. Schermerhorn suggest that teams larger than 6 or 7 members can be difficult to manage for creative problem solving. [22]. Hellriegel and Slocum recommends 5 to 12 people [10], while Felder and Brent recommend 3 to 4 [6]. Our recommendation for student teams is 3-5 members.

The size of a team is a factor because the number of relationships that exist increases as the size increases. It also affects self-awareness and the sense of how to behave in front of the team. In smaller teams, few possible relationships exist therefore allowing teams to work faster and team management becomes easier. In larger teams, inter-member communication becomes difficult and the former intimate contact no longer exists. Also, team management is more difficult as more structure is required.

Classification of Roles

In order to achieve high levels of team performance team members must understand that their responsibility is greater than merely showing up for meetings. In addition to the time investment, team members must have a clear understanding of their roles and responsibilities individually and collectively. It is important to the success of the team that roles are clearly defined and norms established early in the team formation process. Following is a description of some recommended roles for student teams.

Team Coordinator: Coordinates and prepares the meeting agenda which includes information on what needs to be discussed and establishes a process to conduct the meeting. This person also coordinates the time, date and place of meetings, and ensures that all necessary resources are available for meetings. He/she is also the person who monitors the code of cooperation. This individual also monitors the decision-making process and coordinates the process check. This person should not be viewed as a person with superior authority. The term team coordinator is recommended over team leader as this approach encourages equal participation amongst all members, which is more desirable.

Recorder: The recorder is responsible for collecting and disseminating information discussed during team meetings. This person should maximize participation by the rest of the team. The recorder also ensures that the processes being used by the team are documented and may prepare an action list to keep record of assigned actions. In addition the recorder needs to make sure that each member signs off on the final product and that copies of the work are distributed to each member.

Time Keeper: The timekeeper needs to keep track of time during the meetings so that the team does not get behind in accomplishing the task. This person is also required to keep the team moving so that they can finish the task at hand without delay.

Checker: The responsibility of the checker is to make sure that each member understands what is being said or done for each assignment or milestone.

Encourager/Gatekeeper: The encourager/gatekeeper has the job of providing encouragement to all team members and ensures that there are balanced levels of contribution. This person should encourage silent members to speak up and dissuade dominant members from being too verbose.

Devil's Advocate: The devil's advocate takes a position opposing the team to ensure all aspects of an issue are considered and that groupthink does not occur.

This role structure will enable the team to cope more effectively and efficiently with the requirements of the task at hand. In the event that there are fewer team members than the number of roles listed, the roles of devil's advocate and encourager could be the responsibility of all team members. Role rotation is strongly recommended as it provides each member an opportunity to experience and learn from the different positions.

Careful attention to formation and role clarity alone will not ensure a successful team experience. Students will also need training.

Training

Team success heavily depends on the training received. We recommend the following topics for those working with student teams. These topics were chosen as they have a significant relationship to achieving effective teams and promoting cooperative learning. While this list may appear lengthy and involved many of these topics can be covered with a brief overview.

1. Roles and responsibilities
2. Norms
3. Goal specification and setting
4. Effective meetings
5. Communication and listening techniques
6. Conflict resolution
7. Techniques for team processing
8. Performance expectations

Special attention should be paid to goal specification, norms, communication and techniques for team processing. Goal specification is important since the main focus should not be each person's individual goal but the groups overall goal.

Norms are the rules governing team members' behavior while working on the given task. These rules often captured in a code of cooperation are useful in monitoring team member's behavior. The code of cooperation provides the guidelines on how team members will interact with each other while working on the given task. The code of cooperation should be developed, adopted, improved and/or modified by all team members on a continuous basis. It is recommended that the code of cooperation be in the form of a written document that is visible at all team meetings.

The team needs to develop an effective communication network so that every member is included and no one is left out of the loop. Effective interpersonal communication is vital to the smooth functioning of any team. Most teams experience tension as they test out their new environment and observe the various personalities involved. Communication patterns develop in the early stages. If time is spent initially and periodically in improving the communication process, greater efficiency can be achieved.

There are number of existing techniques which have been developed to facilitate team discussion, exploration of

Tool	Description
Modified Nominal Group Technique	Helps a team quickly reduce a large list of items to a smaller number of high priority items. Promotes team ownership.
Forced Field Analysis	Helps teams find out what is driving, slowing or not allowing change. Helps teams work together, to find a starting point from which to take action, and to show both sides of the change issue.
Issue Bin	A member assigns the following issues to the issue bin topics that will or may be addressed later, questions that need to be deferred until the end of the agenda, or items that should be the subject of future agendas.
Process Check	Monitoring of processes so that necessary improvements can be made. Should be used at the end of all process related activities.
Impact Changeability Analysis	This tool helps prioritize a set of options and to see the impact of certain changes being made to the process.

Table 1. Useful Tools in Team Processing

ideas, and decision-making. Some examples include modified nominal group technique, forced field analysis, prioritization matrix, issue bin, impact changeability analysis and process check. Table 1. above summarizes these tools. While these are very useful techniques they may be optional when working with student teams.

Although many faculty members lack expertise in these areas, there are individuals on most campuses who are more than qualified to assist you in this endeavor. The final consideration for any faculty member who aspires to use teams in the classroom is evaluation.

Evaluation

Teamwork implies collaboration, joint effort and equal contribution by each member. It is counterproductive to the teaming process if one person does all the work and members share grades equally or poor performers are not penalized in some manner. There are several methods available to the faculty member for evaluation: 1) the faculty assigns everyone the same grade, 2) each member gets a proportion of the overall grade, 3) each member gets two grades, an individual grade and a team grade, or 4) teams submit one assignment and all receive the same grade yet team members are required to evaluate the contributions of their team members. There are pros and cons to each method and in most cases each person needs to experiment with each method and chose one that best fits their needs. In some cases a combination of methods is effective. Each method will be briefly discussed and advantages and disadvantages presented. We feel it is up to the individual faculty member to make the final selection based on their needs and objectives for their teaming experience, although method four is the most commonly used.

Under method one the instructor evaluates the final product and assigns one grade that each member gets. While this method is probably the quickest it does not allow for feedback from individual members regarding others' performance and is not utilized very often.

Method two asks each member to assign some portion of the overall team grade to each team member. It is important to note that point totals allocated for each student do not have to be equitably assigned. Once assigned the faculty member average the scores of each member and that is the grade given to each member.

Method three requires that each member turn in an individual assignment, which is graded and averaged with other team members' grades to become the team grade. This method requires more work for the faculty member, as he or she will be required to do more grading. One advantage of teams in the classroom is a reduction in the grading for the faculty member.

Method four, the most commonly used, is to have teams submit one assignment, which is graded and subsequently becomes the grade for each member and then have each member separately evaluate each other. This evaluation becomes a team member evaluation grade, which can be done periodically throughout the semester/quarter with averages taken if given multiple times or once at the end of the teaming experience.

When using the fourth method of evaluation, team members evaluate each other using criteria such as the willingness to cooperate, attendance at meetings, punctuality, knowledge of subject matter, and amount of contribution made to the team as a team player etc.

Finally regarding evaluation, faculty members may want to collect information on the student's satisfaction with the teaming process. Satisfaction considers behavioral and attitudinal attitudes. Attitudinal attitudes consider whether or not the teaming process enhances the capability of members to work together interdependently in the future. Behavioral attitudes consider how the teaming process contributes to the growth and personal well being of team members. True team effectiveness embodies performance, attitudes of team members and behavior outcomes.

Conclusion

This article presents the primary considerations, an examination of teams vs. groups; composition and size; roles; and evaluation, for faculty members interested in the successful incorporation of teams into the classroom. Initially, the faculty member should be prepared to put more time, effort and energy into team structure and training for students. However, once effective classroom teams are created, the faculty member's role in the teaming process will decrease.

Faculty members may want to begin the teaming process by explaining to students the importance of performance skills in industry and how teaming in class can help prepare them to meet industry expectations. The use of an outside

source, preferably a professional from industry, may also be instrumental in helping students realize the importance of teamwork.

Finally, an ongoing consideration is cohesiveness, the lack of which can also be a problem for teams. Cohesiveness refers to the attractiveness between team members. Teams need to be cohesive such that membership is positively valued and the members are drawn towards each other. Patterns of interpersonal attraction within a team are a very prominent concern. Teams should ensure that all members feel comfortable working together and that no member is feeling alienated or isolated. When there is team cohesiveness, task cohesiveness emerges, making the skills and abilities of the team member's mesh together to allow effective performance.

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